How Information and Communications Technology Can Achieve The Sustainable Development Goals

ICT & SDGs

Acknowledgements

This report was conducted by a team from the Earth Institute at Columbia University in collaboration with Ericsson. Under the lead of the Director of the Earth Institute, Professor Jeffrey D. Sachs, the research team worked with a variety of multidisciplinary experts in order to gain a thorough and rich understanding of the impacts of Information and Communications Technology (ICT) on achieving various Sustainable Development Goals (SDGs).

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We wish to thank the following people from the Ericsson team for their kind reviews and helpful guidance throughout the whole report process.
Sergio Lopez Ramos, Technology For Good, Program Director, Ericsson, Sweden
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Special Thanks to:
Hans Vestberg (Ericsson), Alexandre Tourre (SIPA-Columbia), Dr. Radhika Iyengar (Earth Institute), Saloni Jain (Columbia), Sara Mazur (Ericsson), Zohra Yermeche (Ericsson), Anders Lundqvist (Ericsson), Paul Landers (Ericsson), Matilda Gennvi Gustafsson (Ericsson), Ivan Lupic (Ericsson), Dr. Silvia Montoya (UIS), Monica K. Carty (SDSN), Kathy Zhang (SDSN), Dr. David Hollow (Jigsaw Consult), Martin Schaaper (UIS), Peter Wallet (UIS), Jim Teicher (CyberSmart Africa), Dr. Sonia Sachs (Earth Institute), Elizabeth Zehe (Earth Institute), Debbie Creque (Earth Institute), Claire Bulger, Olimi Rugumayo (Shifo.org), Rustam Nabiev (Shifo.org), Erik Wetter (Flowminder), Anne Liu (Earth Institute), Jonathan Jackson (Dimagi), Darko Gvozdanovic (Ericsson), Anuraj H. Shankar (Harvard), Dr. Roberto Araya, Irmgarda Kasinskaite-Buddeberg (UNESCO), Prachi Jain Windlass (MSDF), Chandrika Bahadur (SDSN), Arvind Nagarajan (PALF), Christine McCaleb and Jennifer Russell (iEarn).

Final thanks to John and Stephanie Stislow from Stislow Design for their wonderful work on the design of this report.

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Key Research Insights: ICT and the SDGs

Summary

Key Research Insights: ICT and the SDGs

The new Sustainable Development Goals (Figure 1), or SDGs, call for several bold breakthroughs by the year 2030, including the end of extreme poverty (SDG 1) and hunger (SDG 2), universal health coverage (SDG 3), universal secondary education (SDG 4), universal access to modern energy services (SDG 7), sustainable cities (SDG 11), combatting climate change (SDG 13), and protecting marine (SDG 14) and terrestrial (SDG 15) ecosystems.[1] To many, these goals will seem utopian. They are definitely "stretch" goals that will require a transformation of societies that is far deeper and faster than in the past. If they are to be achieved, these goals must leverage existing and widely deployed technologies, such as broadband, but also require new innovative services and improved reach of technological solutions; economic growth in a business-as-usual (BAU) context will not be sufficient for success. In our view, the broad application of information and communication technology (ICT) is a profound reason for optimism, since the rapid development of ICT-based services and systems offer the possibility for the needed deep transformation of the world economy and societies more broadly.

ICT will play a special role in today's low-income countries, a point strongly and cogently emphasized by the UN's Broadband Commission.[2] In essence, ICTs are "leapfrog" and transformational technologies, enabling all countries to close many technology gaps at record speed.[3] High productivity growth in the ICT-producing industry, driven by Moore's law, has resulted in considerable price decreases which have enabled a rapid diffusion of ICT-products. The nearly universal uptake of mobile telephony is a case in point. Mobile subscriptions in Africa have gone from almost no subscribers in 2000 to around 900 million today. Mobile phones have already allowed for dramatic breakthroughs in e-finance and e-health, overcoming long-standing gaps in access to facilities such as bank branches and clinics. ICT today is in many parts of the world enabling transformation of the most expensive public services such as education, health care and also advance low income countries' economies such as agriculture, trade/ecommerce, and transportation. This transformation needs to be scaled up. It is also our assertion that future advances in ICTs—including mobile broadband, the Internet of Things (IoT), robotics and artificial intelligence, 3-D printing, and others—will provide the tools for additional, unprecedented advances in healthcare, education[4], energy services, agriculture, and environmental monitoring and protection.

Figure 1. The Sustainable Development Goals

One of our key points, however, is that governments, academic and other institutions , businesses and people in the developing countries (and indeed in the developed countries as well) must prepare themselves for this ICT-enabled transformation; many of them are not ready today. While private-sector applications of ICT have soared, many of the challenges of sustainable development—health, education, infrastructure, and environmental sustainability—require a deep role of the policy makers and the public sector. This, in turn, puts a spotlight on institutions, which are in general important determinants of the success or failure of development. Governments and policy makers more broadly have a special responsibility to ensure that key public –sector agencies, institutions and policy frameworks are reformed to support ICT-enabled transformation. Every government process—payments, tax collections, procurement, training, human resources, program design, public deliberation, information management, analytics, legislative drafting, even voting—should be upgraded with the ICTs' transformative capability in focus. Institutional quality will matter, but will be increasingly defined by the extent to which it usefully incorporates cutting-edge solutions to facilitate the provision, transparency, openness, and efficiency of public services.

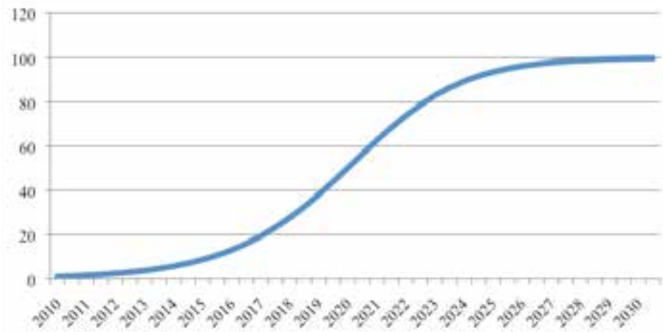
The main policy conclusion of our study is that governments need to ensure that the entire public sector, including service delivery in health, education, and infrastructure, is fully supported by high-quality ICT infrastructure. This includes:

- Broadband connectivity of all public facilities by 2020
- ICT training of all relevant public officials and service providers
- ICT-based delivery systems for healthcare, education, and infrastructure
- Deployment of the Internet of Things (remote sensing and control of connected devices) for the public infrastructure and environmental management
- Encouragement of universities to scale up education and incubation of ICT solutions, including through partnerships with the business sector
- Public-Private Partnerships (PPPs) for ICT-enabled systems
- Deployment of an ICT-based SDG information system that connects public services, public facilities, the business sector, and the public

Our core observation is that ICT has the potential to increase the rate of diffusion of a very wide range of technologies, applications, and platforms across the economy. Key sectors in which technology diffusion can be accelerated include: healthcare, education, financial services, electrification, and high-yield agriculture. The accelerated uptake of ICT-based services constitute the key to achieving the Sustainable Development Goals by their target date of 2030. In fact, ICT not only empowers other technologies and services, it in itself is also one of the technologies that can accelerate uptake,

If we consider the uptake of a technology (such as electrification, secondary-level education, or primary health coverage), the diffusion (or uptake) of the technology will typically follow an S-shaped curve as in Figure 2. The use of the technology will start at a very low level, and initially will increase only gradually. After some time, the uptake of the technology will accelerate. Later on, as the coverage rate approaches 100%, the growth will slow again and finally come to a halt when coverage is complete.

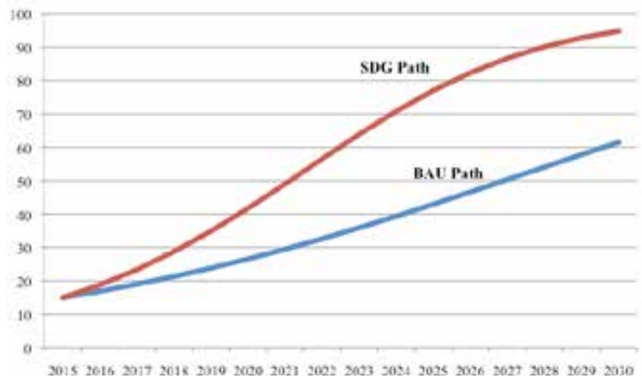
Figure 2. Illustrative S-Shaped Technology Diffusion Curve



As noted earlier, many of the SDGs call for the economy to reach universal coverage of some core service by 2030, e.g. healthcare (SDG 3), pre-primary up to secondary education (SDG 4), access to safe water and sanitation (SDG6), and access to reliable electricity (SDG 7). In most low-income countries, the Business-as-Usual (BAU) path will not be sufficient to achieve these universal coverage goals by the target date of 2030. As illustrated in Figure 3, the BAU path will support partial achievement of the goals but will not be sufficient to facilitate full achievement. The path to the universal coverage must be accelerated, as shown by the SDG path in Figure 3. We believe that ICT-based solutions are the key to that acceleration, if governments, universities and the private sector work in partnership towards those goals.

There are five major ways in which ICT can dramatically speed the uptake of SDG-supporting services. Firstly, that ICTs themselves diffuse with remarkable speed and at a global scale. The uptake of mobile phones, computers, the Internet, and social media, have been the fastest adoptions of technology in human history. Mobile subscriptions went from a few tens of thousands in 1980 to around 7 billion subscriptions in 2015. Facebook users went from zero in 2004, the year Facebook was launched, to 1.5

Figure 3. Comparison of BAU and SDG Paths



billion users in mid-2015. According to projections by Ericsson Mobile Report June (2015)[5], mobile broadband coverage (3G or above) worldwide will go from almost 1 billion subscribers in 2010 to 7.7 billion subscribers in 2020, covering roughly 90 percent of the world's population. Smartphones will go from near-zero subscriptions in 1999 (when NTT DoCoMo introduced the first smartphone) to 6.1 billion subscriptions in 2020 according to projections by Ericsson (2015).

The second way is that ICT can markedly reduce the cost of the deploying the new services. In healthcare, for example, ICT makes possible a greatly expanded role for low-cost Community Health Workers (CHWs), enabling many diagnoses and treatments to be made at the community level (during CHW visits to the households) rather than at high-cost facilities; in education, ICT enables students to access quality online teaching even when no qualified teachers are locally available; and online finance allows individuals to obtain banking services even when no banks are present. These simple examples are of course just the tip of the iceberg: cost savings from ICT are already disrupting major sectors across the economy in high-income countries, and introducing vital services for the first time in low-income countries.

The third way is that ICT can dramatically speed up public awareness of new services and technologies, and therefore the demand and readiness for these. In the past, information on new technologies spread by word of mouth, local demonstrations, and the scale-up of government programs and services. Now, with torrents of information flowing through the Internet, social media, mobile communications, and other e-channels, information travels nearly instantly around the globe, except in the few societies isolated by closed regimes. Songs, fashions, fads, personalities, and new technologies all ricochet around the world in days, not years as in the past.

The fourth way is that national and global information networks can support the rapid upgrading of new applications. Every new technology, including ICT-based technologies, must go through a learning curve in which the technology passes through several "generations" of improvement, with each generation in principle marked by lower costs, greater resilience, easier use, and wider applicability. ICT can speed up these generational cycles. Global information flows are enhanced, and technology developers are much more attuned than in the past to advances being achieved in other parts of the world. There is a trend toward many ICT applications becoming open source, or at least inter-operable, which allow for gains made by one developer to be picked up and improved by others. The whole process of technology upgrading has thereby accelerated, with the winners of this intense competition often carrying home the prize of a large slice of the global market. While much of the technology development will occur beyond the borders of any single country, each country can and should speed its own learning curves and shorten the time of each technology generation, especially for ICT-based solutions that necessarily have strong local content (e.g. for education, healthcare, agriculture, and environmental management).

The fifth way that ICT can accelerate technology diffusion is by providing low-cost online platforms for training workers in the new technologies. The revolution of Massive Open Online Courses (MOOCs), for example, enables students anywhere to gain free access to high-quality university courses, including courses in the design and use of ICTs. Special training materials are also being delivered conveniently over smart phones, tablets, laptops, and other devices. These multiple channels for training materials are making it much easier to provide workers with real-time, in-service training that does not disrupt their work schedules, but rather builds the training right into the work itself. In this way, ICT-hosted training modules and courses offer the way to train millions of workers, especially young and under-employed workers, in the uses of new ICT applications for SDG-oriented service delivery.

Lessons from Key Sectors

This report summarizes the lessons to date and the future prospects for ICT in four sectors: health, education, financial services, and infrastructure, focusing on electricity power. The main insight is that ICT offers an acceleration of technology uptake in all four sectors. They do so by reducing the unit costs of service delivery; expanding the range of services that can be offered; economizing on scarce resources (such as local skilled workers, who can be engaged online rather than local presence); and accelerating the institutional learning through online communities.

Nonetheless, our case studies highlight the many practical hurdles to effective large-scale implementation of areas such as e-health, m-health, m-commerce, e-education, and smart energy services.

1. The public sector regulations should enable the full utilization of ICT.

2. The current fragmentation of many small demonstration projects need to be transformed into an increasingnumber of national-scale programs.

3. The physical infrastructure for wireless broadband will need rapid expansion and upgrading, especially to public facilities like schools and clinics.

4. The various components of an ICT-based system will need to be interoperable across several competing platforms.

5. There will need to be significant training of personnel to manage the new systems.

6. There will need to be the incubation of new ICT start-ups capable of providing locally appropriate services as part of Public-Private Partnerships.

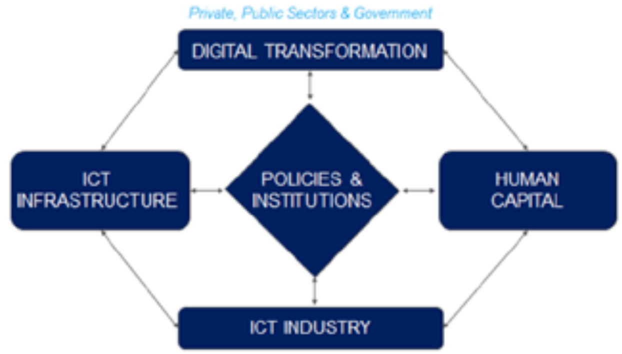
In general, however, the many case studies in this report point to an exciting future. Many of the breakthroughs that we will need for the SDGs are already in operation, albeit on a very small scale. The good news is that ICTs, by their very nature, make the rapid scale up of today's demos to tomorrow's national programs both feasible and realistic.

The Components of National ICT Deployment

In these times of rapid ICT enabled transformation—standing still is the biggest enemy. The central role of policy makers have been already highlighted, but even more these actors not only need to act as socio-economic accelerators but also mobilize national collective action for transformation.[6] National governments are at the center of the economic transformation process, and are responsible for ensuring the rapid uptake and adoption of ICT. Governments and policymakers more broadly are accountable for the policies and legislative framework that govern the deployment of ICT. Governments are also responsible for land use, the allocation of spectrum, right-of-ways for fiber and other infrastructure, tax and regulatory policies, that will determine the speed of roll out of the ICT backbone and access networks, the service providers, and the uptake of ICT-based solutions in public services such as health and education.

A convenient way to visualize the interconnected components of a rapid and successful ICT deployment is shown in Figure 4. At the center of the deployment process are the government policies and institutions needed to deploy ICT. Those shape all other aspects of the ICT system. They influence the roll out of the physical infrastructure (shown on the left) such as the fiber/microwave backbone and the wireless access network; the ICT and general skills of the workforce (shown on the right); the local operating presence of the ICT industry (shown on the bottom); and the readiness of both the public and private sectors to adopt ICT solutions (shown at the top).

Figure 4. The Interconnected Components of Successful ICT Deployment



Source: Hanna, Transforming to a Networked Society, Guide for Policy Makers, 2015.

Let us consider each of these briefly.

(1) Government policies must allocate the needed spectrum; support and facilitate the right-of-ways for the fiber backbone; allow the easy entry of ICT-based companies into the economy even when they disrupt existing business models and practices; and ensure that the public administration itself is prepared for an ICT-based transformation. Most of all, the government should convey the vision of a networked society, calling on all parts of the society to join in ICT services and to facilitate the rapid diffusion and uptake of ICT-backed systems.

(2) The ICT infrastructure, especially mobile broadband, needs to be urgently in place in all regions of the country, and throughout the public sector. All clinics, hospitals, schools, universities, infrastructure networks, and the public administration should be connected to a high-speed broadband network no later than 2020. If the basic infrastructure is delayed, the 2030 SDG targets will become impossible to achieve. Private-sector operators will finance much of the needed infrastructure, and in fact no industry has scaled like the mobile industry, which was based on fair competition, global standards and economies of scale, all of which served to to drive down prices, drive up the inflow of needed capital, and improve accessibility.

(3) Government must take the lead in ensuring that the population is ICT ready through age-appropriate STEM (science, technology, engineering, and mathematics) education at all levels of schooling. It is notable, for example, that New York City has recently ordered all schools to teach computer science to all students in the NYC public schools within the next 10 years.[7] Universities and ICT businesses, working in cooperation with government, must also do their part to ensure training at all levels, including the technical workers needed to write the apps and manage the infrastructure of the new

ICT systems, and the incubation of new business models. Training in entrepreneurship can help to spur new business development.

(4) ICT industries, both local and international, should be encouraged by government policies to operate within the country. Local ICT companies are vital for providing local solutions and apps for the local context. International ICT companies operating locally will certainly facilitate the rapid diffusion of ICT-based solutions. In turn, the international ICT companies should be good local citizens, committing themselves to participate actively in public-private partnerships (PPPs) to achieve the SDGs in every host country in which they operate.

(5) All public and private firms should accept and help to lead the digital transformations in their respective sectors. Construction companies should facilitate wired or wireless broadband in all buildings. Transport and infrastructure companies should deploy ICT technologies, including the Internet of Things (IoT) including smart metering of infrastructure and remote sensing of environmental conditions. Most importantly, the public sector, often the most challenging to change should rapidly adopt ICTs in all public service delivery, including e-governance (e.g. online payments, taxation, regulatory compliance, public documents, civil registrations, unique identification, etc.), health services, education services, and infrastructure management. All public facilities—schools, clinics, hospitals, universities, power grids, roads and rail, and public administration (e.g. tax services)—should be part of the high-speed broadband network no later than 2020.

It is important to emphasize some of the specific challenges and obstacles that will need to be faced. To orchestrate ICT enabled transformation and realize the benefits policy makers could take a much broader and a more coherent approach to ICT policy making The associated policy decisions or lack of them will have significant impact on; R&D investments (knowledge creation), value creation (innovation), roll out (diffusion), and use (adoption) of ICT. These ICT policies (see below) will determine the cumulative strength and sustainability of ICT in driving transformational change and the distribution of socio-economic benefits. They are also central as they impact key stakeholders' timing and degree of willingness to invest in ICT, and hence the long-term supply of ICT-related capabilities. They also determine end users' (individuals, businesses, and public services) ability to benefit from ICT as they define the speed, scope, and intensity of opportunities and benefits available from ICT-enabled service adoption.

Supply-side ICT policy issues

- **National broadband (BB) policies** aim to increase the roll out of BB infrastructure within a geography (region or a country) typically specifying an ambition in terms of expected BB service speeds, service roll out time plan, and sometimes adoption. They may also include public funding and cooperation mechanisms.

- **Network regulation** aims to address technical (standards), market (incumbent, new entrant) and consumer (protection, pricing) specific conditions with the aim to improve market efficiency, public interest (universal access) and increase protection of consumers (contract terms).

- **Spectrum management** aims to efficiently manage scarce resources and allocate new spectrum to highest value. Also includes global or regional coordination and harmonization of spectrum usage to decrease cost of technology by increasing economies of scale.

Demand-side ICT policy issues

- **Industrial Internet/ Internet of things**—an umbrella term concerning emerging issue across a number of sectors currently experiencing accelerated rate of digitization such as, health, electricity, and energy. Increased use of ICT may result in changing relationships in existing value chains and in new business models, upsetting the status quo.

- **Media/ content regulation** aims to regulate, increasingly in a multi-platform environment, obligations, roles and responsibilities of media service and content providers while creating, aggregating, and making available audio-visual content.

- **Data protection** aims to regulate data subjects' rights and data controllers and processers' obligations while collecting, processing, using and disseminating personal data. It also regulates transfer of data across national boundaries and roles and responsibilities in data processing value chains. Increasingly the challenge is about optimising a data protection perspective focusing on protecting citizens with a data driven innovation paradigm aiming to enable new form of innovation, services and industries to evolve (see emerging policies section below).

Horizontal policies impacting supply and demand side

- **Internet governance** concerns rules and principles for the operation and use of the Internet—the mandate, organization, and responsibilities of governing entities.

- **Trade policies** aim to regulate trade (financial, products, services, technologies, etc.) between countries and regions. Trade policies can facilitate liberalization resulting in more trade, economic and social integration, as well as transfer of technologies and innovations.

- **Intellectual Property Rights** (IPR)—an umbrella term including trademarks, patents and copyrights. The regime aims to protect private interest and increase incentives to invest in new knowledge creation and innovations on one side, and on the other, stimulate diffusion of new knowledge and innovation—for example, foster positive spillovers for greater societal benefit, thereby also limiting the private interest to appropriate some portion of the value attached to intellectual property investments.

Emerging policies impacting supply and/or demand side

- **Critical infrastructure and cyber security**—critical infrastructure refers to any vital infrastructure for the functioning of modern societies, such as electricity and ICT. The policy aim is to take extra security measures—physical, logical, procedural, and redundancy—to assure continued availability beyond the demand and willingness to pay by the commercial market, as well as to cope with stressful environmental or other situations. Cyber security is a much broader term that includes considerations covered by critical infrastructure, as well as additional considerations such as offensive and defensive measures to protect against and resist cyber-attacks targeted ICT at any level: network, IT-infrastructure, software, device, and user.

- **Data Driven innovation.** Big data and analytics refer to large scale collection of data whose analysis drives innovation that creates new opportunities for society. Policies primarily touch upon data protection when they are applied at the individual level. When applied at the business level, they deal with issues of copyright, liability, and trade secrets. At the societal level they touch upon issues of open data, transparency and e-government initiatives. Increasingly there is need to view data driven innovation as a new phenomenon that is about creating new set of opportunities for new industries to be created.

Can national governments and the other sectors of society prepare and implement this rapid ICT-led advance? The answer is yes, if there is a strong, shared vision of how to proceed, and if new ICT-supporting policies are quickly put in place. In addition to the steps outlined for government, we see three more critical partners: the global ICT sector, both public and private; the universities around the world; and global donors, including philanthropists and foundations.

(1) The international ICT sector, represented for example in the UN Broadband Commission, will need to step forward to provide, advice, expertise, financing, and tools for rapid scale up.

(2) The universities, in partnership with governments and businesses, will have to undertake massive training programs, and become the host of new ICT business incubators. The UN Sustainable Development Solutions Network, which has hundreds of universities around the world as members, is gearing up to support universities to undertake this ICT leadership role.

(3) Global donors will have to provide quick seed funding to get these activities underway.

In conclusion, the SDGs represent a complex, global-scale problem-solving exercise that cuts across all sectors of the economy and that must engage all sectors and all parts of the world. The entire world has adopted the SDGs; now we will have to deploy all of the tools available, and especially ICT, to make them a success.

Endnotes

[1] See "Transforming our World: The 2030 Agenda for Sustainable Development" (2015).

[2] See "Means of Transformation: Harnessing Broadband for the Post-2015 Development Agenda" (2014).

[3] World Economic Forum,. Global Information Technology Report. 2015.

[4] See the Broadband Commission Report on "Technology, Broadband, and Education" (2013).

[5] http://www.ericsson.com/res/docs/2015/ericsson-mobility-report-june-2015.pdf

[6] For more inspiration on how to do that please see: Transforming to an Networked Society, Guide for Policy Makers available: http://www.amazon.com/Transforming-Networked-Society-Policy-Makers/dp/1942916000/ref=sr_1_fkmr0_2?ie=UTF8&qid=1442820856&sr=8-2-fkm-r0&keywords=Hanna%2C+Transforming+to+a+Newtorked+Society%2C+Guide+for+Policy+Makers

[7] http://www.nytimes.com/2015/09/16/nyregion/de-blasio-to-announce-10-year-deadline-to-offer-computer-science-to-all-students.html?_r=0

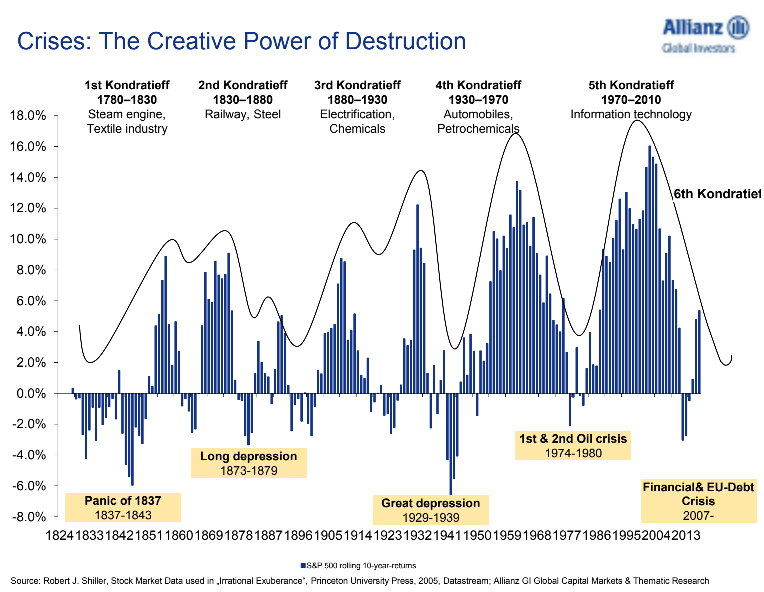
1.

ICTs and the Sustainable Development Goals

1.1. Introduction

The Information Age, made possible by Moore's Law and associated Information and Communications Technologies (ICTs), can be considered the fifth great technological age since the onset of the Industrial Revolution. These five ages, sometimes known as Kondratieff Waves, have been dated as in Figure 1.1: Steam (1780-1830), Rail and Steel (1830-1880), Electricity and Chemistry (1880-1930), Automobiles and Petrochemicals (1930-1970), and Information (1970-Present).[1] Each new wave of technology has provided a major impulse to global economic development. The Information Age has spurred global economic growth for at least three decades, but we argue that the greatest gains from ICTs are yet to be achieved. Put succinctly, the Information Age can and should lead to the Age of Sustainable Development, a sixth great wave of sustainable technologies that will make possible the achievement of the Sustainable Development Goals (SDGs).

Figure 1.1. The Five Waves of Technology, and the possible Sixth Wave of Sustainable Development built on "Intelligent Technologies" (Allianz)



The SDGs call for several bold breakthroughs by the year 2030, including the end of extreme poverty (SDG 1) and hunger (SDG 2), universal health coverage (SDG 3), universal secondary education (SDG 4), universal access to modern energy services (SDG 7), sustainable cities (SDG 11), combatting climate change (SDG 13), and protecting marine (SDG 14) and terrestrial (SDG 15) ecosystems.[2] To many, these goals will seem utopian. They are definitely "stretch" goals that will require a transformation of societies that is far deeper and faster than in the past. If they are to be achieved, these goals require new and improved technological solutions; economic growth with our current technologies will not be sufficient for success. In our view, the ICTs are a profound reason for optimism, since the rapid development of ICT-based technologies and systems offer the possibility of the needed deep transformation of the world economy.

The ICTs will play a special role in today's low-income countries, a point strongly and cogently emphasized by the UN's Broadband Commission.[3] In essence, the ICTs are "leapfrog" technologies, enabling poor countries to close many technology gaps at record speed. The nearly universal uptake of mobile telephony is a case in point. Mobile subscriptions in Africa have gone from almost no subscribers in 2000 to around 900 million today. Mobile phones have already allowed for dramatic breakthroughs in e-finance and e-health, overcoming long-standing gaps in access to facilities such as bank branches and clinics. It is our assertion that future advances in ICTs—including mobile broadband, the Internet of Things (IoT), robotics and artificial intelligence, 3-D printing, and others—will provide the tools for unprecedented advances in health care, education[4], energy services, agriculture, and environmental monitoring and protection.

One of our key points, however, is that government and academia in the low-income countries must prepare themselves for this ICT-based transformation; they are not ready today. While private-sector applications of ICTs have soared, many of the challenges of sustainable development—health, education, infrastructure, and environmental sustainability—require a deep role of the public sector. This, in turn, puts a spotlight on public institutions, which are in general important determinants of the success or failure of development. Governments have a special responsibility to ensure that key public-sector institutions are re-engineered for a world of ICTs. Every government process—payments, tax collections, procurement, training, human resources, program design, public deliberation, information management, analytics, legislative drafting, even voting—should be upgraded with ICTs. Institutional quality will matter, but will be increasingly defined by the extent to which it usefully incorporates cutting-edge technologies to facilitate the provision, transparency, openness, and efficiency of public services.

The main policy conclusion of our study is that governments need to ensure that the entire public sector, including service delivery in health, education, and infrastructure, is fully supported by high-quality ICT systems. This includes:

- Broadband connectivity of all public facilities by 2020
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We discuss the recommendations throughout this chapter and in detail in the various sector discussions in the report.

1.2. ICT As An Accelerator for Achieving the SDGs

1.2.1. THE INFORMATION AGE AND THE ACCELERATION OF TECHNOLOGICAL DIFFUSION

To keep the ICT revolution in perspective, it is important to understand what has been achieved to date, and what lies ahead. The Information Age dates back to the conceptual breakthroughs of Gödel, Turing, and Von Neumann in the 1930s and 1940s, and to the first vacuum-tube-based computers of the late 1940s, yet it was the invention of the transistor in 1947 and of the integrated circuit in 1958 that truly created the Information Age. The integrated circuit (IC) made possible a unprecedented and continuing advancement in the ability to store, manage, and transmit digital information, creating a world wide web of information not only in the literal sense of the World Wide Web, but far more generally in the nearly instantaneous flow of massive data through multiple channels connecting almost all of the world.

Moore's Law has been the key impulse of this revolution. As famously expressed by Gordon Moore, then the Director of R&D for Fairchild Semiconductors, in 1965, the transistor count on integrated circuits has had a doubling time of roughly 18-24 months going back to the first IC in 1958.[5] Based on this insight, and his prediction that the transistor count would continue to rise at this rate for at least another decade, Moore made an astoundingly prescient prediction for the future:

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment.

Indeed, just 13 years after Jack Kilby created the first IC, Intel created a microprocessor in 1971 with around 2,300 transistors on the IC. By 2015, the transistor count had reached 5.5 billion transistors, representing around 21 doublings since 1971, roughly one doubling every two years. (Figure 1.2a). The counterpart of this astounding rise in microprocessor performance in multiple dimensions (such as clock speed, cache memory, lithography size, number of cores, etc.) is the stunning decline in microprocessor prices per unit of quality. A recent attempt to create a quality-adjusted price index for microprocessor units (MPUs) shows a decline of more than 1000X between 2000 and 2013.[6] (Figure 1.2b).

Figure 1.2a. The Transistor Count on Intel Microprocessors, 1971-2012 (based on Intel data[7])

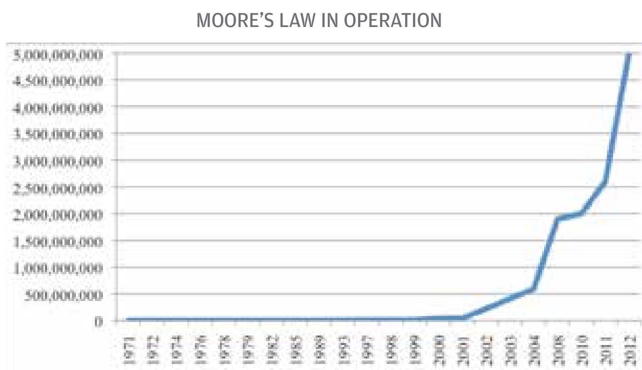
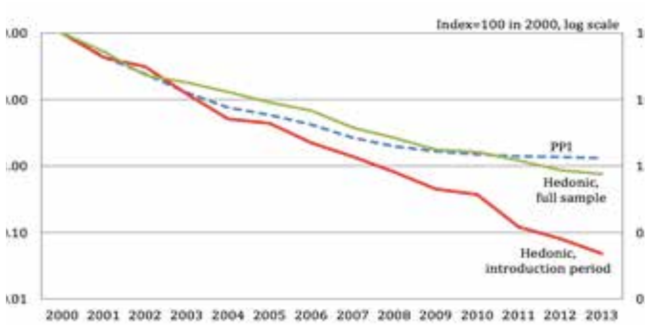


Figure 1.2b. Price Index for Microprocessor Units (MPU), quality adjusted[8]



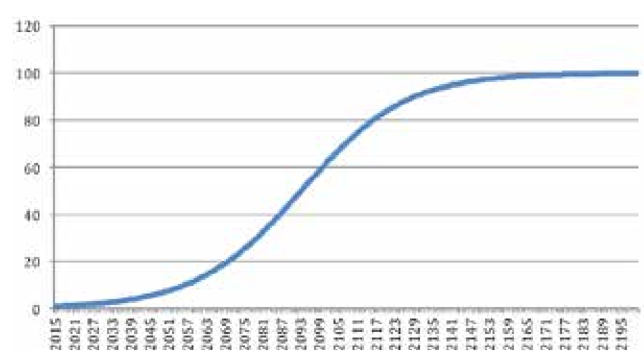
Of course the ICT Revolution is not based on one technology, even one as central as integrated circuits. The ICT Revolution represents the interaction of many crucial technologies. These include computer design, ICs, photonics and fiber optics, digital wireless, digital signaling, statistical multiplexing, encryption, packet switching, satellite communications, robotics, machine learning, artificial intelligence, remote sensing, lithium-ion battery technology, and countless other contributing technologies. Rapid advances are occurring along multiple dimensions—communications, data storage, data processing, artificial intelligence, computing, nano-assembly, and more—that in combination are creating what Ericsson has termed the Networked Society.[9]

Equally important, the uses of ICTs are pervasive as well. They constitute what economists call a General Purpose Technology (GPT), meaning a technology that affects and transforms the entire economy. According to the influential paper by Bresnahan and Trajtenberg, GPTs are characterized by pervasiveness, inherent potential for technical improvements and innovational complementarities.[10] The names attached to the waves of technology mentioned earlier (coal, rail, electricity, automobiles) also constitute important General Purpose Technologies. The impacts are so pervasive, with so many complementarities as described by Bresnahan and Trajtenberg, that Ericsson has rightly viewed ICTs as creating an overall societal transformation, the so-called Networked Society.[11]

ICTs have demonstrated the fastest global diffusion in history. The time it has taken for the global public to adopt ICT-based applications, including mobile phones, social networking, e-finance, and other ICT solutions has outstripped previous technologies, and are likely to continue to set records in the future. This may be verified by examining the diffusion curves of ICT technologies compared with past technologies, as I do below.

A typical technology diffusion pattern is an S-shaped curve, as shown in Figure 1.3, where time is on the horizontal access and the share of the (relevant) population using the technology is on the vertical access. We define the coverage rate of the technology as $C = N/N^*$, where N is the number of users and N^* is the number of potential users. (For each technology N^* must be defined as a subset of the population. For agricultural technology, N^* may be the number of farmers; for education, N^* may be children of school age; etc.) In the S-shaped diffusion pattern, C grows in absolute size very slowly at the start, then accelerates rapidly in a middle phase, and then grows at a slowing rate as C reaches saturation (100% coverage of the relevant population). In terms of proportionate (geometric) growth, the growth rate starts out at a diffusion rate "r" and then declines over time as C approaches 100% saturation. (See BOX on Logistic Growth).

Figure 1.3. Logistic Diffusion of Technology (Illustrative Data)



Logistic Growth

The familiar S-shaped curve results from some variant of logistic growth, in which the diffusion of the new technology starts out as exponential growth and then slows as the coverage rate reaches 1. Letting dN/dt be the rate of increase of the number of users at any point of time, logistic growth assumes:

(1) $dN/dt = r \times N \times (1-C)$

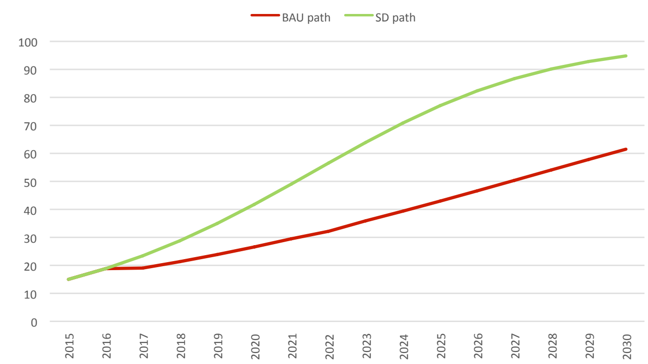
When $C \approx 0$, then $dN/dt \approx r \times N$. Growth is approximately exponential. When $C \approx 1$, then $dN/dt \approx 0$. Growth slows to a zero as saturation of the technology is reached.

At any time t, N(t) equals:

(2) N(t) = N(0) ert/[1 + N(0)/N* x (ert-1)]

Starting at t = 0, N equals N(0); as t becomes large, N approaches N*. t

Figure 1.4. Comparison of the Business-as-Usual (BAU) and Sustainable Development (SDG) Trajectories



Our core observation is that ICTs have the potential to *increase the rate of diffusion* of a very wide range of technologies across the economy. Key sectors in which technology diffusion can be accelerated include: healthcare, education, financial services, electrification, and high-yield agriculture. The accelerated uptake of these technologies and others empowered by ICTs constitute the key to achieving the Sustainable Development Goals by their target date of 2030.

Specifically, we suggest various ways that ICTs can raise the diffusion rate "r" in the S-shaped diffusion curve. We will speak about two diffusion curves, which we will call the Business-as-Usual (BAU) and Sustainable Development Goal (SDG) trajectories. We assume that the diffusion rate r_{SDG} is greater than the diffusion rate r_{BAU}. The qualitative difference of the BAU and SD trajectories is illustrated in Figure 1.4. Obviously, the SDG curve, with the higher diffusion rate, reaches any level of technology uptake faster than the business-as-usual trajectory.

As noted earlier, many of the SDGs call for the economy to reach *universal coverage* of some core service by 2030, e.g. healthcare (SDG 3), pre-primary up to secondary education (SDG 4), access to safe water and sanitation (SDG6), and access to reliable electricity (SDG 7). In most low-income countries, the BAU path will not be sufficient to achieve these universal coverage goals by the target date of 2030. The path to universal coverage must be accelerated. We believe that ICT-backed systems are the key to that acceleration, if governments, universities and the private sector work in partnership towards those goals.

There are five major ways that ICTs can dramatically speed the uptake of SDG-related technologies. The first is that ICTs themselves diffuse with remarkable speed. The uptake of mobile phones, computers, the Internet, and social media, have been the fastest adoptions of technology in human history. Mobile phones went from a few tens of thousands of subscribers in 1980 to around 7 billion subscribers in 2015. Facebook users went from zero in 2004, the year Facebook was launched, to 1.5 billion users in mid-2015. According to projections by Ericsson (2015), mobile broadband coverage (3G or above) worldwide will go from under 1 billion subscribers in 2010 to 7.7 billion subscribers in 2020, roughly 90 percent of the world's population. Smartphones will go from near-zero subscriptions in 1999 (when NTT DoCoMo introduced the first smartphone with a mass uptake) to 6.1 billion subscriptions in 2020 according to Ericsson's (2015) projections.

The second ways is that the ICTs can markedly reduce the cost of the deploying the needed technologies. In health care, for example, ICTs make possible a greatly expanded role for low-cost Community Health Workers (CHWs), enabling many diagnoses and treatments to be made at the community level (during CHW visits to the households) rather than at high-cost facilities; in education, ICTs enable students to access quality online teaching even when no qualified teachers are locally available; and online finance allows individuals to obtain banking services even when no banks are present. These simple examples are of course just the tip of the iceberg: cost savings from ICTs are already disrupting major sectors across the economy in high-income countries, and introducing vital services for the first time in low-income countries.

The third way is that the ICTs can dramatically speed the public's awareness of the new technologies, and therefore the demand and readiness for those technologies. In the past, technologies spread by word of mouth, local demonstrations, and the scale-up of government programs and services. Now, with torrents of information flowing through the Internet, social media, mobile communications, and other e-channels, information travels nearly instantly around the globe, except in the few societies isolated by tyrannical, closed regimes. Songs, fashions, fads, personalities, and new technologies all ricochet around the world in days, not years as in the past.

The fourth way is that national and global information networks can support the rapid upgrading of new applications. Every new technology, including ICT-based technologies, must go through a learning curve in which the technology passes through several "generations" of improvement, with each generation in principle marked by lower costs, greater resilience, easier use, and wider applicability. ICTs can speed up these generational cycles. Global information flows are enhanced, and technology developers are much more attuned than in the past to advances being achieved in other parts of the world. Many ICT applications are open source, or at least inter-operable, so that gains made by one developer can be picked up and improved by others. The whole process of technology upgrading has thereby accelerated, with the winners of this intense competition often carrying home the prize of a large slice of the global market. While much of the technology development will occur beyond the borders of any single country, each country can and should speed its own learning curves and shorten the time of each technology generation, especially for ICT-backed technologies that necessarily have strong local content (e.g. for education, healthcare, agriculture, and environmental management).

The fifth way that ICTs can accelerate technology diffusion is by providing low-cost online platforms for training workers in the new technologies. The revolution of Massive Open Online Courses (MOOCs), for example, enables students anywhere to gain free access to high-quality university courses, including courses in the design and use of ICTs. Special training materials are also being delivered conveniently over smart phones, tablets, laptops, and other devices. These multiple channels for training materials are making it much easier to provide workers with real-time, in-service training that does not disrupt their work schedules, but rather builds the training right into the work itself. In this way, ICT-hosted training modules and courses offer the way to train millions of workers, especially young and under-employed workers, in the uses of new ICT applications for SDG-oriented service delivery.

Governments, business, and universities should identify the range of occupations in which rapid scale-up of training is most needed. This would include, for example, hundreds of thousands of Community Health Workers who will be using ICT-backed systems in their future work; teachers at all levels who will be called upon to introduce ICT-supported teaching into the classrooms; agricultural extension workers, who will use ICT-based support systems to give advice on crop choice, fertilizer use, planting dates, and other key agricultural information; civil engineers who manage the public infrastructure; and other vital trade and crafts, such as mechanics, plumbers, machine operators, data managers, and other occupations needed for rapid economic growth and SDG success.

ICT platforms can and should also be developed to promote international work teams, in which workers located in several countries work seamlessly on product development, systems design, and systems operations (e.g. in the health sector). Such work teams can fill skill gaps and can promote rapid skill upgrading through online mentors, coaches, and tutors that are located abroad. Universities in low-income countries can and should form international partnerships to upgrade their own curricula and to give their students and faculty to ability to tap into ad-

Figure 1.5. Technology Ownership by US Households (%)[12]

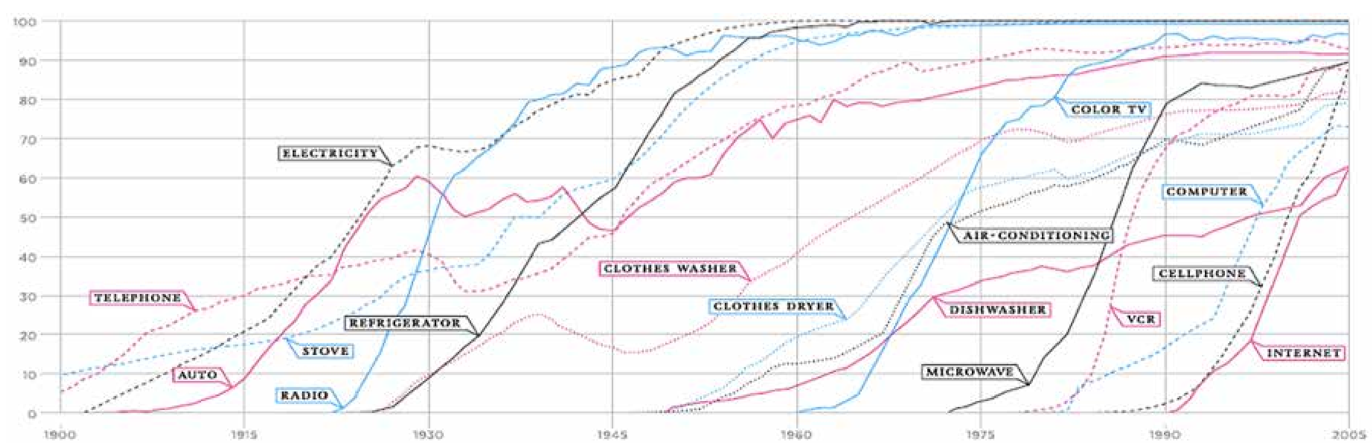


Figure 1.6. E-Money by Region (GSMA)[13]

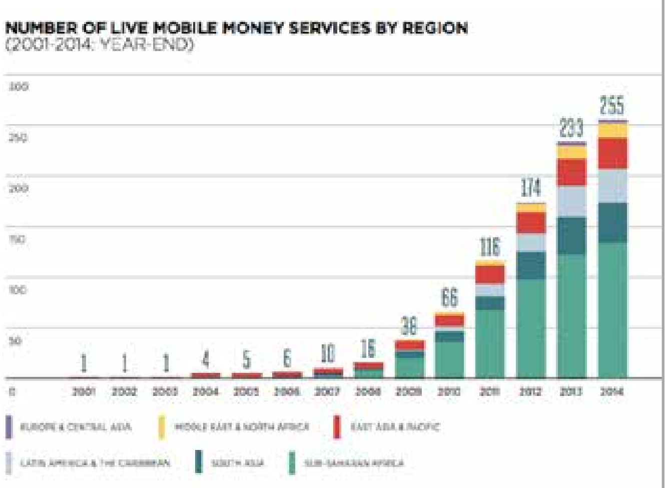
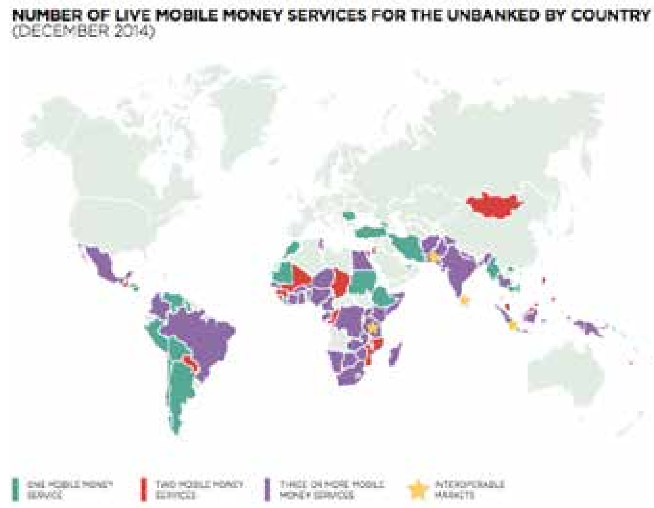


Figure 1.7. The Geographic Coverage of E-Money Services (GSMA)[14]



vanced training and courses of leading universities abroad, all with the view of narrowing the existing gaps in the quality of course offerings and university-based research programs. One key to this rapid upgrading is partnership with leading ICT companies, who can second their engineers and managers to help local universities to build programs in ICT-based solutions.

1.3. The Accelerating Pace of Diffusion

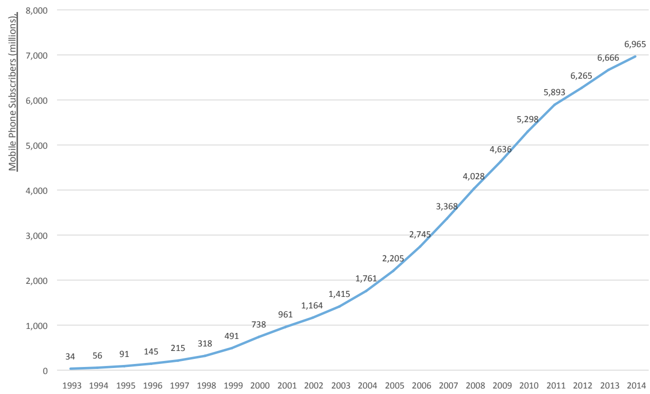
For all of these reasons, ICT has already had a remarkable record of rapid diffusion, one that can be extended into the future. The speed of diffusion of mobile telephony and now mobile broadband reflects certain critical characteristics of the technologies, including: (1) their rapidly declining costs; (2) business models that have enabled access of poor households to the technologies; (3) the remarkable range of low-cost or free applications; (4) the relative ease of building the hardware backbone (e.g. the fiber network) and by the ability of wireless broadband to reach the "last mile" through microwave transmission rather than physical cable. For these and related reasons, the global diffusion of mobile phones has surpassed every previous technology, including radio, television, color TV, and other communications breakthroughs in the past, all of which had set their own records of rapid diffusion. The comparative rate of diffusion of these technologies among US households is illustrated in Figure 1.5.

Wireless broadband, in conjunction with other ICT-empowered technologies, therefore offers unprecedented opportunities for developing countries, even the poorest, to close the huge current gaps in service delivery and access to infrastructure. Consider, for example, the lightening uptake of e-payments and e-finance by mobile applications. Within just a few years, hundreds of millions of people, notably in India and Africa, are receiving payments and opening bank accounts online. This remarkable burgeoning of new platforms is illustrated in Figure 1.6. Interestingly, as suggested by the map in Figure 1.7, the least-banked part of the world, low-income sub-Saharan Africa, seems to be jumping ahead of middle-income Latin America.

PUBLIC POLICIES TO MOBILIZE ICTS FOR THE SDGs

The global diffusion of ICTs to date has largely been market driven. Mobile subscriptions reached 7 billion people this year not through the public provision of phones and subscriptions but largely through competitive, profit-driven market forces. Yet we should also remember and emphasize that the "upstream" technological revolution that made all of this possible was strongly supported by government. Every major ICT advance of the past 75 years—computer design and science, semiconductors and solid-state physics, integrated circuitry, fiber optics, microwave transmission, satellite communications, packet switching and the Internet, and much more—depended on government support via public financing of R&D, early government procurements (e.g. the US Defense Department's purchases of computers in the 1950s and NASA's purchases of integrated circuits in the 1960s), direct public provision of services (e.g. NSF hosting the first Internet services and CERN's hosting of the original World Wide Web), and many forms of public-private partnerships. Only after these key government-backed technologies had matured sufficiently for commercialization, was the private sector well placed to achieve the stunning successes of scale.

Figure 1.8. Mobile Phone Subscribers (millions), Global, 1993-2014[15]



The current pace of diffusion is unprecedented. The mobile industry got off the ground in the early 1980s with fewer than a million subscribers in the first years. By 1993, the global mobile subscriptions had reached 34 million. Then explosive market-driven growth occurred, leading to 7 billion subscribers by today, producing the logistic curve in Figure 1.8. The uptake of social networks has been even more rapid. Similarly remarkable is the sudden ubiquity of online social networks and sharing applications, led by Facebook, and including Twitter, YouTube, Snapchat, and other applications each with hundreds of millions of users. As shown in Figure 1.9, Facebook users went from zero in 2004, the year of Facebook's start, to 1.5 billion today. Adding in China's massive social networks (Tencent, Weibo, Renren, and others) and other network and sharing services beyond Facebook (such as Twitter, You Tube, Snapchat, and other sharing applications), total users these social networks and sharing sites may already total around 3 billion, and all within one decade. Figure 1.10 shows the total of Internet host sites worldwide, rising from zero in 1970 to around 1 billion sites today.

The ICT sector will continue to produce such rapid growth in the future even on a Business-as-Usual (BAU) trajectory. Wireless broadband applications will continue to soar. The Internet of Things (IoT)—in which billions of devices will be connected to wireless networks—will grow even more rapidly than devices and applications for human use. Rapid advances in machine learning will allow for rapid improvements in language recognition, artificial intelligence, pattern recognition, virtual-reality entertainment, and robotics, giving rise to countless more applications. New materials and nanotechnology will lead to soaring applications of 3-D printing and other globally networked production systems.

Nonetheless, the BAU trajectory, based on private-sector-led growth, will not achieve the Sustainable Development Goals. That is because the SDGs aim for *universal access to high-quality public services*—such as quality healthcare and public education, and safe and reliable infrastructure. Universal access will be achieved for those services only if governments skillfully and actively embrace the ICT revolution, and deliver public services using the massive benefits of ICTs. The public-sector uptake of ICTs will be far less automatic than the private-sector uptake in the past. Governments will have to overturn existing practices to make way for ICT applications and systems.

Figure 1.9. Facebook Users by quarter (Statista, 2015)[16]

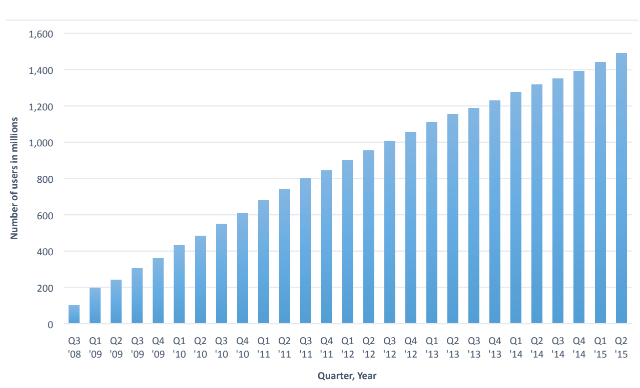
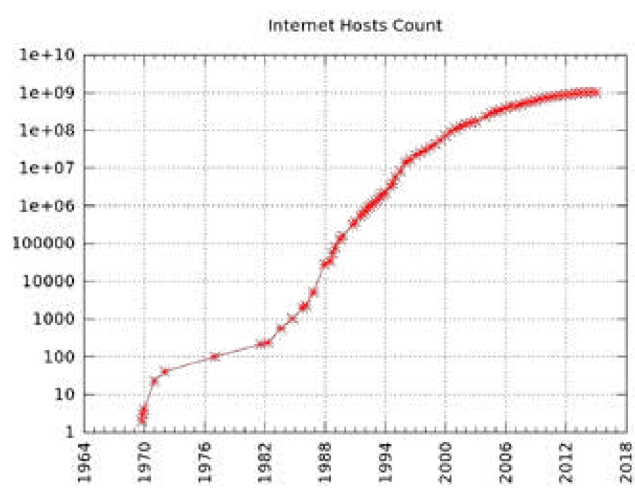


Figure 1.10. Internet Hosts Count[17]



As our case studies make clear, the public sector should adopt the following seven key precepts to be successful in this unusual and unprecedented challenge, remembering that government bureaucracies are rarely the leaders in disruptive technologies!

(1) Achieving the SDGs will require the rapid roll-out of ICTs throughout the public sector, including in e-governance, public administration, and the provision of ICT-supported public services including health, education, and infrastructure;

(2) Governments should establish timelines for universal broadband connectivity of public facilities and public services no later than 2020 to achieve the SDGs by the target date of 2030;

(3) Public services should be ICT-enabled so that businesses and citizens can interact with the public administration online for purposes of payments, transfers, tax administration, vital registrations, documents, and other purposes. This e-governance will lower the cost of public services, reduce the opportunities for corruption, and create a flow of "big data" that can be collected, processed, and analyzed to improve public service delivery and to support evidence-driven policymaking.

(4) Government should partner with the universities to scale-up ICT training programs and to create innovation hubs to develop new ICT applications;

(5) Governments should foster Public-Private Partnerships to accelerate the development and uptake of locally designed and targeted ICT applications;

(6) Governments should upgrade STEM (science, technology, engineering, and mathematics) education in primary and secondary education to build long-term skills and technology readiness;

(7) Governments should create national online and open databases that incorporate the big data from public service provision (e.g. the data collected in schools and clinics) and from satellites, remote sensors, and other connected devices in the Internet of Things. This real-time online data will be a critical resource for achieving the SDGs, and for promoting investments by the private sector.

Consider briefly one example that is elaborated in the report: public health. The provision of low-cost and high-quality public health services will be dramatically facilitated through ICT. To capture the potential gains from ICT, all public clinics, hospitals, and health workers should be online and connected in a national network. Every individual should have an electronic medical record that is updated with each hospital visit or meeting with a community health worker. The online data collected by the CHWs, clinics, and hospitals can be processed in real time and turned into "data dashboards" for health managers.

ICT will facilitate a wide range of health services. Community health workers can be trained on line. They can receive expert advice online as they meet with patients. They can transmit a patient's symptoms by smartphone to an expert working in a distant location; radiologists halfway around the world can read X-rays and other medical images shared on line, while computers themselves will probably soon take over the task of reading routine X-rays and MRIs. Online meters worn by patients (so-called "wearables") will track blood pressure, blood sugar levels, pulse, oxygen levels, and other vital statistics.

Obviously this kind of high-performance ICT-backed health system will not be achieved automatically or through the private sector. The government will have to ensure that all health facilities are online; that the software applications used by each facility are interoperable with other systems; that individual patient data and facilities-based data are seamlessly integrated; and that the resulting "big data" are processed, analyzed, and used to produce policy dashboards for health managers, all while protecting patient privacy. Universities will have to train a new generation of ICT-capable health workers; university engineering departments will have to be tasked with incubating new applications for use in the national health system.

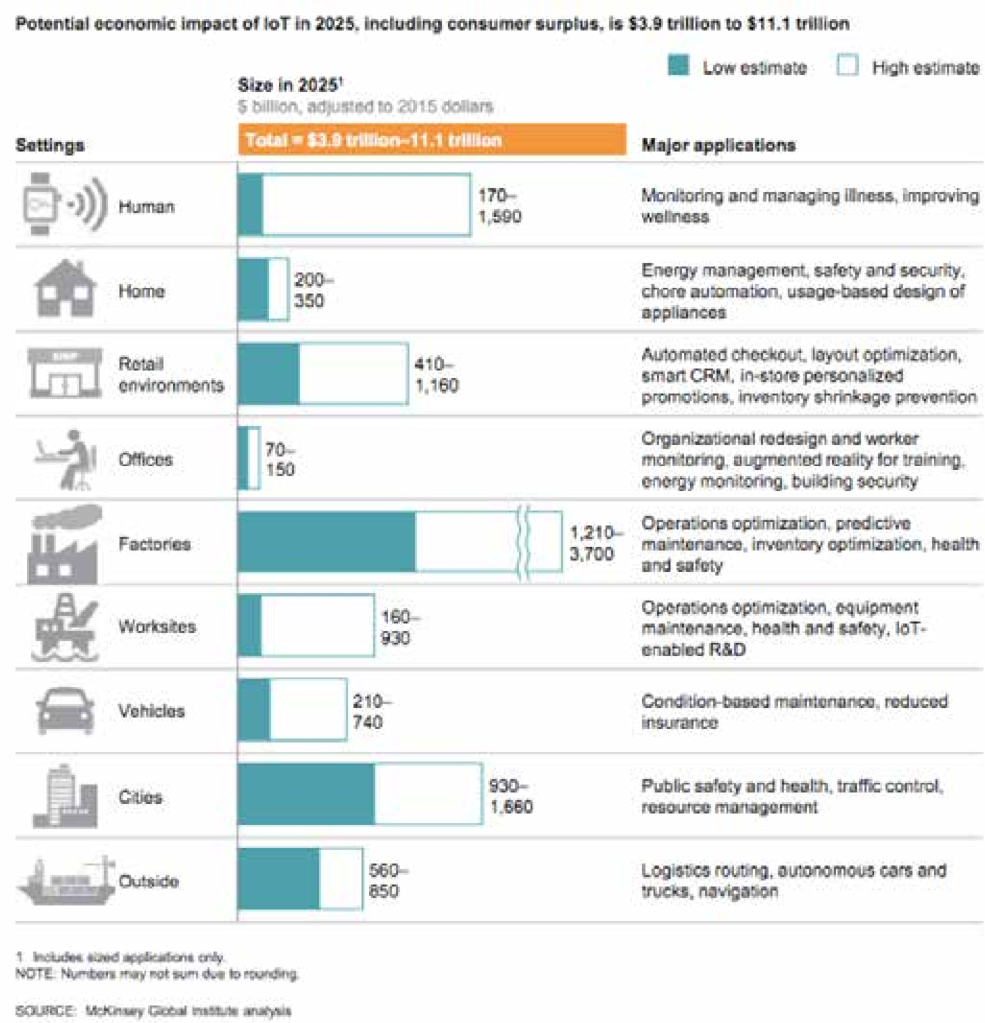
Much can go wrong in this process. Many governments have so far failed to achieve even the first step of ensuring broadband coverage of all public facilities. Many governments and NGOs have introduced small-scale demonstration projects of ICT systems that fail to scale up or to be interoperable with other projects. Many governments are at least two or three technology cycles behind the technology frontier in mobile broadband, e.g. deploying CHWs without ICT support, or relying on cellphones rather than smartphones in service delivery and data capture. Most governments have far too little awareness of the promise of ICTs in improving public-sector service delivery. And alas, the donor agencies and UN agencies are themselves often as far behind in ICT applications as the national governments they are purportedly helping.

1.2.2. The Internet of Things, Robotics, Artificial Intelligence, and Big Data

The role of ICTs in the SDG era (2016-2030) will evolve very rapidly for two fundamental reasons. First, as just described, ICTs will increasingly transform governance and the provision of every type of public services. Second, the underlying technologies will continue to evolve rapidly and dramatically, making way for new breakthrough capabilities. We mention here briefly four breakthrough ICTs that will greatly support the SDG process.

The first, already mentioned several times, is the Internet of Things (IoT), introduced by McKinsey (2015) as follows:

Figure 1.11. The Internet of Things, Nine Major Settings (McKinsey, 2015)



We define the Internet of Things as sensors and actuators connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Connected sensors can also monitor the natural world, people, and animals.

In its useful recent study, McKinsey identifies nine major settings for the deployment of the IoT, including the home, factory, and public infrastructure. Ericsson (2015) notes that there are already 230 million cellular Machine-to-Machine (MTM) subscriptions for IoT applications, and it projects up to 26 billion connected devices by 2020.[18] The applications are far more diverse than for people-to-people connections. Major functions of IoT include: anomaly detection and control of complex equipment and integrated systems; systems optimization; prediction; data capture and analytics; systems maintenance; and many other functions. McKinsey estimates that IoT will add around $11 trillion of market value globally by 2025, roughly divided equally between the high-income and developing economies.

The second breakthrough, also well underway, is advanced robotics, which is already transforming many industrial and service sectors. China's President Xi Jinping has recently called for an "industrial robot revolution," and China is investing heavily in the R&D and deployment of advanced robotics. There is a surge in both industrial and consumer robot applications, and an integration of advanced robotics into the IoTs.

The third breakthrough, that is also driving the robotics revolution, is artificial intelligence and enhanced machine learning more generally. Machine learning algorithms are enabling rapid breakthroughs in robotics pattern recognition, voice recognition, natural language capabilities, and problem-solving capacities. Robots will quickly enter the high-tech service economy in legal analysis, medical diagnostics, and other areas of complex problem solving.

The fourth area, also of crucial significance for sustainable development, will be the mobilization of "big data" for development. As already mentioned, the SDGs will require real-time data for public management, strategy and budgeting, and to hold governments accountable for achieving goals and targets. In traditional development practice, data are collected through censuses and retrospective surveys, often with lags of many years. In the Information Age, the relevant data can be collected in real time, as part of the delivery of services and the normal functioning of the economy. With the use of big data, it will be possible to produce high-quality vital statistics (births, deaths, population), and indicators for health (e.g. epidemic outbreaks), education (e.g. learning outcomes), and the environment (e.g. air and water quality), in real time. A core part of any nation's ICT strategy should therefore be an upgraded information platform that harnesses the flow of big data in the service of public management.

1.2.3.The Implications of ICTs for the Pace of Economic Growth

In 1987, Robert Solow famously quipped that "you can see the computer age everywhere but the productivity statistics." The implication, repeated many times since then, is that the Information Revolution has been exaggerated and hyped.[19] Some have argued that we are in fact in a period of declining long-term growth ("secular stagnation") caused by a decline in the pace of technological change. In this view, the breakthroughs of ICT are modest, not at all comparable in importance to earlier General Purpose Technologies.[20] Nevertheless, research based on tradition economic models such as growth accounting indicate that ICT contributed more than 50 percent to labor productivity growth in the US 1995–2000.[21] Another view holds that ICTs are potentially important, but have so far been more disruptive than constructive. A third view—indeed our own—is that the gains are indeed in the data, but not exactly where we are looking for them.

It's hard to argue that Science and Technology (S&T) as a global knowledge enterprise has slowed in any way. Studies based on published scientific papers and references thereto show an *acceleration* of scientific output in recent decades. According to one such bibliometric study, scientific output grew at a rate of 1 percent during the period from 1650 to 1750; 3 percent during 1650 to 1950; and 8-9% during 1950-2012. Fundamental advances across many S&T disciplines empowered by computation and mass digital information—in ICT, solid-state physics, nanotechnology, molecular biology and genomics, neuroscience, and many other fields—would seem to belie the notion of any kind of slowdown.

Moreover, global economic growth has been relatively robust for the quarter century despite sharp financial crises in 1997 and 2008. China has achieved roughly a 30-fold rise of output since 1978, an achievement that would have been utterly unimaginable without the depth of globalization made possibly by ICT. Sub-Saharan Africa's recent growth of 4-5% per annum is the highest on record for the region, and seems clearly to have been bolstered by the rapid spread of mobile communications. Cross-country studies linking national growth rates to the penetration ratio of ICTs add statistical support to these impressions.

What is true is that the economic growth many European High-Income Countries (HICs) has been modest and perhaps lower than might have been expected in view of the advances in ICTs.[22] Is this a case of the ICTs delivering less than expected, or of the ICTs offsetting other causes of growth slowdown, such as aging of the labor force and the population? Such issues are heatedly debated and still unresolved.

I would suggest that two points, however. First, there is ample reason to believe that the official data understate the rate of true economic progress, and perhaps significantly. Many of the benefits of ICTs—such as the ubiquity of free, online entertainment—are not captured by market transactions. Online shopping may means leisure time and less time in the shopping mall, an economic gain but a decline in market transactions and therefore a fall in measured

GDP. Gains in healthy life years of retirees are a significant gain of wellbeing, but a gain that is not captured by GDP as traditionally measured. Thus, the kinds of gains in wellbeing in HICs that are made possible by ICT—more leisure time, less commuting time, dematerialized goods, wider variety of online goods and services, improved health of retirees, etc.—might generally have the ironic and misleading effect of reducing measured GDP.

Second, ICTs are most likely already causing a significant shift in the income distribution in high-income labor markets, away from workers with relatively low educational attainments and towards workers with higher education in management (to lead more complex organizations and systems), and in STEM (science, technology, engineering, and mathematics). It is both theoretically possible, and perhaps predictable, that the advance of robotics and smart systems would displace many occupations of workers with educational attainments of high school or less. And indeed, the relative earnings of workers with lower educational attainments have declined markedly during the past 30 years.

1.3 Considerations

1.3.1. DOWNSIDE RISKS: SYSTEMS FAILURE, CYBER WARFARE, SURVEILLANCE

It is well beyond the aims of this essay to detail the potential downsides of ICT-based sustainable development, yet the concerns should at least be mentioned. These touch on at least six broad areas of concern. The first is that the online world will literally reshape brain development, perhaps leading a loss of "human" skills. The second is that virtual (online) communities will in some way "crowd out" real human communities, leading to a decline of human interactions, trust, and sociality; this is the "bowling alone" phenomenon argued by sociologist Robert Putnam. The third is that robots will displace human work to the point of causing mass unemployment and economic misery. There may be a glimmer of truth in such arguments, but the essential fact is that with appropriate public policies, technological advances improve wellbeing. The fourth concern is that a networked economy is far more vulnerable to network failures than a pre-ICT economy; massive performance failures of the Internet or power grid could bring the economy to a grinding halt. The fifth concern is that such disruptions of the networked economy will become deliberate acts of cyber-warfare. And the sixth great worry is that an ICT-based economy is a surveillance economy, with pervasive spying and loss of privacy. The spying may be by government, giant ICT firms, or a partnership of the two. The revelations by Edward Snowden offered a shocking confirmation of some of these fears, not the least of which was the dissembling and lies of official institutions regarding their surveillance policies.

This brief summary is not meant either to validate these concerns or to dismiss them. They are serious concerns that require serious answers. Alongside the breakthroughs made possible by the ICT revolution, we need already to ensure against the downsides of the same revolution. Humanity's experience with technology dating back to the start of the Industrial Revolution is that we neglect the inadvertent downsides of technology to our great peril.

1.4. Conclusions and Recommendations

The first job of every government is to place the SDGs alongside current realities and the current pace of change. They will find, with few exceptions, that the Business-as-Usual trajectory is insufficient to achieve the SDGs by 2030. Then, they must engage in a "back-casting process," to ask what it will take to achieve success by going from the target in 2030 to the steps that are needed today.

The governments will identify the need for a rapid acceleration of public investments and services in key areas, especially health, education, and infrastructure. Yet the needed pace of scale up on conventional grounds will seem to be impossible, beyond financial and logistical feasibility. This is, of course, where ICTs come in. They offer the possibility of much faster technology upgrading, training, and service provision at low cost, but only if the systems are quickly designed and deployed. With 2030 targets looming, there will be no opportunity for a slow, gradual, cautious uptake of new approaches.

Recommendations:

Can individual governments and the world as a whole be ready for this rapid advance? The answer is yes, if there is a shared vision of how to proceed, and if new institutions are quickly put in place.

(1) The international ICT sector, represented for example in the UN Broadband Commission, would need to step forward to provide, advice, expertise, financing, and tools for rapid scale up.

(2) The universities, in partnership with governments and businesses, would have to undertake massive training programs, and hosting of new ICT business incubators.

(3) Global donors would have to provide quick seed funding to get these activities underway.

In short, the SDGs represent a complex, global-scale problem-solving exercise that cuts across all sectors of the economy and that must engage all parts of the world. We have adopted the SDGs; now we will have to deploy all of the tools needed, including the ICTs, to make them a success.

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Endnotes

[1] Wilenius & Kirki (2014).

[2] See "Transforming our World: The 2030 Agenda for Sustainable Development" (2015).

[3] See "Means of Transformation: Harnessing Broadband for the Post-2015 Development Agenda" (2014).

[4] See the Broadband Commission Report on "Technology, Broadband, and Education" (2013).

[5] Moore (1965).

[6] Byrne et al. (2015).

[7] Based on Intel data.

[8] Byrne et al 2015.

[9] http://www.ericsson.com/thinkingahead/networked_society

[10] Bresnahan & Trajtenberg (1995).

[11] See http://www.ericsson.com/thinkingahead/networked_society.

[12] Credit: Nicholas Felton.

[13] See GSMA (2014).

[14] See GSMA (2014).

[15] Based on World Bank Data.

[16] Statista's data from the Facebook Quarterly Earnings Slides Q2 2015, page 5

[17] Based on Internet Systems Consortium data.

[18] See Ericsson Press Release, "Ericsson Software Unlocks Indoor Performance and 'Internet of Things' Adoption" (2015).

[19] Gordon (2014).

[20] Gordon (2000).

[21] Jorgenson et al. (2008).

[22] van Ark et al. (2008).

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