An Insight into ICT's Energy Consumption and its Implications

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Abstract

The major components of an ICT infrastructure is hidden to the general public which creates a false perception that the ICT sector is energy efficient and a significant underestimate in its total energy consumption. This work is a preliminary investigation into the energy demand of the Nepali ICT sector. We present a statistical model to analyse the contribution of the ICT sector in the national energy consumption scenario with a specific focus on the telecommunication sector. Although the model leaves out some important dimensions due to lack of publicly available data, the stable regression model can easily be expanded to accommodate new dimensions (indicators). The results show that even with the most lenient assumptions regarding the behaviour of the ICT sector, it is a (statistically) significant consumer of energy. The hidden from public view is aided by the fact that the energy consumption of the present ICT sector is well below the transportation networks. However, the fast rise in prevalence of the personal computing devices (in households and offices) and expansion of communication networks (especially Telecoms) is likely to see ICT play a critical role in the national energy production framework within our lifetime. Globally the technological innovations have managed to reduce the energy consumption in smart technology applications such as power grids and transportation network with each generation. But it is struggling to keep up with the massive demand for greater performance. As with any technology, the solution to the energy problem is socio-technical rather than purely technological. The understanding of the context of energy use is as important as the technology that delivers energy savings. We therefore recommend that an energy audit of the ICT sector along with large scale studies on the context of technology use has to be done simultaneously. These have to precede the wholesale changes portrayed by the dreams of the ICT policy, e-governance master plan and the like[1]

1 Background

The recently floated ICT policy draft and the IT policy of 2010 have both missed to address the energy demand of the proposed infrastructure and service developments beyond hinting it as a barrier. The wholesale developments in the ICT infrastructure to support online services that caters virtually every aspect of the society can bring the power infrastructure to its knees and by its own. There are fundamental limits to how far and fast the efficiency of the digital technology can evolve. The potential of ICT to improve the energy scenario assumes that the digital technology will be situated in every aspect of our lives to extract every tiny drop of efficiency from transportation, power and electricity, telecommunication to lighting our streets. The idea can be described as a move from the material to immaterial resource. There are obvious flaws to such arguments for a country like Nepal. First, the saving of critical resources such as the energy due to the adoption of ICT and its efficient use will be buried by the growth that is expected from the IT and ICT policies themselves. This is not a new observed effect in the realm of technology and market dynamics. Since the early days of computing, ICT sector has seen massive improvement in the amount of energy consumed by computations. However, the necessity of the increase in the processing power and

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[1]Readers can see Martin Chautari (2014, 2015) for discussions on ICT policy regime and findings from stakeholders' interviews.

the exponential increase in the number of computers over the years have well and truly cancelled the gains over the years. The energy (specifically electricity) required by the computations have overtaken the efficiency in computing. Alarmingly the “Green by IT/ICT" and “Green in IT/ICT" enthusiasts have failed to give due attention to this rebound effect Hilty and Aebischer (2015).

The optimism placed in the digital technology to self-improve at a pace in order to be sustainable relies on technological assumptions some of which require the fundamental limits to be pushed by technological innovations. The improvement of the semiconductor industry is closely tied with the economics of the computer industry. The improvement in the technology to meet the doubling effect of number of electronic components inside the chip requires huge research investment. It is widely acknowledged that as long as the industry is getting the returns, the empirical interpretation of the Moore's law is likely to continue. However, there are numerous challenges to such claims, that the halt in the pace is nearer than expected (as soon as 2036), as they rely on the transistors size to shrink beyond the current fundamental limits Powell (2008).Similarly the demand of the users' for a faster broadband Internet and communications have been pushing the fundamental limits of the optical fibres specifically the Shannon's limit Ellis (2012).

These challenges to the trends, the regression effects and the halt in efficiency gains as the technology approaches the fundamental limits is likely to be seen in our lifetime and not in next-generation or beyond. These should have serious implications on the shape and size of the policy interventions regarding situating ICT as the key driver to economic growth expecting it to deliver sustainable growth while these unanswered questions are on the verge of bringing the house down.

2 Introduction

It has been estimated that the collective electricity consumption of communication networks, data centers and personal computers is growing at a rate of 6.6% per year. Worldwide, the growth rate of Internet users is about 20 percent per year. In developing countries this growth rate is closer to 40 to 50 percent (Vereecken et al., 2011). Studies had estimated by the end of 2012 with an annual growth rate of 10.2% the worldwide electricity consumption from the Telecom operators networks alone will increase to about 260 TWh/y. Clearly, the global ICT sector is on a fast climb where the demand for the ICT performance is increasing faster than the energy efficiency of the technologies. With every technological evolution it is hoped to be more energy efficient. But the argument that progress in technology by itself will balance out energy efficiency and demand is the case of a ball rolling down a slippery slope. Technology also faces the problem of a physical limit (three atom transistor aka "Feynman's limit") where advancement of technologies will no longer be possible. Some claim that this will be reached as early as 2041 considering the current pace of improvement (Hilty and Aebischer, 2015).

The estimated growth in energy consumption by this sector is around 10% worldwide which is lot more than the overall consumption of around 3%. These numbers can vary a lot in different studies based on what ICT components are placed inside the system boundary (such as whether you include end-devices or not and whether you include refrigeration units). Communication networks, personal devices and data centers are usually included as they are the major energy consuming categories in an ICT system. These are also the places where energy efficiency can be achieved with technological advancement and use of cleaner energy alternatives. The exclusion of other components like an optical transport networks are for two main reasons. First, these consume very little compared to other network equipment such as modems, routers and base stations. Second, it is difficult to get a reliable worldwide estimate. It is also common to find studies that solely focus on Telecom operator networks which makes up almost three quarters of the network electricity consumption. The remaining quarter is used by customer premises equipment and office networks Lambert et al. (2012).

The ICT sector manages to keep itself hidden from the general public except when it manifests itself as gadgets, wires and the antennae portion of the telecommunication towers. For most of us ICT is synonymous with what could be categorized as personal computers. These include devices such as mobile phones, TV sets, monitors, laptops, desktops and printers being used in households and offices. Populous cities of Nepal in the last five years has seen massive fiber roll-outs, increase in the smart devices with Internet access for the applications (apps) and exponential growth in the number of mobile subscribers. These are the visible sections of the ICT growth that are popularly reported. However, very little is known, available and understood about the communication networks and core numbers that describe the Nepali ICT infrastructure. For instance, we do not know the number of telecommunication towers, actual number of mobile subscribers (people and not sim count), number of personal computing devices and associated electronic equipments in use, the economic size of the industry, the skilled manpower keeping it running, the life-cycle of the products and the energy required to deliver always on ICT services. The list of unknowns is long and the very little that is publicly known are from the indicators published by the Nepal Telecommunications Authority (NTA), Central Bureau of Statistic (CBS) and international institutions like the World Bank and International Telecommunication Union.

The purpose of this study is to assess whether ICT in Nepal can be considered to be a significant consumer of energy. To answer the question, we present a statistical model to analyze the relationships between the publicly available indicators and the national energy consumption data. This study however excludes the contribution to energy consumptions from customer premise equipments, office networks, computers (desktops/laptops), monitors and data centers (servers). The reason behind is the absence of such data for Nepal and we solely rely on the publicly available data and utilize the accepted global indicators as reported by the World Bank. Therefore, we only use the mobile subscribers number published by the Nepal Telecommunication Authority (NTA) as the key indicator for the ICT sector. This is to our knowledge the only publicly available ICT data that is available from 2003 onwards and has not been produced through extrapolation. We therefore do not attempt to develop an accurate model of energy demand analysis. We rather focus on establishing the significance of ICT in the National energy consumption scenario. We recommend the idea proposed in paper to be taken as a starting point to develop sophisticated models of energy consumption analysis.

Unfortunately the subscribers count do not give the complete picture of the telecommunication sector. Though Telecom are the energy hogs of the Nepali ICT sector specifically with absence of huge data centers, it is a significant underestimation of the contribution of the ICT sector. Absence of data on actual towers in operation, its energy profile in different environment and use conditions and consumption by the network equipments and servers restricts what we can test. With the absence of such important data we are unable to forecast the energy demand/consumption of Nepal in the coming years accounting for the rate of adoption and technological advancement of ICT technologies and services. We also do not test the factual and methodological correctness of publicly available statistical reports. However, we are able to shed some light on it by comparing it with the global trends.

This paper is organized as following. Section 3 describes the energy demand of the ICT infrastructure in the global scenario but with assumptions that are valid in context of Nepal. Section 4 describes the creation of the ridge regression based model of Nepal's energy consumption with our chosen indicators. Section 5 then briefly discusses the environmental and social implications due to overall increase in energy consumption and the contribution from the ICT sector.

3 ICT Energy Demand in the Global Perspective

In an ICT ecosystem, data centers (servers, storage, cooling units), personal computing devices (monitors, desktops, laptops, tablets) and the communication network (Telecom operator networks, office networks, customer premise access equipments) are considered to be the energy hogs. The growth in consumption of electricity by the communication network which is around 10% is outpacing the overall energy consumption of around 3% (Lambert et al., 2012). The data centers and personal computers are themselves growing at an rate of 5% and 4% respectively. But the progress in technological innovation and the effect of energy demand by the ICT sector extends beyond the direct use scenarios. Transportation infrastructure and power grids, for instance, rely on ICT to deliver power savings. It seems reasonable to argue that the cost benefit characteristics of ICT should be studied together. There is a balancing act between the ever growing demand for high performance ICT devices, the number of such devices, services delivered through them and the increasing efficiency of ICT. This is a matter that requires a socio-technical solution rather than an only technological.

3.1 Data Centers

If we look at the technologically advanced countries, data centers (with massive refrigeration units) are one of the major energy guzzlers. In a 2007 study by the Environmental Protection Agency (EPA) in the USA, the projected energy consumption by the data centers was expected to increase from 60 TWh/y in 2005 to 250 TWh/y in 2017 (Brown et al., 2008). A later study showed that in 2013, they had consumed an estimated 91 TWh/y of electricity. This as they put is the "equivalent annual output of 34 large (500-megawatt) coal-fired power plants enough electricity to power all the households in New York City twice over" (NRDC, 2014). Nepal even with the absence of data powerhouses such as Amazon, Google and Facebook will have seen an increase in the data servers that power banks and other small and middle-sized organizations. Telecommunication institutions such as NDCL and Ncell would require huge servers to hold the transaction details of its mobile subscribers. This is only going to increase as the services through mobile phones and computers get popular. However, the substantial increase will most likely come from the demand of small and middle-sized institutions.

3.2 Personal Computing

This category generally include devices that are computers or directly connected to one such as the desktops, laptops, monitors and hand-held mobile devices. Desktops and monitors are expected to follow a decline in sales due to the prevalence of laptops. Laptops meanwhile are likely to continue its increasing trend in the short term but eventually fall behind the portable devices (Andrae and Edler, 2015). However, sales of devices have shown that consumers rather than replacing their existing computing device, are adding newer devices. A 2013 study shows that although laptop sales increased massively in the USA, there was only a small dip in desktop sales (Hischier and Wäger, 2015). Hischier using estimates from four such forecasters, calculated that the estimated number of sales in 2016 would be around 117.9M for desktop, 194.7M for laptop and 320.5M for tablets. The tablets show a dramatic jump from the 134.2M count of 2012 while the desktop and laptop market remains similar. The portable devices alone consumes significant percentage of overall personal computing ecosystem, around 14% in 2011 (Somavat et al., 2011). The study includes the devices in the data centers as part of the ecosystem.

3.3 Base Transceiver Station

A typical wireless communication network consists of chiefly three sections: (i) Mobile Switching Centre (MSC); (ii) Base Transceiver Station (BTS); and (iii) Mobile terminal devices such as phones and laptops. BTS is undoubtedly the power guzzler in the system and the place where efficiency can be achieved with technological innovation. This is the reason why most studies solely focus on this component. Typically within the BTS, 60% of the power is consumed by the radio equipments and amplifiers, 11% by the DC power system and 25% by the air conditioning cooling unit. Most studies agree that radio equipments and the cooling unit are the two places where from the energy savings can be obtained (Lubritto et al., 2011). In their 2011 study, they calculated that a yearly consumption from a BTS is around 35500 KWh. The accurate values depend on the technology used such as Global System for Mobile (GSM), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE). The key difference between the technologies is in the coding scheme and data rates that can be achieved.

4 Statistical Estimation of Energy Consumption due to ICT

As discussed in section 3, the ICT infrastructure has a wide range of energy consuming components that makes actual calculations intricate. An exact analysis of energy consumption due to ICT will follow from a series of thorough evaluation of the data centers, trends in the personal computing sector and multiplication of the base transceiver station throughout the country. Though this bottom-up approach yields more reliable results, it requires a significant time and cost resources. Econometric techniques are thus popular alternatives for analyzing energy consumption pattern on the national scale.

We find two broad categories of econometric approaches generally used on the national level energy consumption analysis. The first approach is to analyze causal relation between energy and a social-economic variable. For example, Dhungel (2014) has established a short and long term causal relationship between electricity consumption and foreign aid in Nepal using the method of error correction. Bhusal (2010) has shown a causal relationship between oil consumption and economic growth in Nepal using Granger causality. The second approach is to analyze the relation between energy consumption with a set of variables. Rijal et al. (1990) have analyzed the relation between energy consumption in a village with various demographic consumption using multivariate linear regression. For the purpose of energy forecasting, models based on the second approach are preferred. In this paper we do not examine the causal links between ICT and energy in the Nepali context. We use an elementary statistical tool to show that ICT energy requirements are a significant portion of the overall national energy demand. Various econometric and statistical methods are available for such an analysis (see Bhattacharyya and Timilsina (2009)). We have selected the linear regression model because its results have simple interpretations and allow for more focused discussions.

Linear regression and its variants are powerful tools used for forecasting in general. Parajuli et al. (2014) describes linear models for forecasting energy demand in various sectors of Nepal. Bianco et al. (2009) provides an electrical energy consumption forecast in Italy using regression models. Mohamed and Bodger (2005) uses linear regression for forecasting electricity consumption in New Zealand. Despite the simplicity of the linear models they provide reasonably accurate estimates. For example, Ekonomou (2010) compares the prediction of Greek energy consumption by the application of neural networks, support vector machines and linear regression. It reveals that though linear regression has poorest performance among the three, its prediction error is still less than 10%, which is tolerable for making policy level decisions.

For our work, we have considered the time series data from 1975 to 2011. These are mostly obtained from the World Bank[2] website. The data for the land-line and mobile telephone subscribers are available from Nepal Telecommunications Authority's reports. Vehicle statistics were taken from the Department of Transport Management [3]. This data is available from 1990 onwards so we have used the values extrapolated using exponential regression. Table 1 summarizes the variables used in this study.

Variable	Description
EN	Annual energy consumption per capita in Kg of oil equivalent (koe)
GDP	Real gross domestic product (in US dollars, constant at 2005)
CPI	Consumer Price Index
$TSUB_{ph}$	Number of landline telephone subscribers per hundred person
$MSUB_{ph}$	Number of mobile phone subscribers per hundred person
$IUSER_{ph}$	Number of ICT iusers per hundred person, assumed to be maximum among $TSUB$ and $MSUB$
VEH_{pc}	Number of vehicles per capita

Table 1: Various variables used in the study.

4.1 Growth Pattern of Mobile Users

There is not a simple indicator that captures the growth of the telecommunication industry. In the literature we can find number of telephone users taken as a parameter to measure telecommunication development in a country (for example, see Datta and Agarwal (2004)). Extending this idea for the present times, we assume an ICT user is a person who either uses a land-line phone and/or a mobile phone. We introduce the variable $IUSER_{ph}$, defined to be the maximum among per 100 person statistics of land-line telephone and mobile users (see table 1). From the NTA statistics, it is reasonable to assume that $IUSER_{ph}$ indicates the intensity of ICT usage.

We now describe the model for forecasting the growth of mobile phone users. The diffusion of a technology, when plotted against time, generally forms a S-shaped curve. This nature of technology diffusion was noted in the classic work by Griliches (1957), and has also been tested in the context of telecommunication users' growth in the European union (Gruber and Verboven, 2001). The growth pattern of mobile subscribers in some of the economically developed countries, shown in figures 1a, 1b and 1c, illustrates this fact. It is evident that the number of telephone subscribers in Nepal is still to reach the saturation level (figure 1d). Let the S-shaped logistic function be described by

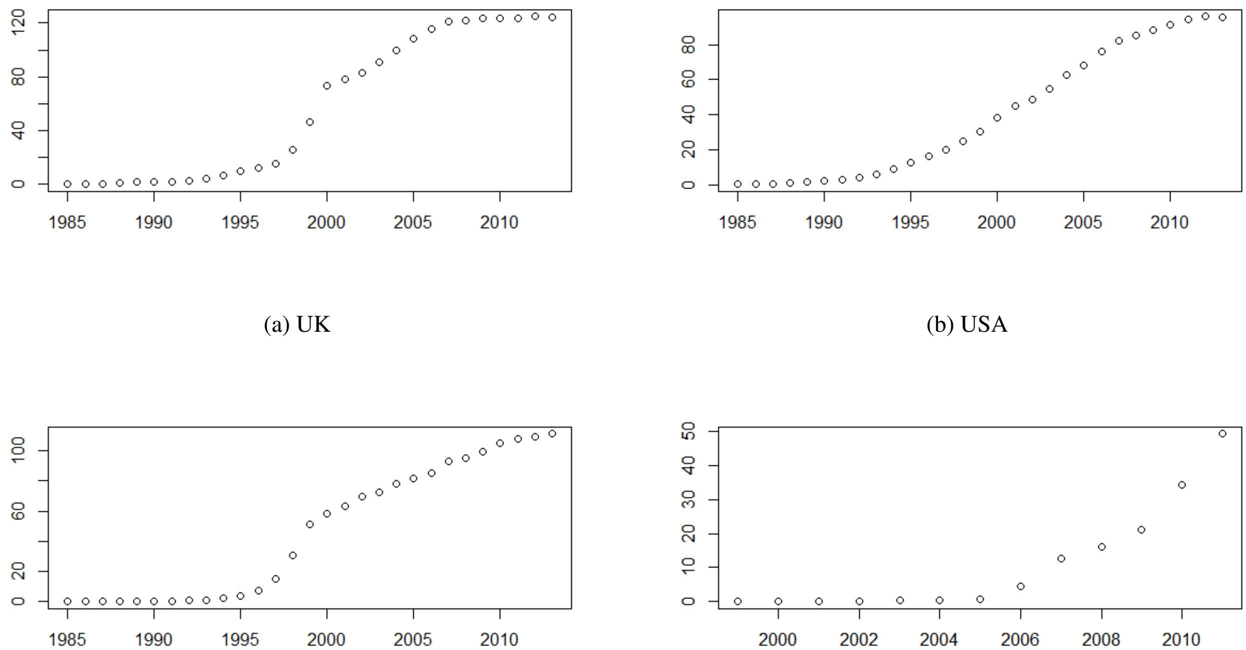
$$f(t) = \frac{S}{1+ae^{-bt}} \tag{1}$$

Here, $f(t)$ is the percentage of Internet users, S is the saturation level, and a, b are constants. Taking natural logarithm on both sides of the equation 1 followed by a rearrangement, we have

$$\ln\left(\frac{S}{f(t)} - 1\right) = \ln a - bt \tag{2}$$

Table 2 is the result from the regression on the mobile growth data of UK, USA, Korea Republic and Nepal. The saturation level for the growth was taken as the closest upper bound to the data. Since the number of telephone users is still growing in

[2] http://data.worldbank.org/data-catalog/world-development-indicators
[3] http://www.dotm.gov.np/en/



(a) UK

(b) USA

(c) Korea Republic

(d) Nepal

Figure 1: Growth pattern of mobile users per 100 people

Nepal, we take the saturation level equal to 1.1. This ensures the predicted percentage of Internet user at 2015 (104%) matches with the actual percentage (99.94%).

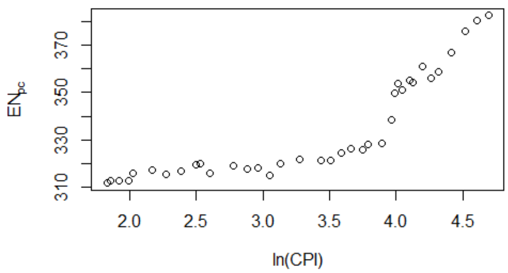
Country	Assumed Saturation Level	Coefficients		t value	p value	R sq	Adj Rsquared
UK	1.25	$\ln a$	7.240933	46.41	<2e-16	0.9892	0.9888
		$-b$	-0.451226	-49.67	<2e-16		
USA	1	$\ln a$	5.955234	49.72	<2e-16	0.9879	0.9874
		$-b$	-0.326914	-46.88	<2e-16		
Korean Republic	1.2	$\ln a$	8.07314	21.80	<2e-16	0.9345	0.9319
		$-b$	-0.42912	-19.25	<2e-16		
Nepal	1.1	$\ln a$	5.77190	18.080	1.57e-09	0.8936	0.8839
		$-b$	-0.38661	-9.612	1.10e-06		

Table 2: Results of regression on the mobile user growth model of equation 2

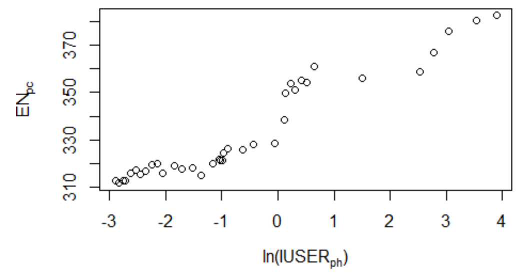
After the mobile telecommunication boom in Nepal, the number of mobile subscribers has shadowed the number of land line telephone users. The future growth pattern of $IUSER_{ph}$ is captured by the growth pattern of number of mobile users per hundred persons, $MSUB_{ph}$.

4.2 Ridge Regression based Energy Consumption Model

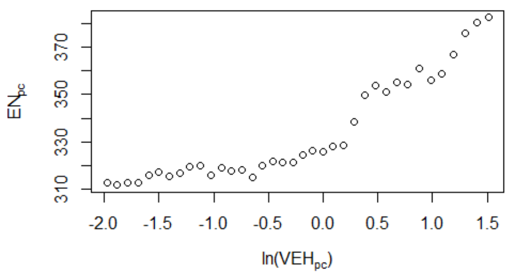
Figure 2 shows the scatter plot of EN_{pc} versus the logarithms of the probable predictor variables CPI, $IUSER_{ph}$, VEH_{pc}, and GDP_{pc}. The relationship between EN_{pc} and the logarithms of these variables appear to be linear thereby suggesting the possibility of a linear model existing. However, the variables are highly correlated. This correlation persists even after taking logarithms (see table 3). This clearly indicates linear regression would not be reliably appropriate for the data. We thus analyze energy consumption using ridge regression (Hoerl and Kennard, 1970) model, which is specifically applicable for highly multi-collinear data.



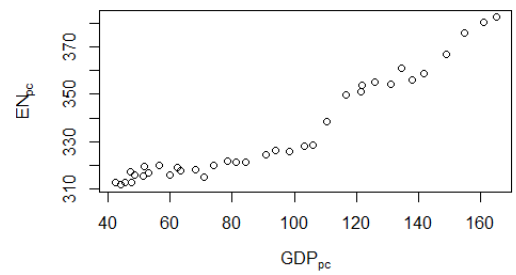
(a) EN_{pc} vs $\ln(CPI)$



(b) EN_{pc} vs $\ln(IUSER_{ph})$



(c) EN_{pc} vs $\ln(VEH_{pc})$



(d) EN_{pc} vs $\ln(GDP_{pc})$

Figure 2: Plot of EN_{pc} versus various variables

	EN	$\ln(CPI)$	$\ln(IUSER_{ph})$	$\ln(VEH_{pc})$	$\ln(GDP_{pc})$
EN	1	0.8670457	0.9542098	0.9202035	0.902716
$\ln(CPI)$		1	0.9238908	0.9901741	0.9938488
$\ln(IUSER_{ph})$			1	0.9586715	0.9412552
$\ln(VEH_{pc})$				1	0.9959809
$\ln(GDP_{pc})$					1

Table 3: Pearson Correlation Coefficient between the variables of equation 3

Coefficient	Standardized	Original
Intercept	0	298.9649
$\ln(CPI)$	-2.0199150	-49.414460
$\ln(IUSER_{ph})$	0.4198021	4.826849
$\ln(VEH_{pc})$	1.5768117	33.156083
$\ln(GDP_{pc})$	0.9442751	47.486286
Standard Error	0.2245668	4.889427
	Adjusted R^2	0.9495698

Table 4: Results of Ridge Regression on equation 3 with biasing parameter $\lambda = 0.01203691$

We propose the following linear model for describing energy consumption pattern.

$$EN_{pc} = \beta_0 + \beta_1 \ln(CPI) + \beta_2 \ln(IUSER_{ph}) + \beta_3 \ln(VEH_{pc}) + \beta_4 \ln(GDP_{pc}) + \varepsilon \quad (3)$$

The optimal value of the ridge biasing parameter for the normalized variables using the algorithm of Hoerl et al. (1975) is found to be $\lambda = 0.01203691$. The result of ridge regression is shown in table 4 and the regression curve in figure 3. The adjusted R^2 for the fit is 0.9460079. Since variable selection on the basis of statistical significance is not appropriate in presence of multicollinearity, tests for the significance of coefficients is usually not done in ridge regression analysis (Marquardt and Snee, 1975).Basic Dickey-Fuller test shows the residuals are stationary within a p-value of 0.05291. The coefficients indicate that energy consumption increases with the ICT usage, number of vehicles, and GDP, but decreases with consumer price index, as expected.

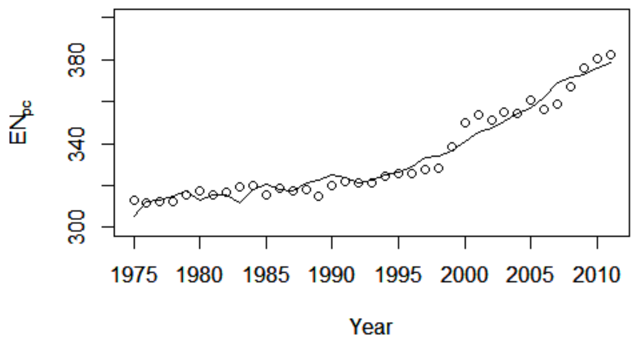


Figure 3: Actual and regressed values of energy per capita. The dots show the actual values.

5 Implications

5.1 Energy Consumption Scenario

In this section, we discuss the implications of the energy consumption model developed in section 4. The overall trend of energy consumption, assuming logistic growth for mobile subscribers (see section 4.1) and exponential increase for remaining three variables, is shown in figure 4. Following this pattern, energy consumption per capita would reach 395.4, 399.8, and 404.2 koe in 2020, 2025, and 2030 respectively. The net increase in energy per capita from 2011 to 2030 would be 21.6 koe. It is difficult to comprehend how the nation will cope with the economic and environmental challenges posed by such a massive increase in energy demand. Taking Nepal's population at 27.8 millions, annual increase in energy consumption by 21.6 koe is equivalent to annual oil consumption increase by 681.9 million litres. To make the number easy to comprehend this amount is equivalent to 1,551.9 kilo-tonnes of firewood and roughly equal to 17,776 Sal trees.

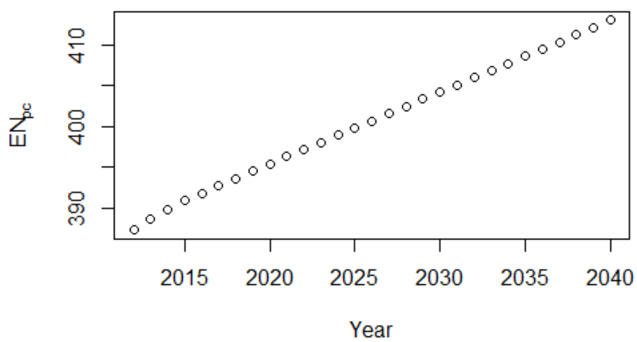


Figure 4: Predicted trend of energy consumption.

The energy demand of Nepali ICT is therefore enormous. The increase in energy consumption due to ICT users during the period of Telecom industry growth (1999-2011) while keeping other variables constant is about 16.1 koe. Table 5 shows this value is comparable with the partial energy consumption increase by the other variables of our model. Since the number of ICT users has still time to reach the saturation level (see section 4.1), the change of energy consumption per capita after 1999, assuming other factors constant, would reach 20.1 koe. As mentioned earlier, this value becomes gigantic when total population is accounted for. These calculations demonstrate the tendency of energy consumption by the growth in number of ICT users.

Variable	Partial Energy Consumption Growth (koe)
CPI	-38.25596
$IUSER_{pc}$	16.11119
VEH_{pc}	38.67561
GDP_{pc}	16.95808

Table 5: Partial growth of energy consumption per capita due to various variables during the period 1999-2011

The number of ICT user will reach near its saturation after 2015 and thus increase in ICT users thereafter, according to equation 3, will not significantly increase the energy consumption. This is an underestimate as our analysis considers ICT usage through land line or mobile telephones only. The impact of future ICT on energy consumption is a topic of research on its own.

About 75% of national energy is extracted from firewood. ICT and motor vehicle both require efficient form of energy, which cannot be achieved by firewood. Unsurprisingly the increase in ICT usage, or vehicle numbers, will not directly increase firewood consumption. We also cannot expect hydro-power which currently provides less than 2% of national energy to feed the power requirements of the future ICT and related industries. The growth in energy demand will automatically increase the import of petroleum, together with its economic and environmental challenges.

5.2 ICT Application and Sustainability Scenario

"ICT for sustainability" has been a popular interdisciplinary topic of interest for discussion on how innovative applications of ICT can help for sustainable development. Economic growth, economic activities, consumption of resources and environmental consequences are the major dimensions where ICT's impact and potential is assessed. One popular solution that is proposed is to replace material resources with software (immaterial and thus can be replicated in large numbers). Within the sustainability domain, green ICT/IT focuses on the role of ICT towards the increase of carbon-dioxide emissions or towards its use to conserve energy in other areas. However, Nepal poses a big challenge as industrial energy consumption is only 5.25% of the total, whereas household consumption is 89.06%. This is in sharp contrast if we look at USA whose industrial sector uses 44.87% and domestic sector uses only 21.79% of the total national energy. Furthermore, the Jevons paradox which basically states that the technological efficiency (how the resource is used) and the demand for the resources head in the opposite direction and has been verified with many empirical evidences clearly shows that technology is not an obvious solution. Interestingly, the paradox is distinctly evident in the computing industry as the increase in electricity use for computing is phenomenal (see Koomey et al. (2011)). The energy consumption of the transportation sector in Nepal is a clear demonstration of the paradox. A strong argument therefore can be made that for Nepal the solution is socio-technical and not entirely technological. We need to understand how the population uses ICT in households and offices. The technological innovations and efficiency argument for sustainability that could apply to the digitally industrialized nations do not apply to Nepal under the simplistic argument it is usually portrayed. It is at best speculative. This gets even muddier as we factor in the use of the Internet. It is difficult to accurately measure for instance how much energy is saved when we buy grocery online instead of going to a shop. The results can vary by many orders of magnitude in different studies depending on the choice of boundary and type of assessment (top-down or bottom-up) (see Coroama et al. (2015) for examples of this behavior).

6 Conclusions

We have argued that the growth in the number of mobile subscribers can be modeled with a sigmoid (S-shaped) curve. The fit shows that number of mobile phone subscribers in Nepal is yet to reach the saturation level. It is also clear that the number of mobile subscribers will go beyond the 100 percent population mark. This can be easily explained by the fact that the subscriber counts are not person count but rather count of sim-cards. It is also not clear if the counts includes in-use sim card only or number of pieces sold or if it is multiplied by some constant term to describe access. Although the relationship of the mobile subscribers count with energy consumption is unlikely to become insignificant (statistically) in the light of true numbers, it is incorrect to use 100% as some magic number, as it is common to hear in the media, to push forward radical policy recommendations for national growth and rural development. The growth could well go beyond 200 mobile subscribers per 100 persons as in case of Hong Kong and other few countries. Our regression results show the energy consumption of the ICT sector, though well below the use for transportation, is significant now. The gap is ever narrowing with the growth in personal computers for household and office uses outpacing technological innovation. It will be far more when huge data centers (with its large cooling requirements) are established to support e-governance, e-commerce and other data intensive always-online services. The problem is however socio-technical and will need more than just a technological solution such as green energy alternatives and rapid hydro-power developments. Though green energy could help reduce emissions of toxic gases, it is yet to be seen in practice if the technology could meet the huge demands of Telecoms, let alone whole of ICT, to a substantial degree. If the dreams of the ICT policies and e-governance and e-commerce roadmap are to re realized, ICT sector will be near the top (or the topmost) consumer of energy. We therefore suggest that an energy audit of the ICT sector along with large scale studies on the context of technology use to be done simultaneously for Nepal. Otherwise, drafting such documents are a waste of energy.

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