Policy Recommendations for Reducing the Carbon Footprint of Information and Communication Technology Devices

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Abstract

The purpose of this document is to examine the carbon footprint of the Information and Communication Technology Industry in Canada and make sound policy recommendations leveraging technology in a manner that will reduce the carbon footprint of Information and Communication Technology.

Acknowledgements

Learning is a gift, one that I have done throughout my life; if one wants to move forward with the word one must commit to learn continually. Many people helped to steer me through this endeavour to achieve this goal, for this I give them the thanks they so richly deserve.

To Dr. Gail Krantzberg, whose guidance was invaluable throughout my time in the Master of Engineering, Public Policy program. You instilled within me new thoughts and ideas that have expanded my mind to realizing the variety of possibilities that exist in the world today.

To Dr. Lotfi Belkhir, for the guidance on helping to hone my focus down this path of inquiry, I believe this paper is but one chapter in a deeper exploration of this topic, and this topic is but one of many avenues for the overall improvement of society that can lead to a richer and more fulfilling life.

To the many other wonderful professors who guide us on this journey of knowledge and discovery. Esteemed individuals who care about the growth and development of individuals who seek to improve themselves this world would not be the wondrous place that it is.

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Lastly and most importantly, to my wife, Annette and my children, Jennifer and Chloe who afforded me the time and encouraged me to complete this enriching experience. The knowledge that I acquired during my time in this effort will certainly be passed on down to my children so that they too, can pursue a path that will lead to a rich and rewarding life.

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Introduction

Interactive Information and Communication Technology (IICT), (computers, tablets, cell phones) are becoming omnipresent in their manifestation throughout society, and are a global driving force on how we live our lives and conduct business. As these IICT devices become enmeshed in our daily lives so too does their reliance on a steady flow of electricity become. The generation of this much-needed electricity powering all the IICT devices on the market today is a significant contributing cause towards the creation of carbon dioxide, a leading Green House Gas (GHG) (Carbon Dioxide Emissions, n.d.). Given that the number of IICT devices increasing but also taking into consideration the increase in variety of IICT devices; it can easily be inferred that the GHG from the their electrical consumption will increase as well.

Examining a few of the more prevalent technologies within the last several years, we see the following occurring; just last year (2014) in October, the number of cell phone subscriptions in the world exceeded the population of the world (Boren, 2014). By 2020, 6.1 billion cell phones will be Smartphone's, up from the current 2.7 billion in the world today; according to cell phone maker Ericsson (Smartphone Subscribers Likely to Double by 2020: Ericsson Forecast, 2014). Other key figures are the fact there are over one hundred countries where the number of cell phone subscriptions exceeds one cell phone per person and several countries that exceed two cell phones per person (Mobile Cellular Subscriptions (per 100 People), n.d.). Tablets are showing a greater accelerated growth compared to cell phones, in five short years tablets worldwide increased from sixteen million to almost six hundred million; a 3700 percent growth rate (Tablets (Installed Base), n.d.). Personal computers have been on the market for almost 40 years, and estimated that as of 2014 there are approximately two billion personal computers (Van Der Meule, 2008) in almost fifty percent of the world's households (ITU Statistics, 2015). These are but three examples of how the interactive Information and Communication Technology is becoming ubiquitous in our society.

These devices did not just come on the market recently, but are the result of many different achievements over a relatively short period, in terms of human history; starting from approximately 1840 to present day. Figure 1 is a subset visual representation of the rapidity and exponential pace which new or different electronic devices, including, but not limited to IICT devices, are emerging into society.

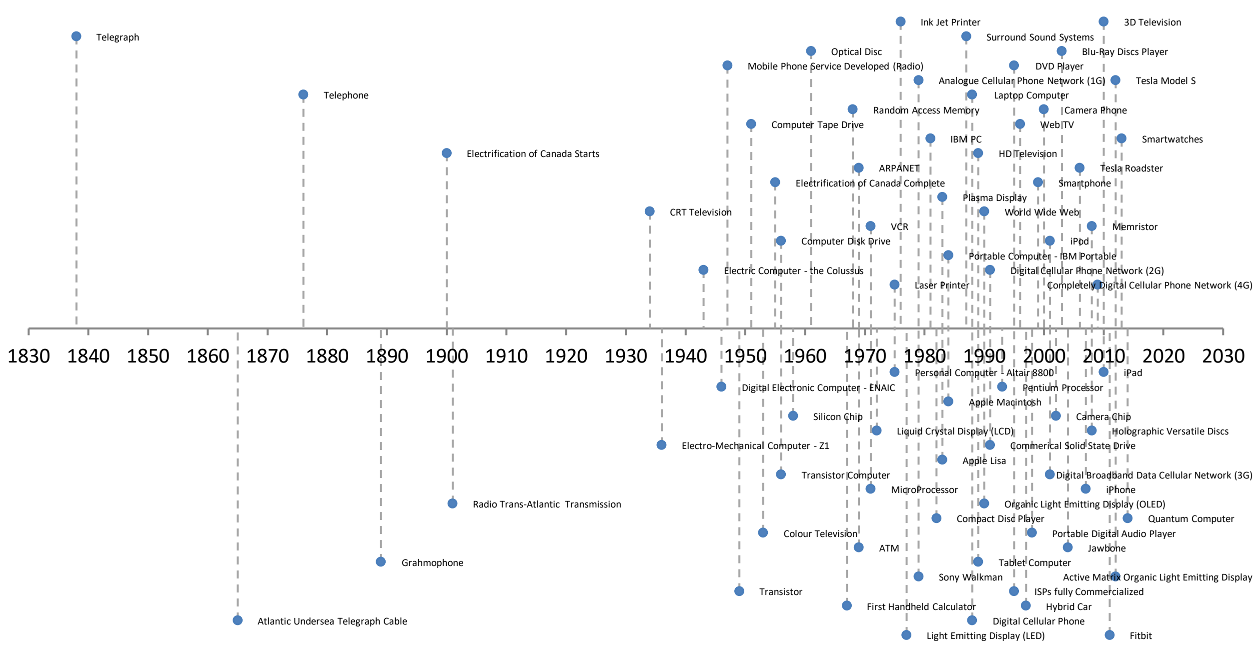

Figure 1: Sample of Electronic Devices to Market[1] (very difficult to decipher, except for the density of inputs)

[1] Appendix A – Source Dates for Figure 1: Sample of Electronic Devices to Market

As seen in Figure 1, the proliferation of electronic devices since the early 1940's, when early electronic computers were first developed, is occurring at an ever-increasing pace. Moore’s Law (Moore's Law and Intel Innovation, n.d.), which states, that the number of transistors on a computer chip doubles every twenty-four months, basically means technologies performance and functionality available doubles every twenty-four months, is one of the main reasons that electronic devices are evolving at an apparent exponential pace. Given this and the classic idiom "Keeping up with the Joneses" it is understandable that consumers want to have the latest technology available to them. This is exemplified by the fact that in the last 50 years, global consumption of electronic devices has grown six fold while human population has little more than doubled (Wann, 2011). The ready consumption of electronic devices is a global problem of huge concern, not only for the waste of resources used to create and dispose of these electronic devices, but also by the energy used in the process of creating them, running them and finally disposing of them.

However, solving the world's problems is difficult, but we can make incremental improvements in our own country, Canada, by reducing the amount of carbon dioxide produced because of the creation and use of various IICT devices. Considering the Triple Bottom Line of economic, environmental and social responsibilities the use of leading edge policies can be a key lever to influence not only the consumer, but the manufacturers of IICT devices so that they consume less electricity, consume less raw materials which will make the cheaper to not only run but to manufacture as well. Changes within the telecommunications industry will also allow for these more affordable IICT electronic devices to be used across all social levels within Canada.

The Current Environment

To create the policies that will reduce the impact from a green house gas perspective we first need to understand the impact of these IICT devices. As seen in Figure 1 there are copious arrays of products that potentially affect our environment in terms of GHG emissions, however focus will be put on the IICT devices as this technology is readily becoming the focal point of our society. Understanding the proliferation of these IICT devices Figure 2 visually illustrates the growing trend that consumer consumption of electronic devices is happening at an increasing pace.

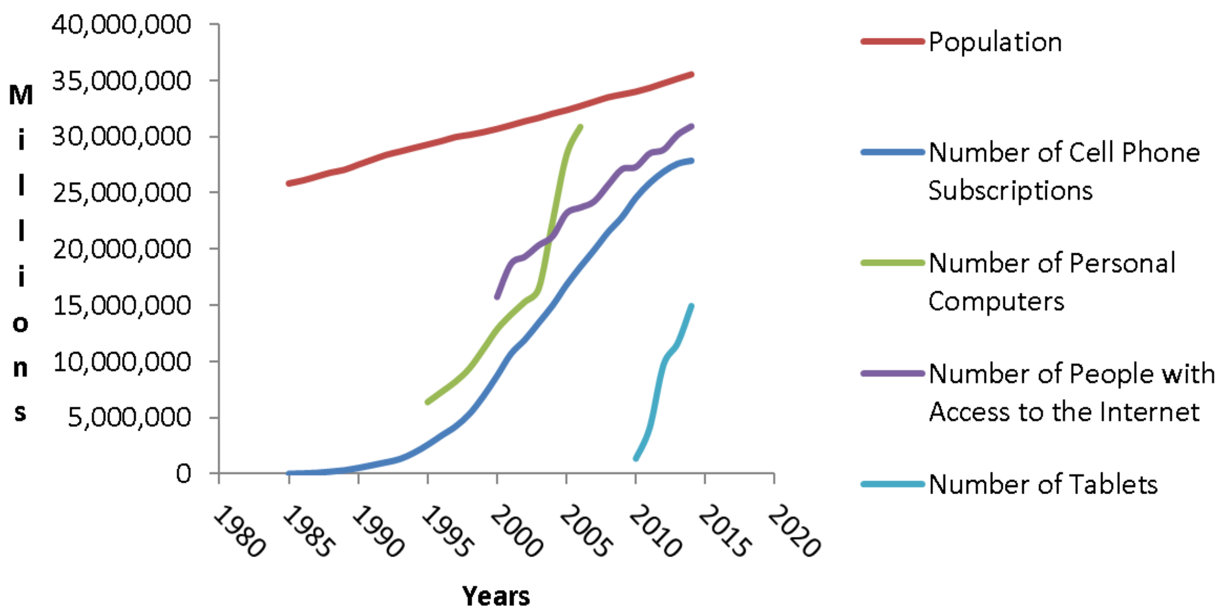

Figure 2: ICT device and connectivity proliferation in Canada [2] [3] [4] [5] [6] [7]

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[2] Statistics Canada. *Table 051-0001 - Estimates of population, by age group and sex for July 1, Canada, provinces and territories, annual (persons unless otherwise noted)***,** CANSIM (database). (accessed: 2014-06-06)
[3] "Facts & Figures." *CWTA*. Canadian Wireless Telecommunication Association. Web. 6 June 2014. <http://cwta.ca/facts-figures/>.
[4] "Personal Computers (per 100 People) in Canada." *Personal Computers (per 100 People) in Canada*. Trading Ecomomics. Web. 6 June 2014. <http://www.tradingeconomics.com/canada/personal-computers-per-100-people-wb-data.html>.
[5] Oliveira, Michael. "Tablet Ownership Doubles in Canada." *The Toronto Star* 30 Jan. 2013. Toronto Star Newspapers Ltd. Web. 6 June 2014. <http://www.thestar.com/life/technology/2013/01/30/tablet_ownership_doubles_in_canada.html>.
[6] "Individuals_Internet_2000-2013.xls." *ICT Facts and Figures 2014*. International Telecommunications Union, 1 Jan. 2014. Web. 6 June 2014. <http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>.
[7] Oliveira, Michael. "More than 42% of Anglophone Canadians Now Own a Tablet: Study." *Fort Frances Times Online* 16 Apr. 2014. Fort Frances Times Ltd. Web. 6 June 2014. <http://www.fftimes.com/node/268668>.

As illustrated in Figure 2 there is a marked increase into the market for these IICT devices, this however, only exacerbates the problem since as stated earlier people are replacing their IICT devices at an incredible rate. The United State Environmental Protection Agency has found that people are replacing their cell phones on an average of every eighteen months (The Life Cycle of a Cell Phone, n.d.) in order to get the latest features available to them. Personal computers do not fair much better. Studies have shown that the typical lifespan of a personal computer is up to six years, however people are, on average, purchasing a new computer every three years, they then store the old computer for another 3 years before disposing of it. (Babbitt, 2009). As tablet have only been on the market for a short period of time there is not yet enough data to determine the life cycle of a tablet.

Factors that need to be considered in the frequent turnover of these IICT devices include; first, as stated earlier is Moore's Law (Moore's Law and Intel Innovation, n.d.), where technology doubles every twenty-four months; second, the theory and practice of Planned Obsolescence (Bulow, 1986) by the various technology companies. However, aptly demonstrating this phenomenon on the release of each new product to market, are the early adopters who line up, sometimes for days, to acquire the latest and greatest technology.

Cell phones, computers and tablets are but a segment in the vast amounts of electronic products available. Extrapolating this further, consider Gaming consoles, Digital Camera's, Personal Music Players, Televisions, DVD players, appliances, and cars, an endless list all carrying a similar turnover and all of which are increasing becoming part of the ICT device family.

Calculating the Current Environment

Given the ubiquitous nature of these IICT devices, we need to get an understanding of their power consumption, both in the manufacturing and the running of these. This will provide a good indication on the creation of GHG with IICT devices. To do this, an analysis will be performed on an array of electronic devices under the IICT umbrella, this will include computing devices (i.e. Desktops, Laptops, Gaming Consoles), and handheld computing devices (Tablets, Cell Phones).

This analysis will include the following considerations when determining the consumption of Electricity/Energy and thus their contribution of GHG produced in terms of carbon dioxide from these IICT devices.

1. Total number of IICT devices currently being used (Home Use, Work Use)
2. Total Electricity/Energy used in the manufacturing of IICT devices
3. Total Electricity/Energy used in the running/use of IICT devices

Given these three factors let us first determine the number of IICT devices currently being used, to do this we will use the Toronto Census Metropolitan Area (CMA) as many statistics are readily available for this area (Household Size, by Census Metropolitan Area (2011 Census) (Ottawa-Gatineau, Kingston, Peterborough, Oshawa, Toronto), 2011).

Based on two million households in Toronto CMA with approximately 2.8 person per household for an approximate five and half million people.

Toronto CMA with 2,000,000 households with an average of 2.8 people per household using CANSIM is Statistics Canada's key socioeconomic database[8] and CRTC data[9]

Metric	Percent	Total Households	Total People
Internet Availability household[8]	88	1,760,000	4,928,000
Accessing Internet with more than one device[8]	70	1,400,000	3,920,000
Desktop Computers[8]	65	1,300,000	3,640,000
Laptop Computers[8]	75	1,500,000	4,200,000
Gaming Systems[8]	25	500,000	1,400,000
Tablets[9]	42	840,000	2,352,000
Cell Phones (Regular + Smartphone)[9]	86	1,720,000	4,816,000
Smartphones[9]	66	1,320,000	3,696,000

Table 1: IICT Devices in Toronto CMA households

Toronto CMA workforce of approximately 3,400,000 as obtained using Statics Canada Labour force data[10] and workers using computers[11]. The assumption is the computers would be a combination of Laptops and Desktops. The assumption is Cell Phone statistics are included with household data. There are not enough reliable statistics for Tablet devices in the work setting, however, this number will rise over the next few years.

Metric	Percent	Total People
Total Workforce using computers[10]	80[11]	2,720,000

Table 2: IICT Devices within the Labour force

[8] "CANSIM." *Government of Canada, Statistics Canada*. Government of Canada, Statistics Canada. Web. 5 July 2015. <http://www5.statcan.gc.ca/cansim/a01?lang=eng>.

[9] "Communications Monitoring Report 2014: Telecommunications Sector." *Government of Canada, Canadian Radio-television and Telecommunications Commission (CRTC)*. Government of Canada, Canadian Radio-television and Telecommunications Commission (CRTC). Web. 5 July 2015. <http://www.crtc.gc.ca/eng/publications/reports/PolicyMonitoring/2014/cmr5.htm>.

[10] "Labour Force Characteristics, Unadjusted, by Census Metropolitan Area (3 Month Moving Average) (Toronto (Ont.), Hamilton (Ont.), St. Catharines-Niagara (Ont.))." *Government of Canada, Statistics Canada*. Government of Canada, Statistics Canada. Web. 5 July 2015. <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/lfss04f-eng.htm>.

[11] "Statistics Canada: Working with Computers." *Statistics Canada: Working with Computers*. Statistics Canada: Working with Computers. Web. 5 July 2015. <http://www.statcan.gc.ca/pub/75-001-x/00501/5724-eng.html>.

Turning the attention now onto various IICT devices and the consumption of power being used looking at a representative variety of IICT devices the following has been found;

Desktops[12]	**Watt Range**	**Watts Avg**
1. Apple iMac/Intel	52-56	54
2. Apple iMac/Intel	92-96	94
3. Apple iMac/Intel	141-147	144
4. Apple iMac/Intel	146-154	150
5. Dell Optiplex 9010 All-in-One	43-45	44
6. Dell Optiplex 9010	66	66
7. Dell Optiplex 990	33-37	35
8. Dell Optiplex 980	64-71	67
9. Dell Optiplex 760	95-111	103
10. Lenovo ThinkCentre M91	50-68	59
Total		**816**
Average		**81.6**
Laptops[12]		
1. Apple MacBook Pro	49-53	51
2. Apple MacBook Pro	58-60	59
3. Dell XPS 12	38-40	39
4. Dell Latitude E4200	38-40	39
5. Dell Latitude XT2 XFR	28-32	30
6. Dell Inspiron Mini 10	19-21	20
7. Lenovo ThinkPad X100e	19-21	20
8. Lenovo ThinkPad T410s	39-58	49
Total		**307**
Average		**38.375**
Game Console[13]		
1. PS4	90-150	120
2. Xbox One	70-120	95
3. Wii U		35
4. PS3 Slim		85
5. PS3 Original		190
6. Xbox 360 S		90
7. Xbox 360 O		180
8. Wii		40
Total		**835**
Average		**104.375**
Cell Phones[14]	**~3.5 to 4.9 kwh annually**	
Tablets[15]	**~15 kwh annually**	

Table 3: Power Consumption of IICT Devices

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[12] "Computer Power Usage." *Penn - Information Systems & Computing*. The University Of Pennsylvania. Web. 5 July 2015. <https://secure.www.upenn.edu/computing/resources/category/hardware/article/computer-power-usage>.

[13] Delforge, Pierre, and Noah Horowitz. "The Latest-Generation Video Game Consoles - How Much Energy Do They Waste When You're Not Playing?" *NDRC Issue Paper*. National Research Defense Council, 1 May 2014. Web. 5 July 2015. <http://www.nrdc.org/energy/game-consoles/files/video-game-consoles-IP.pdf>.

[14] "How Much Energy a Smartphone Uses in a Year (And What It Means for Your Budget)." *Lifehacker*. Lifehacker, 2 Oct. 2012. Web. 6 July 2015. <http://lifehacker.com/5948075/how-much-energy-a-smartphone-uses-in-a-year-and-what-it-means-for-your-budget>.

[15] "How Much Energy Does It Take to Power Those IPads?" *Gigaom*. 22 June 2012. Web. 6 July 2015. <https://gigaom.com/2012/06/21/so-how-much-does-it-cost-to-charge-an-ipad-every-year/>.

Other key values that we need in our calculations include;

1. the number of hours spent online (as an indicator of use of IICT devices) which according to the CRTC is currently at 20.1 hours per week (CRTC Issues Annual Report on the State of the Canadian Communication System, 2013).
2. Hours worked per week, which according to Employment and Social Development Canadians are currently working 36.6 hours per week (Work - Weekly Hours Worked, n.d.), we will make an assumption that once people are not a work, they will shutdown their computer system, however it can be assumed many people leave them on.
3. Amount of Electricity/Energy used to manufacture a IICT device compared to running the IICT device. It is estimated that the Electricity/Energy used to create an IICT consists of 70 percent and 80 percent of its total consumption over it lifespan, (William, 2004) for our calculations a value of 75 percent was chosen.
4. Average lifespan of an IICT computing device (Desktop, Laptop, Game Console) is an average of three years (Babbitt, 2009).
5. Average lifespan of a cell phones is currently eighteen months (The Life Cycle of a Cell Phone, n.d.)
6. Calculations will be done using kWh as a base.

Given that we have the various values, a rough order of magnitude equation is derived from the above information. Given that we do not know the exact usage of the various IICT home computing devices that individuals will use at any particular time we will assume that they cannot use all these devices at the same time; however, there are likely many individuals using more than one device at a time. We will calculate using the information we have available. We will also separate the calculation between home use and work use. For work use, we will assume that either individuals will most likely work on a Desktop Computer or a Laptop Computer, a 50 percent each assumption is used for these calculations.

Calculation to determine usage of various IICT home computing devices as a percentage of all IICT home computing devices.

$$\frac{\text{Percentage of Desktops}}{\text{Total percentage of IICT accessing internet}} = \frac{65}{65 + 75 + 25} * 100 \approx 40\%$$

$$\frac{\text{Percentage of Laptops}}{\text{Total percentage of IICT accessing internet}} = \frac{75}{65 + 75 + 25} * 100 \approx 45\%$$

$$\frac{\text{Percentage of Game Consoles}}{\text{Total percentage of IICT accessing internet}} = \frac{25}{65 + 75 + 25} * 100 \approx 15\%$$

To get an idea of the amount of electricity used by each device a rough order of magnitude calculation was made using the following formula. Without exact specifics on device usage, these are at the very least, best guesses since access to exact data is unavailable.

Percentage of IICT home computing device

	Total Operational Electricity Consumption over average lifespan of IICT computing device	
=	Percentage of IICT devices	(As determined from above calculations)
*	People able to access the internet	(Statistics Canada, internet availability Toronto CMA)
*	Internet Use Per Year	(CRTC, 20.1 hours per week * 52 weeks)
*	Average Wattage per IICT device	(Average from Representative Variety)
/	1000	(To get kWh)
*	Average Lifespan	(Per Device)

	Total Operational Electricity Consumption over average lifespan of IICT tablet/cellphone/smartphone	
=	People who own devices	(Statistics Canada, internet availability Toronto CMA)
*	Average Annual kWh	(Average from Representative Variety)
*	Average Lifespan	(Per Device)

Total Operational Electricity Consumption over average lifespan of Desktop Computers[16]

=	Percentage of IICT devices	40% (.4)
*	People able to access the internet	4,928,000 (Toronto CMA)
*	Internet Use Per Year	20.1 hours per week * 52 weeks (CRTC)
*	Average Wattage per IICT device	81.6 (Desktop Value)
/	1000	(To get kWh)
*	Average Lifespan	3 years
=	**504,361,009 kWh**	

Total Operational Electricity Consumption over average lifespan of Laptop Computers

=	Percentage of IICT devices	45% (.45)
*	People able to access the internet	4,928,000 (Toronto CMA)
*	Internet Use Per Year	20.1 hours per week * 52 weeks (CRTC)
*	Average Wattage per IICT device	38.375 (Laptop Value)
/	1000	(To get kWh)
*	Average Lifespan	3 years
=	**266,840,814 kWh**	

Total Operational Electricity Consumption over average lifespan of Game Console[16]

=	Percentage of IICT devices	15% (.15)
*	People able to access the internet	4,928,000 (Toronto CMA)
*	Internet Use Per Year	20.1 hours per week * 52 weeks (CRTC)
*	Average Wattage per IICT device	104.375 (Game Console Value)
/	1000	(To get kWh)
*	Average Lifespan	3 years
=	**241,924,082 kWh**	

Total Operational Electricity Consumption over average lifespan of Tablet[17]

=	People who own a device	2,352,000 (Toronto CMA)
*	Average Annual kWh for device	15 kWh per year (Tablet)
*	Average Lifespan	3 years
=	**105,840,000 kWh**	

Total Operational Electricity Consumption over average lifespan of Smartphone[18]

=	People who own a device	3,696,000 (Toronto CMA)
*	Average Annual kWh for device	4.9 kWh per year (Tablet)
*	Average Lifespan	1.5 years
=	**27,165,600 kWh**	

Total Operational Electricity Consumption over average lifespan of Regular Cell Phone[19]

=	People who own a device	(4,816,000 - 3,696,000) (Toronto CMA)
*	Average Annual kWh for device	3.5 kWh per year (Tablet)
*	Average Lifespan	1.5 years
=	**5,880,000 kWh**	

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[16] This does not include electricity used by the display device.
[17] Will make an assumption of 3 years as data is not available
[18] As Smartphone's use greater power will use the upper range 4.9 kWh as the calculated value
[19] As regular cell phones use less power will use lower range 3.5 kWh as calculated value also need to subtract Smartphone owners

Given these rough order of magnitude calculations for the various IICT home computing devices under consideration we can now calculate the total amount of electricity that used in the running of these various devices we can now calculate the total energy used. To calculate the total electrical consumption we will assume that 75 percent of the total electricity consumed is during the manufacturing of computing (Desktop, Laptop, Game Console) devices. We will assume the same for Tablets and Cell phones (Smartphone and Regular). The equation to calculate this is

$$\frac{25\%}{100\%} = \frac{\text{Total electricity used during operation}}{\text{Total electricity during operation + Total electricity during manufacturing}}$$

Desktop Computers

$$\frac{25\%}{100\%} = \frac{504{,}361{,}009 \text{ kWh}}{X} \quad \mathbf{= 2{,}017{,}444{,}036 \text{ kWh}}$$

Laptop Computers

$$\frac{25\%}{100\%} = \frac{266{,}840{,}814 \text{ kWh}}{X} \quad \mathbf{= 1{,}067{,}363{,}256 \text{ kWh}}$$

Game Consoles

$$\frac{25\%}{100\%} = \frac{241{,}924{,}082 \text{ kWh}}{X} \quad \mathbf{= 967{,}696{,}328 \text{ kWh}}$$

Tablets

$$\frac{25\%}{100\%} = \frac{105{,}840{,}000 \text{ kWh}}{X} \quad \mathbf{= 423{,}360{,}000 \text{ kWh}}$$

Smartphones

$$\frac{25\%}{100\%} = \frac{27{,}165{,}600 \text{ kWh}}{X} \quad \mathbf{= 108{,}662{,}400 \text{ kWh}}$$

Regular Cell Phones

$$\frac{25\%}{100\%} = \frac{5{,}880{,}000 \text{ kWh}}{X} \quad \mathbf{= 23{,}520{,}000 \text{ kWh}}$$

Now that we have calculated the total electricity that the IICT home computing devices use over their lifetime we can calculate this to a total amount of electricity used for all IICT home computing devices. This can be calculated by summing the various totals.

	Total Electricity Used for all IICT home computing Devices	
=	2,017,444,036 kWh	Total kWh needed for Desktop Computers
+	1,067,363,256 kWh	Total kWh needed for Laptop Computers
+	967,696,328 kWh	Total kWh needed for Game Consoles
+	423,360,000 kWh	Total kWh needed for Tablets
+	108,662,400 kWh	Total kWh needed for Smartphone's
+	23,520,000 kWh	Total kWh needed for Regular Cell Phones
=	**4,608,046,020 kWh**	

Therefore, total electricity used form home computing IICT devices is almost three billion kWh over their lifespan in the Toronto Census Metropolitan Area (CMA).

We can now calculate how much electricity people in the working environment use. The following is known and some assumptions will be made;

1. There are 2,720,000 people working in the Toronto CMA using computers
2. People work an average of 36.6 hours per week. We will assume for 46.5 weeks per year to account for Statutory Holidays, Vacations and sick days. According to the OECD Canadians work 1704 hours per year (Average Annual Hours Actually Worked per Worker, n.d.) , which falls in line with 36.6 hours per week times 46.5 weeks.
3. We will assume that of computers at workplaces, 50% will be desktops and 50% will be laptops, no credible information can be found on percentage breakdowns.

	Total Operational Electricity Consumption over average lifespan of IICT computing device	
	50% split	Using assumption of a 50/50 split
*	People using computers at work	(Statistics Canada: Working with Computers)
*	Hours worked per year	(36.6 * 46.5 weeks)
*	Average Wattage per IICT device	(Average from Representative Variety)
/	1000	(To get kWh)
*	Average Lifespan	(Per Device)

Total Operational Electricity Consumption over average lifespan of Desktop Computer[20]

	50% split	.5
*	People using computers at work	2,720,000
*	Hours worked per year	(36.6 * 46.5 weeks)
*	Average Wattage per IICT device	81.6 (Desktop Value)
/	1000	(To get kWh)
*	Average Lifespan	3 years
=	**566,610,163 kWh**	

Total Operational Electricity Consumption over average lifespan of Laptop Computer

	50% split	.5
*	People using computers at work	2,720,000
*	Hours worked per year	(36.6 * 46.5 weeks)
*	Average Wattage per IICT device	38.375 (LapTop Value)
/	1000	(To get kWh)
*	Average Lifespan	3 years
=	**266,466,483 kWh**	

Using the equation to determine total electrical consumption over the average lifespan

$$\frac{25\%}{100\%} = \frac{\text{Total electricity used during operation}}{\text{Total electricity during operation + Total electricity during manufacturing}}$$

Desktop Computers

$$\frac{25\%}{100\%} = \frac{566{,}610{,}163 \text{ kWh}}{X} \quad \mathbf{= 2{,}266{,}440{,}652 \text{ kWh}}$$

Laptop Computers

$$\frac{25\%}{100\%} = \frac{266{,}466{,}483 \text{ kWh}}{X} \quad \mathbf{= 1{,}065{,}865{,}932 \text{ kWh}}$$

Now that we have calculated the total electricity that the IICT work computing devices use over their lifetime we can calculate the total amount of electricity used;

	Total Electricity Used for all IICT work computing Devices	
=	2,266,440,652 kWh	Total kWh needed for Desktop Computers
+	1,065,865,932 kWh	Total kWh needed for Laptop Computers
=	**3,332,306,584 kWh**	

[20] This does not include the display device

Now that we have calculated the both the total amount of electricity used by home IICT devices and the total amount of electricity used by work IICT devices we can now add these two together to get the total amount of electricity used by all IICT devices in the Toronto Census Metropolitan Area;[21]

Total IICT kWh = Home IICT kWh + Work IICT kWh
Total IICT kWh = 4,608,046,020 kWh + 3,332,306,584 kWh
Total IICT kWh = **7,940,352,604 kWh**

Therefore, to run Interactive Information and Communication Technology devices in the Toronto Census Metropolitan Area requires almost 8 billion kWh over the lifespan of these IICT devices.

To put this large number in some more quantifiable perspectives, Canadian'a on average used 40 Giga Joules, which translates to 11,111.11 kWh of electricity per year (Table 3-2 Household Energy Use, 2012) per household, multiple this by three so that we can determine the average kWh use per year it comes to 33,333.33. If the total IICT kWh is divided by the average household kWh (7,940,352,604 kWh / 33,333.33 kWh) this would mean that for the three years to run these IICT devices 238,211 homes could be powered. This is representing 12 percent of the households in the Toronto CMA.

This falls directly in line with a study done by Mark Mills, which estimates that ICT technology uses approximately 10 percent of the global electrical production per year (Mills, 2013).

This also does not include IICT devices that are located in Data Centres, this will be discussed with Potential Solutions.

[21] This does not include IICT devices located in Data Centres

Current Environment Green House Gas Impact

Realizing that IICT use represents 12 percent of electrical usage, the question is how much of an impact does this have in terms of Green House Gases? For this, the IICT devices need to be considered on a global scale rather than just on the local scale.

Figure 3: Global Chain of ICT Electronic Devices[22]

Reviewing this global supply chain in Figure 3, it is apparent that IICT devices do not just consume electricity from just one location, given that approximately 75 percent of the power used in their lifetime comes from the manufacturing process (Williams, 2004). Therefore, when considering the carbon impact it needs to be considered using global values. According the

[22] "A Practical Approach to Greening the Electronics Supply Chain." *Business for Social Responsibility (BSR)*. Business for Social Responsibility (BSR), 1 June 2010. Web. 10 July 2015. <http://www.bsr.org/reports/BSR_EICC_A_Practical_Approach_to_Greening_the_Electronics_Supply_Chain.pdf>.

International Energy Agency the world carbon dioxide value per kWh is 504 grams or .504 kilograms. Given this, a calculation determining how much carbon dioxide generated over the lifespan of IICT devices, using the following equation;

total kg of carbon dioxide = total electricity used in kWh * kg of carbon dioxide per kWh
total kg of carbon dioxide = 7,940,352,604 kWh * 0.504 kg
total kg of carbon dioxide = 4,001,937,712 kg of carbon dioxide over the life of the IICT device

This means that in the Toronto Census Metropolitan Area, that the IICT devices alone in this area produce 4,001,937,712 kg of carbon dioxide over their lifespan. This seems like a very large number but to understand the context of this, let's put this in relatable terms. For this a determination will be made as to how many midsized cars can be run for the amount of carbon dioxide produced from the IICT devices. For an average midsized car travelling 1000 kilometers per month, it is estimated that it will produce 3,600 kg of carbon dioxide (Bloch, n.d). This needs to be calculated in roughly the same timeframe as the IICT devices which is three years which is 10,800 kg of carbon dioxide over three years. Therefore to calculate the total number of cars the equations would be;

Total number of midsized cars = total IICT kg of carbon dioxide / kg of carbon dioxide by car
Total number of midsized cars = 4,001,937,712 kg / 10,800 kg per car
Total number of midsized cars = 370,550

Therefore, 370,550 cars can be run for three years on the amount of carbon dioxide generated from the manufacture and use of IICT devices over their lifespan within the Toronto Census Metropolitan Area.

The Potential Environment

In order to reduce the amount of electricity and thus reduce the carbon footprint of the IICT devices, we must rethink the entire architecture currently used within the Information and Communication Technology realm. Home based and work based computers utilize a substantial amount of electricity and are a significant contributor to carbon dioxide GHG emissions. It has already been noted that IICT devices (primarily servers) within data centres have not been included in these calculations. This brings about the idea of a complete architecture change. A number of studies have indicated that the servers within data centres are significantly underutilized, ranging anywhere from 6 percent usage on average (Kaplan, 2008) to a peak load usage of 40 percent (Barrosa, 2013). Given this information, a new paradigm can be envisioned where the processing switches from the home or office based IICT machine to the data centres. This gives to the rise of the cloud architecture. Home and office machines can be replaced by what are called thin clients, which use significantly less electricity than the current IICT devices.

Thin Clients[23]	**Watts**
1. HP Compaq t series	19
2. Fujitsu-Siemens Futro A Series	7
3. Fujitsu-Siemens Futro S400	18
4. Fujitsu-Siemens Futro S500	15
5. Wyse S-series	5
6. Wyse V-series	17
7. Igel Smart Series	12
8. Igel Compact Series	18
9. Igel Winestra Series	15
10. Igel Premium Series	18
Total	**144**
Average	**14.4**

Table 4: Electricity Consumption of Thin Clients in Watts[23]

[23] Vereecken, Willem. "Energy Efficiency in Thin Client Solutions." *Www.ibbt.be*. Ghent University - IBBT. Web. 10 July 2015. <http://www.greengrids.org/presentations/03_vereecken.pdf>.

Calculating the Potential Environment

Using the statistics found earlier for the number of people using IICT computing devices to access the internet for home use and if the same numbers were applied, this time substituting a thin client paradigm instead of the traditional IICT computing device, excluding Tablet and Smartphone/Regular Cell Phone numbers, and utilizing the equation;

	Total Operational Electricity Consumption over average lifespan of IICT computing device	
=	Percentage of IICT devices	(As determined from above calculations)
*	People able to access the internet	(Statistics Canada, internet availability Toronto CMA)
*	Internet Use Per Year	(CRTC, 20.1 hours per week * 52 weeks)
*	Average Wattage per IICT device	(Average from Representative Variety)
/	1000	(To get kWh)
*	Average Lifespan	(Per Device)

	Total Operational Electricity Consumption over average lifespan of IICT computing device	
=	Percentage of IICT devices	100%
*	People able to access the internet	4,928,000
*	Internet Use Per Year	(CRTC, 20.1 hours per week * 52 weeks)
*	Average Wattage per IICT device	14.4 (average watts per thin client)
/	1000	(To get kWh)
*	Average Lifespan	3 years (use same timeframe as IICT computing device)
=	222,512,210 kWh	

The now needs to be applied to number of people using IICT computing devices from a work perspective and if the same numbers were applied, this time substituting a thin client paradigm instead of the traditional IICT computing device and utilizing the equation;

	Total Operational Electricity Consumption over average lifespan of IICT computing device	
*	People using computers at work	(Statistics Canada: Working with Computers)
*	Hours worked per year	(36.6 * 46.5 weeks)
*	Average Wattage per IICT device	(Average from Representative Variety)
/	1000	(To get kWh)
*	Average Lifespan	(Per Device)

	Total Operational Electricity Consumption over average lifespan of IICT computing device	
*	People using computers at work	2,720,000
*	Hours worked per year	(36.6 * 46.5 weeks)
*	Average Wattage per IICT device	14.4 (average watts per thin client)
/	1000	(To get kWh)
*	Average Lifespan	(Per Device)

= 199,980,058 kWh

We then determine the total electricity used to operate the thin client device, again we will assume that there same cost of 70 to 80 percent of the electricity consumed by the thin client device is used during the manufacturing of the product by using the equation to determine total electrical consumption over the average lifespan

$$\frac{25\%}{100\%} = \frac{\text{Total electricity used during operation}}{\text{Total electricity during operation + Total electricity during manufacturing}}$$

Home Thin Client

$$\frac{25\%}{100\%} = \frac{222{,}512{,}210\ \text{kWh}}{X} = 890{,}048{,}840\ \text{kWh}$$

Work Thin Client

$$\frac{25\%}{100\%} = \frac{199{,}980{,}058\ \text{kWh}}{X} = 799{,}920{,}232\ \text{kWh}$$

However, in order to run these thin clients a series of cloud based servers would be required. Based on the numbers currently available servers use anywhere from 100 to 800 watts of power and can handle anywhere from 50 to 600 clients. Using the optimal servers available, these currently handle almost 600 clients and utilize around 240 watts, in the interest of efficiency these will used for calculations. Using the various numbers already found and making assumptions that if people are working they cannot be using the computer at home we will create an equations that looks like this;

	Servers required to support a work based thin client cloud based architecture	
=	2,720,000	Number of people working on an IICT computing device in Toronto CMA
/	600	Number of people per cloud based server
=	4,534	

	Servers required to support a home based thin client cloud based architecture	
=	4,928,000	Number of people using an IICT computing device in Toronto CMA
/	600	Number of people per cloud based server
=	8,214	

From this using an equation similar to what was used to calculate the kWh per device the total kWh for the servers can be calculated.

	Total Operational kWh Consumption of home server over average lifespan of Thin Client	
=	8,214	Number of Cloud Based Servers Required for work
*	(20.1 * 52)	(CRTC, 20.1 hours per week * 52 weeks)
*	240	Wattage per Cloud Based Server
/	1000	(To get kWh)
*	3	3 years (use same timeframe as IICT computing device)
=	6,181,396 kWh	

	Total Operational kWh Consumption of work server over average lifespan of Thin Client	
=	4,534	Number of Cloud Based Servers Required for work
*	(36.6 * 46.5 weeks)	Use per year
*	240	Wattage per Cloud Based Server
/	1000	(To get kWh)
*	3	Assume use of standard lifespan
=	5,555,819 kWh	

Like other IICT electronic computing devices this only represent a fraction of the total electricity used over the lifespan of this device. To determine the total electricity used we need to use these equations;

$$\frac{25\%}{100\%} = \frac{\text{Total electricity used during operation}}{\text{Total electricity during operation + Total electricity during manufacturing}}$$

Home Cloud Based Servers

$$\frac{25\%}{100\%} = \frac{6{,}181{,}396 \text{ kWh}}{X} = 24{,}725{,}584 \text{ kWh}$$

Work Cloud Based Servers

$$\frac{25\%}{100\%} = \frac{5{,}555{,}819 \text{ kWh}}{X} = 22{,}223{,}276 \text{ kWh}$$

Adding all of the numbers above together will give the total number of kWh that the thin clients including the servers required to do the computing will consume over a three-year lifespan. However, since we did not change the paradigm of Tablet and Smartphones we need to include these number in our totals as well

	Total kWh for thin clients and other IICT Devices	
=	890,048,840 kWh	Total kWh needed for Home Thin Clients
+	799,920,232 kWh	Total kWh needed for Work Thin Clients
+	24,725,584 kWh	Total kWh needed for Home required servers
+	22,223,276 kWh	Total kWh needed for Work required servers
+	423,360,000 kWh	Total kWh needed for Tablets
+	108,662,400 kWh	Total kWh needed for Smartphone's
+	23,520,000 kWh	Total kWh needed for Regular Cell Phones
=	2,292,460,332 kWh	

To put this these number in more quantifiable perspectives as done with the IICT devices, Canadian's on average used 40 Giga Joules, which translates to 11,111.11 kWh of electricity per year (Table 3-2 Household Energy Use, 2012) per household, multiple this by three so that we can determine the average kWh use per year it comes to 33,333.33. Then taking the total thin client kWh divided by the average household kWh (2,292,460,332 kWh / 33,333.33 kWh) this would mean that for the three years to run these thin client devices only 67,774 homes would be powered. This is representing 3.4 percent of the households in the Toronto CMA.

Potential Environment Green House Gas Impact

Since thin devices are manufactured in a manner similar to IICT computing devices global values need to be assigned to determine the GHG impact. Using the same carbon dioxide value per kWh of 504 grams or .504 kilograms, the calculation to determine the amount of carbon dioxide generated over the lifespan of a thin client device;

total kg of carbon dioxide = total electricity used in kWh * kg of carbon dioxide per kWh
total kg of carbon dioxide = 2,292,460,332 kWh * 0.504 kg
total kg of carbon dioxide = 1,155,400,007 kg of carbon dioxide over the life of a thin client

This means that in the Toronto Census Metropolitan Area, that the thin clients and other IICT devices would only produce 1,155,400,007 kg of carbon dioxide over their lifespan. To understand the context of this, let's put this in relatable terms. Using the same equation as before with an average midsized car producing 3,600 kg of carbon dioxide a year traveling 1,000 kilometers per month (Bloch, n.d.) translating to 10,800 kg of carbon dioxide over three years. Therefore to calculate the total number of cars the equations would be;

Total number of midsized cars = total IICT kg of carbon dioxide / kg of carbon dioxide by car
Total number of midsized cars = 1,155,400,007 kg / 10,800 kg per car
Total number of midsized cars = 106,981 cars

Therefore, only 106,981 is the equivalent number of cars that can be run for three years on the amount of carbon dioxide generated from the manufacture and use of thin clients over their lifespan within the Toronto Census Metropolitan Area.

Other Considerations

Moving the core processing of IICT computing devices from a decentralized manner, as is the current paradigm by using desktop, laptop, and game consoles, to a centralized manner, as is the potential new paradigm, will mean that software companies will need to rethink how software is distributed to the consumer. Going with a cloud based centralized system will mean the software will reside in the cloud. Many companies are already travelling down this road with items like Adobe Creative Cloud (Adobe Creative Cloud, n.d.), Microsoft Office Online (Collaborate with Office Online, n.d.) and Google Document (Create Documents, n.d.). There is a shift in how these products are sold as well. Adobe Creative Cloud is a monthly fee based subscription method costing up to $80.00 per month for an individual. Microsoft Office Online and Google Docs are currently free but as time progresses fees will be charged. Given that a number of major companies are already on the path of basing themselves in the cloud other considerations need to be made. Along with this any content that individual currently download and store on their individual IICT computing devices, i.e. movies, music, games, books, etc can now be stored on the cloud.

To accommodate the increase in data transfer and usage an increase in bandwidth and speeds is required. Fortunately many new areas are already running fiber optic cable (Fibre Optics for Contractors and New Housing Developments, n.d.) however older areas will need to be retrofitted to accommodate the increased data traffic. Wireless access speeds would also need to increase, current 4th generational networks will allow downloads of 800 megabyte file in about 40 seconds, when the 5th generational network arrives, expected by 2021, with some early adopters having it by 2017, this time will shrink to about 1 second (Freeman, 2014).

Summary

It is apparently clear given the research presented that moving from decentralized processing IICT electronic device model (PC's, Laptop, and Game Consoles) to a centralized model with a thin client type IICT devices and centralized cloud based servers running the software required and centralized storage will dramatically decrease the GHG effect. This was only looking at a small area in the Toronto Census Metropolitan Area. Total GHG produced using the existing decentralized processing IICT electronic device paradigm is 4,001,937,712 kg of carbon dioxide over the three-year life expectancy, shifting to the new centralized processing IICT electronic device paradigm this would drop to almost one quarter at 1,155,400,007 kg of carbon dioxide over the three-year life expectancy, a dramatic improvement. Many other efficiency can be gained over time using a centralized processing IICT electronic device paradigm;

1. File storage space can be reduced by removing multiple redundant copies of multiple different types of files that are collectively used (i.e. movies, music, books, documents).
2. Personal information will be accessible from any location that you access the cloud from, no longer will information not be available to use, as you do not have your individual IICT electronic device with you.
3. Software will always be at a consistent version, no longer will individuals not be able to use their work on another individual IICT electronic device, as it does not have the correct version of software.

However, to ensure this happens changes must be made with the IICT industry.

Policy Recommendations

Reducing the amount of GHG emissions going into the atmosphere is of paramount importance. No one area will be able to reduce GHG emission by a significant quantity to reach the targets required to limit the amount of climate change should emissions be left unchecked. As identified by the UN, Energy is one of the eight Action Areas that are critical to keeping the global temperature increase to less than two degrees Celsius. This is made even more difficult by the fact that energy demand is increasing with a population that will be approaching nine billion people by 2050. The Sustainable Energy for All, an initiative by the UN and the World Bank would like to see a doubling of electrical efficiency improvement as well as doubling the amount electricity generated from renewable resources (Action Areas - UN Climate Summit 2014, 2014). As has been calculated using rough order of magnitude calculations, moving from a decentralized processing IICT electronic devices to a centralized processing IICT electronic devices will have an efficiency increase of almost four times over what is currently being used, just by the way processing is currently being done. When considering the triple bottom line of Economic, Environmental, and Social benefit the federal government can implement a number policy levers to ensure that this happens in a more expeditious manner.

1. New development areas are receiving the benefit of Fiber Optic communication lines. Retrofitting existing areas within Canada to have access to Fiber Optic communication lines will allow for the paradigm shift of moving from the decentralized processing IICT electronic devices to the centralized processing IICT electronic devices. This would be critical, as data moving is key within a centralized model. Canada currently ranks 23rd of

the 32 countries in the Organisation for Economic Co-operation and Development (OECD) countries (OECD, 2013).

2. Wireless communication needs to be ubiquitous and available to all individuals. Wireless spectrum needs to be increased, Canada currently ranks last of all OECD countries in subscribers per 100 people, it also ranks 23rd in the number of wireless broadband subscribers per wireless communication subscription. These numbers can most likely be attributed to the fact that over the 15 different metrics associated with wireless costs, Canada ranks anywhere from 21 to 32 (there are several at 32) in affordability of the 32 OECD countries (OECD, 2013). Prices need to be reduced so that it is more affordable to all individuals and social classes within Canada.
3. Given the two point above it is apparent that the current oligopoly within the Canadian Telecommunications Industry is not working. Changes need to be made. For example, this can either be done by opening up the environment to more companies to increase competitiveness, or it could become state owned, or it could become a combination of both, where the state owns the infrastructure and a number of companies offer services. Analysis would need to be done to determine the best model to use. The ultimate goal on this would be to improve the services available and reduce the cost of service so that it is more affordable to all social classes within Canada.
4. Currently through an Extended Producer Responsibility program Environmental Handling Fees exist for electronics in a number of Canadian Provinces. These vary from province to province and vary in price from device to device (Managing and Reducing Waste, n.d.). It would benefit industry and practice if this were to be standardized across Canada and

based on the power consumption used by the device. A fee should be applied both to the manufacturer and to the consumer for these devices based on energy consumed by the electronic device.

5. Incentives should be considered to be provided to ICT companies that measurably reduce their carbon footprint by using more efficient servers, increasing usage of servers so that not so many sit idle, have server farms that scale up and scale down server availability depending on system demand. This would need to be analysed to determine how best this could be implemented.
6. Incentives should be considered to be provided to industries within Canada that move towards using more efficient thin client architectures within their business operations. Companies should also look to lengthening out their IICT replacement policies to get as best a return on investment.
7. Incentives should be provided to software companies to develop their software in a manner so as to work on the cloud. This would expedite the shifting of which platform software can run on, if software were easily available on the cloud, consumers may look to purchase thin clients over full systems to save on costs.

Conclusion

Given that a paradigm shift of moving from a decentralized processing IICT electronic device model to a centralized processing IICT electronic device model can benefit the reduction of GHG gases within the Energy Initiative from the UN and the World Bank, it is only if government provides the correct policy levers to expedite the change that will naturally occur. Small incremental improvement in a number of different areas are the key to ensuring that Green House Gas emissions are reduced in a substantial so as to reach the target of preventing the average global temperature raising by two degrees Celsius. Everyone must work together to reach this goal, however a champion need to be there and that champion needs to have the support of the leadership. The United Nation Framework Convention on Climate Change is the champion that the world needs, however individual leaders with the leading countries need to support and champion those ideals within their own countries. Without them being a driving force industry and business will not change until their business model can no longer support an inefficient model of doing business. By that time, it may be too late and no one will be able to cope.

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Appendix A – Source Dates for Figure 1: Sample of Electronic Devices to Market

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