Assessment criteria for policy on ICT and climate change

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Abstract

There is an important connection between ICT-based innovation, environment and climate change. ICTs have a direct impact on the environment, consuming energy, materials and producing e-waste. But ICTs are the major enabling technology for mitigation of environmental impacts across all economic sectors. ICTs can contribute in achieving more sustainable lifestyles, consumption and production. ICT applications can help limit energy use and material consumption. In other words ICTs can be the driver for an emission reduction policy.

Public policies can be pivotal in promoting a "smarter and greener ICT". Government policies can support the application of ICTs across the economy, to tackle the challenges of global warming and environmental degradation. But potential benefits have to be quantified, in order to be fostered, planned, monitored and assessed. An effective ICT-based emission reduction policy needs an assessment of the "net" environmental impacts of green ICTs. This assessment have to take into consideration all kind of effects, both positive and negative, that have to be analyzed and quantified.

Systemic impact of ICTs and their environmental repercussions are relatively unexplored, mainly because of the complexity of assessing future directions of production and consumption. Incomplete data, the difficulty of covering incoming effects and changing general framework conditions are complex issues to deal with. Nevertheless, a serious assessment on the medium- long term "net environmental impact" of ICTs need to take into account changes in user behavior.

For accountability is important to monitor policies and evaluate their outcomes. This leads to link policy objectives to measurable output targets. International reports and studies have used available data to outline the main trends. There is a gap in the analysis of first, second and third order effects of ICTs. The first ones are relatively well known and quite easy to measure. The second ones are difficult to foresee and only at a magnitude order level, but the third ones are really hard to assess.

International organizations, like OECD, suggest to further research into the systemic impacts – intended and unintended – of the diffusion of ICTs. It's important to understand how ICTs and the Internet contribute to environmental policy goals, such as fostering renewable energy sources, reducing transport volumes, optimizing household energy use and reducing material throughputs.

The position paper wants to highlight some methodological open issues. The paper will try and introduce the possibility to follow an Agent Based Model approach to model the rebound effects. This approach needs to cross disciplinary borders between ICTs, energy and environment disciplines as well as social and behavioral sciences.

1. Introduction

ICTs can be environmentally oriented, toward a CO_2 emissions reduction (Masanet/Matthews 2010). While there are many positive benefits of ICTs, such as an improved productivity and quality of life (GeSi 2008), their negative impacts on the environment have to be taken into account. There has been a consistent questioning of the overall net benefit of ICTs.

The recent nuclear accident at Fukushima, with related deep concern about nuclear energy, will open a global debate not only on the energy resource types but also on the consumption styles. More attention to energy resources leads to more attention to energy consumption reduction. The role of ICTs as a key factor will became more important than in the past decades.

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The interest in the use of ICTs for environmental sustainability is increasing. There are concerns about ICTs direct environmental impact, such as energy use and e-waste. The positive effects of using ICTs for sustainability, however, are argued to be bigger and the corpus of research in this area is growing fast (Zapico 2010). There is a risk, however, of rebound effects, whereby unexpected usage and changes in behavior can cancel out the gained efficiency (Hilty 2006).
Governments can stimulate further research into the impacts – intended and unintended – of the diffusion of ICTs in order to assess how ICTs, and mainly the Internet, contribute to long term environmental policy goals. Public policies can be instrumental in promoting a sustainable ICT-based approach and increase public awareness. Government policies can encourage improvement of environmental performance along the entire ICT life cycle and promote ICT applications to make non-ICT sectors more resource efficient.
Overall, much more needs to be done to develop measurable policies to improve environmental performance of ICTs (OECD 2009a). However, the true net impacts of ICT can only be understood when we consider its negative impacts alongside its many possible benefits (OECD 2010a).
This position paper places emphasis on the need to establish shared criteria for an assessment of the effects of ICTs. I will try to highlight the open issues related to the definition of a methodology to evaluate the "net environmental impact" of ICTs.

2. ICT effects on CO2 emission and their assessment: an overview

An environmentally-oriented ICTs strategy needs transparent policy objectives and targets to measure. The compliance with policies have to be monitored on a regular basis to set clear responsibilities and improve accountability (OECD 2010b). Increasing public awareness allow users to monitor and verify the effect of adopted policies. A stakeholders-driven monitoring increases understanding of on going policies, but needs measurement tools.
It's important that measures of the environmental impacts of ICT goods and services, and ICT-enabled applications, are comparable. In other words, the effort should be first into defining a baseline as common reference. An overview (Erdmann/Hilty 2010) on principal macroeconomic studies on ICt and GHG emissions, shows the difficulties to compare their results. There are studies, reports, analysis and guidelines made from different type of public and private subjects, in different countries and following different approaches, most of them based on empirical data. Cross country or cross technology comparison are very difficult. An increased understanding of the effects of government policies (information, incentives, regulations) improving measurement tools and increasing public awareness has to be developed (OECD 2010b).
The effects of ICT on the environment are commonly ranked in first, second and third order effects (Hilty 2008). This analytical framework highlights the importance of analyzing impacts on all three levels to assess the "net" environmental impacts of green ICT. For simplicity I will start from a short overview on assessment issues of each effect type separately, whereas they are conceptually nested (Hilty 2007).

2.1 First order effects assessment

In 2007 the total footprint of the ICT sector was 830 MtCO_2 emissions, about 2% of the estimated total emissions from human activity released that year (GeSi 2008).
Adjustment to the Smart 2020 report are suggested by environmental organization (Greenpeace 2011), highlighting the scale of ICT's estimated energy consumption, and providing new analysis on the projected growth in energy consumption of the internet and cloud computing for the coming decade, particularly as driven by data centers.

Each stage of a computer's life cycle, from its production, throughout its use, and into its disposal, increases carbon dioxide emissions and impact on the environment. The total electrical energy consumption by servers, computers, monitors, data communications equipment, and cooling systems for data centers is steadily increasing. ICT devices are becoming more and more compact and energy efficient. Computers are continuously making astonishing progress in energy efficiency, measured in performance per watt, due to innovative design techniques, coming from technological aspects to the processing architectural dynamic management(Murugesan 2008). The power density is also increasing. But the demand for ICT is increasing even faster than the energy efficiency of ICT devices (Hilty 2006).

New generation IT systems provide more computing power per unit of energy but, despite this, they are actually responsible for an overall increase in energy consumption. This is because users are taking and using the increased computing power offered by modern systems regardless its implication on sustainability. New software in particular is devouring more and more power (Sissa 2010).

Although the per-unit consumption is relatively straightforward and the total number of final users of a given service on a given geographical area is known, assumption have to be made for the usage patterns of the equipment, the intensity of use and the service life of the equipment (Coroama/Hilty 2009).

Moreover cloud computing is changing how to quantify the ICT direct effects. Thus the computing world is rapidly transforming towards the development of software for millions to consume as a service, rather than to run over their individual computers (Buyya 2009). The network is the platform for all computing, where everything we think as a computer today is just a device that connects to the internet. To move to cloud computing appears, in line of principle, to be more environmentally friendly compared to traditional data center operational/deployment models. The rule of thumb says that an higher consolidation/optimization will conserve energy.

If, in some ways cloud computing can *enable green*, and could be a great way to reduce the carbon footprint, there are some risks, as for example a new form of lock-in (Micklethwait 2009) and a lack of transparency in the quantifications of energy consumption.

Even in a rough estimate the entire life cycle of the whole system providing a given service should be studied, in order to assess the environmental impact of producing one functional unit of the service.

But quantifications could be not comparable, because of different Cloud computing providing services features and incompatible starting assumptions.

By definition clouds are promising to provide services to users without reference to the infrastructure on which these are hosted. As consumers rely on clouds providers to supply their computing needs, they will require specific QoS to be maintained by their providers in order to meet their objectives and sustain their operations(Buyya 2009). If it's clear that there are critical parameters such as time, cost, reliability and trust/security, less trivial are parameters linking with the green performance of the cloud.

More cloud computing companies are pursuing design and siting strategies that can reduce the energy consumption of their data centers, but primarily as a cost containment measure. For most companies, the environmental benefits are generally of secondary concerns. The emission factor, the rate to convert kilowatt-hours into units of carbon dioxide emissions, is the base for any ICTs direct impact evaluation. But this rate is different country by country or region by region, because it depends on the source from which electric power is produced.

An example of the extent of such geographical- dependency of the emission factor is given by the Australian Computer Society that, in a report about the Carbon Footprint of ICT usage (Australian Computer Society/Connection Research 2010), supplies the emissions factor by each Australian State, showing as there is no unique simple formula for converting kWh to CO_2e (carbon dioxide equivalent), because the formula varies depending upon how the power that is being used is generated. Victoria state, for example, generates most of its power from brown coal, which emits significantly more CO_2 than the black coal used in other regions. Tasmania, which uses a lot of hydroelectric power, is much cleaner. Differences are significant.

This is an example of scientific baseline needs for ICTs effect assessment .
New initiatives have been announced to help the ICT industry to measure its carbon footprint[2], like in the traditional high carbon industrial sectors[3].
Public sector policy can play a significant role with policy for a sustainable ICTs. For policy accountability is important to monitor programs and evaluate their outcomes. This leads to link policy objectives to measurable output targets and leads to define indicators to monitor inputs and to assess outputs (Munck 2010). The UK Cabinet Office Greening Government ICT [4]described how changes, like extending the life of PCs, making double-sided printing the default option and making sure computers are turned off at night, have helped cut the carbon footprint of central government computers.

2.2 Second order effects assessment

ICTs are the essential driver for productivity improvements and innovation (for instance, the virtualization of government and business services), as well as for more efficient management, control, and visualization of all kind of network (buildings, energy production and use, mobility, water and sewage, open spaces, public health, and safety). The American Consumer Institute (Padgett 2008) adds to the discussion of how to reduce greenhouse gas emissions, documenting the reductions that can be realized by the widespread delivery of broadband services in the U.S. This study finds that wide adoption and use of broadband applications can achieve a net reduction of 1 billion tons of greenhouse gas over 10 years, which, if converted into energy saved, would constitute 11% of annual U.S. oil imports.
ICTs can contribute in achieving more sustainable lifestyles, consumption and production. As computer technology becomes more pervasive in the physical world, the potential for optimization in other contexts will increase.
Some ICT services are potentially able to decrease emissions by optimization or substitution of high carbon activities with low carbon alternatives. Planning them is important to be able to quantify the potential benefit, always in terms of potential emission reduction.
Unlike for the relatively straightforward ICT consumption, direct measures are impossible. An ex-ante analysis can be just an estimate (Coroama/Hilty 2009).
A lot of tools allows to calculate the emission equivalence for any activity.
The Ecological Transport Information Tool (EcoTransIT[5]) calculates environmental impacts of any freight transport. Thereby it is possible to determine the energy consumption, CO_2 and exhaust emissions for freight transported by rail, road, ship and aircraft in any combination. The annual "greenhouse gas emissions per passenger vehicle" is at the basis of a lot of ICTs services related to traffic[6].
Individual carbon footprint calculators, provided by government agencies, non-governmental organizations, and private companies. will contribute to awareness and behavioral changes of the single user.
These calculators typically divide the individual's profile into household activities and transportation, and based on differing formulations of user input they produce a quantified amount of carbon dioxide or carbon dioxide equivalents emitted, generally in units of mass of CO2 per year.
The recent rise in carbon calculators has been accompanied, however, by inconsistencies in output
values given similar inputs for individual behavior (Padgett 2008). In some cases, values can vary by as much as several metric tons per activity. These variations in output could influence both the types of steps individuals can take and the overall level of effort.

[2] Governance Document for ICT Sector Guidance 2011_Jan_26
http://www.ghgprotocol.org/feature/new-initiative-announced-help-ict-industry-measure-carbon-footprint
[3] http://www.ghgprotocol.org
[4] http://www.cabinetoffice.gov.uk/resource-library/greening-government-ict
[5] http://www.ecotransit.org/ecotransit.en.phtml
[6] http://www.epa.gov/cleanenergy/energy-resources/refs.html#vehicles

Variations in calculator outputs could also affect the extent and focus of public pressure on policymakers regarding emissions reduction efforts directed at household and personal transportation. Although these calculators employ similar approaches to CO2 estimation, their results often vary, even when using uniform inputs (Padgett 2008). These variations may be due to differences in calculating methodologies, behavioral estimates, conversion factors, or other sources. However, the lack of transparency makes it difficult to determine the specific reasons for these variations and to assess the accuracy and relevance of the calculations. Although these differences may appear small in some cases, when compounded in calculations, they can produce considerable variation in results.
These tools and services allow a quantitative evaluation, by giving only an idea of the magnitude order of potential benefit.

2.3 Third order effects assessment

Systemic impacts of ICTs and their environmental repercussions are relatively unexplored, mainly because of the complexity of assessing future directions of production and consumption (OECD 2010a).
One has to take into account the unwanted and so-called rebound effects as a reaction to growing efficiency, change of economic and institutional structures and change of life-styles (Hilty 2006).
The substantial increases in efficiency that are being demonstrated in the ICT sector itself (as per Moore's Law) through application of ICT to optimize processes, to substitute information services for products or telecommunications for travel, do not automatically cause any resources to be saved. This is due to the so-called rebound effect, according to which a transition to more efficient technologies causes an expansion of activities given constant costs and time budgets. Technological measures alone do not assure a reduction in the use of natural resources by production and consumption (Göhring 2004). Instead politicians have to create framework conditions to incentives for a more economical use of material and energy.
There is a gap in the analysis quality of first, second and third order effects of ICTs on GHG emissions.
The first ones are relatively well known, complex but possible to be quantified. The second ones are difficult to exactly foresee, but can be estimated at a magnitude order level.
The third ones are really hard to assess. Which is the more suitable model for representing and forecasting them?
Behavioral changes induced by the introduction of ICT services oriented are suitable to be modeled following an ABM (Agent Based Model) approach An ABM approach is particularly applicable when the adaptation of the agent and the emergence of a behaviour are important considerations (Borshchev/Filippov 2004). Agent-based simulation has become increasingly popular as a modeling approach in the social sciences because it enables one to build models where individual entities and their interactions are directly represented (Smajgl 2011). It allows modelers to represent in a natural way multiple scales of analysis, the emergence of structures at the macro or societal level from individual action, and various kinds of adaptation, none of which is easy to do with other modeling approaches.

3. Agent Based Model for policy modelling

In policy modeling ABM can be used as a means to overcome the traditional policy approach, based on predictions and external prescriptions, towards participatory models where stakeholders are involved in the modeling and the management of the problem(Grimm et al 2010). Multi-agent systems, simulations, and socially-inspired computing are systems crossing computer science, distributed artificial intelligence, engineering, cognitive and social science (Borrill/Tesfatsion 2010). Agent-based modeling has become an important tool to investigate socio-ecological processes. Its use is driven by increasing demand from decision makers (Bicking et al 2010) to provide support for understanding the potential implications of decisions in complex situations, as, for example technology adoption (Nuttall et al 2009) processes.

Parameterization of human behaviour in agent-based models is a challenge, that needs data. The availability of qualitative and/or quantitative empirical sources, the scale of those available data are key issues . The assessment of the potential benefit of a new ICT-based service needs to know what kind of enabling effects, which activities are involved, how many people are engaged, what timetable is foreseen.

4. The data issue

While the relationship between ICT and the environment is not a recognized field of statistics, individually ICT statistics and environment statistics are recognized fields(OECD 2009b). As far as statistical indicators linking ICT and the environment are concerned, the field ICT and the environment is a new one. Consequently, statistics directed to the policy questions related to this field are scarce. In respect of official statistics, it is necessary to look for data that throw light on relevant aspects of the field, though were not necessarily collected with a view to answering policy questions about the relationship between ICT and the environment (OECD 2009a). At each granularity level, the availability and accessibility of public data is a key factor.

Social networks, social metering systems and geo-referenced social media allow the user to share information, to compare the consumes, to increase collective and individual awareness, playing a key role to promote low-carbon lifestyle. Web and mobile applications allow tracking personal footprints, sharing goals and making green behaviour easier.

A new opportunity for citizens and people addressed by the policy is to directly verify the effect of such a policy (or of a new service or product, etc) by measuring the outcomes. The Internet of things and geo-referenced devices allows an environmental situational awareness and the gathering of on-line data, contributing to build user generated location based data and mapping of environmental quantities.

5. Open Issues

Investigations into the net environmental societal and economic benefits of ICT systems represent complex, but crucial work. Incomplete data, the difficulty of covering incoming effects and changing general framework conditions are complex issues to deal with.

Systemic impacts of ICTs and their environmental repercussions are relatively unexplored, mainly because of the complexity of assessing future directions of production and consumption (OECD 2010a).

Measurement and accounting can help in decision making, to achieve the goal of optimizing, leading to behavior change, and avoiding rebound effects. This kind of ICT-enabled environmental metrics will gain a relevant position in the policy framework definition. The position paper wants to highlight some methodological issues. First of all, which is the right scale to make the net environmental impact evaluation feasible and practically useful. This issue is strictly related to the data availability, their extent, quality and completeness. Second, the opportunity of following an Agent Based Model approach to model the rebound effects. This approach needs to cross disciplinary borders between ICTs, energy and environment disciplines as well as social and behavioral sciences.

It's important to identify the scale for the assessment. The need of data at this scale can suggest the local government level as the most suitable. Stakeholder participation can help to trigger and monitor policies.

To foster a greener use of ICTs, policymakers should use information, incentives, regulations or a mix of them? Government policies need assessment tools to improve decision making processes.

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