White paper
Is the Cloud Green?

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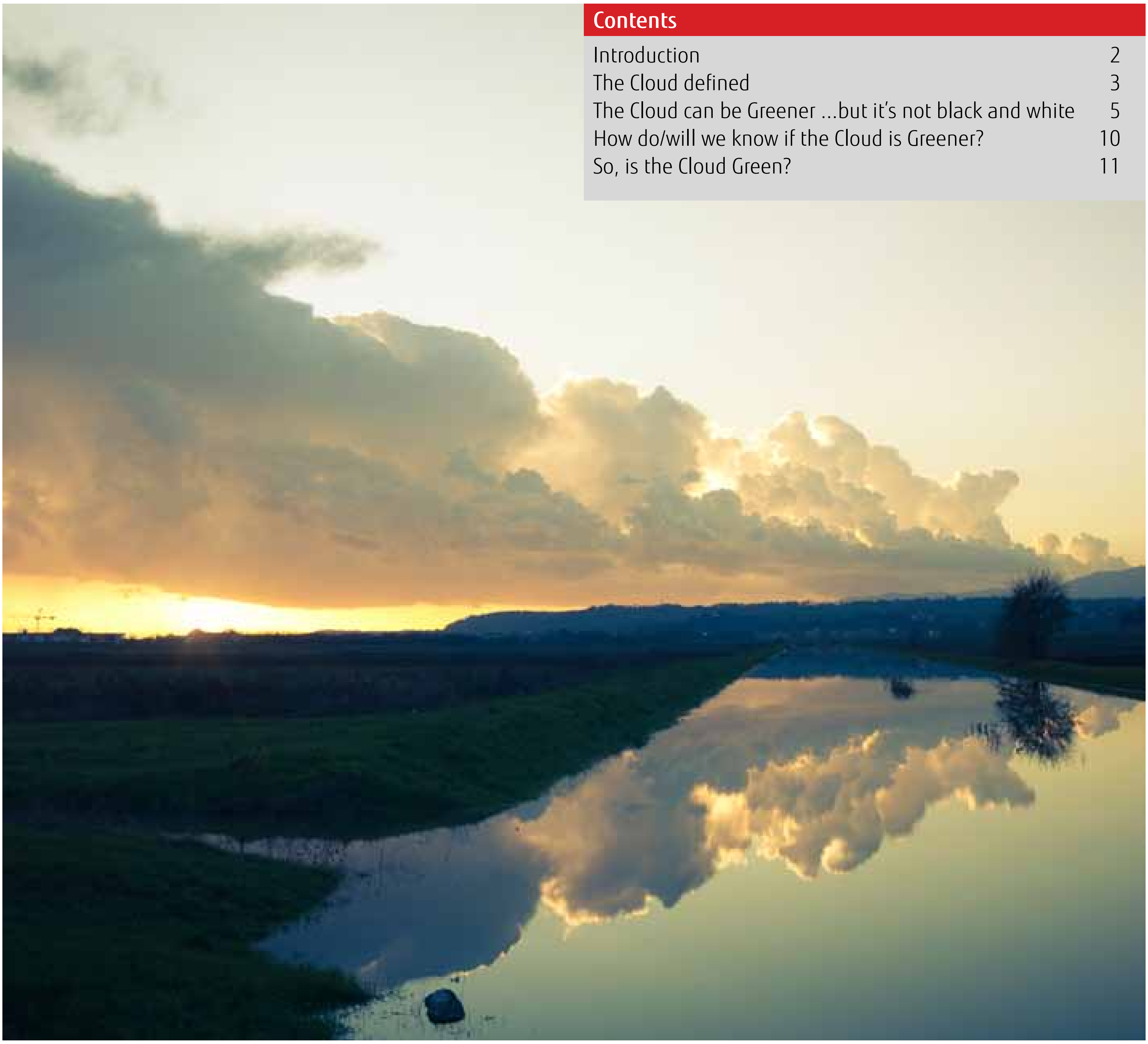


Introduction

Much talked about for several years, Cloud computing, it seems, has finally arrived. If the number of vendors now offering Cloud services and the number of customers now buying and using cloud are any gauge, then 2010 appears to have become the 'tipping–point' for Cloud. In addition to the much-touted cost and agility benefits to customers of adopting the Cloud model, Cloud vendors and other proponents increasingly cite environmental benefits as a further incentive for take-up of their services, in particular reduction of the carbon footprint of the customers' ICT infrastructure and support services. In short, Cloud is Greener than other ways of deploying and operating ICT services.

However, is Cloud really so Green? Is it yet delivering on its Green claims? This paper discusses these questions.

Why is it important to examine the Cloud's Green credentials? Many organizations who have set themselves challenging environmental targets, especially around carbon reductions, are now considering moving their ICT services to the Cloud and so the environmental dimension is playing an increasingly important role in their buying decisions.

Fujitsu, for example, has set a global commitment to reduce customer greenhouse gas (GHG) emissions by 15 million tons over a four-year period to 2012. This target is intended to allow Fujitsu, as a corporate group with a global business, to make a significant contribution to reducing their customer's greenhouse gases worldwide. Cloud will grow over this period and comprise a major share of the ICT services platform for Fujitsu. Fujitsu has confidence that the environmental gains for our Cloud customers will make a major contribution to our global GHG emissions reduction targets.

The primary focus of the paper is on the closely linked subjects of energy use and carbon emissions, as these aspects are central to the issue of Climate Change, are increasingly subject to legislation, and are, therefore, of paramount interest to our customers. Other sustainability aspects covered are:

- Water Use
- Waste and Recycling

Whilst, with regards to Cloud, water and waste are generally less significant environmental dimensions than carbon, they are still important factors for organizations and need to be considered in any holistic environmental assessment.

The Cloud defined

The first thing to know about Cloud is that, in common with several other 'disruptive technologies' over the years, there is no universally accepted definition of what it means. Such fuzziness of terminology provides fertile ground for the making of hard-to-challenge claims by vendors and others about Cloud being better than other computing models on a number of grounds, including environmental ones.

Two of the most widely accepted Cloud definitions:

"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models."

- National Institute of Standards and Technology (NIST) definition of Cloud computing v15.

"A style of Computing where scalable and elastic IT capabilities are provided as a service to multiple customers using Internet technologies"

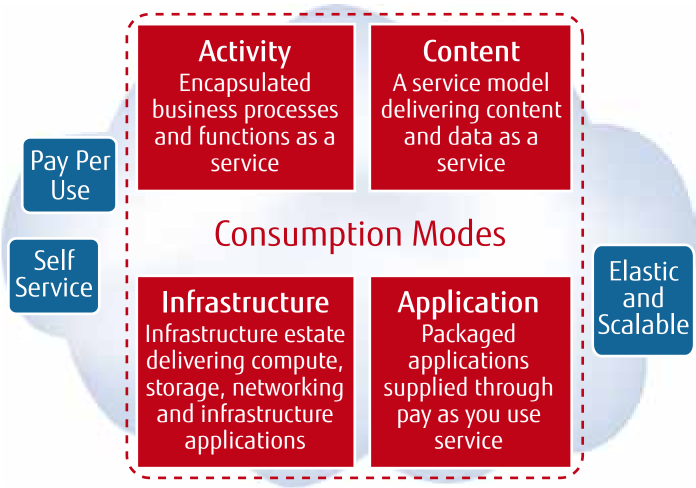
- Gartner: "Five Refining Attributes of Public and Private Cloud Computing" report May 2009.

The Cloud represents a combination of technological capabilities and a distinct commercial model. It means that a user can consume compute capacity or applications or entire business processes as a utility service. By "as a service" we mean metered consumption without any capital investment in equipment or software and without any long term minimum purchasing commitments. If a service does not meet these criteria, it is not Cloud in the true sense.

Fujitsu defines a Cloud service as the consumption of infrastructure, an application, an activity or content where that consumption has three distinct characteristics:

- Pay per use
- Elastic and scalable
- Self service

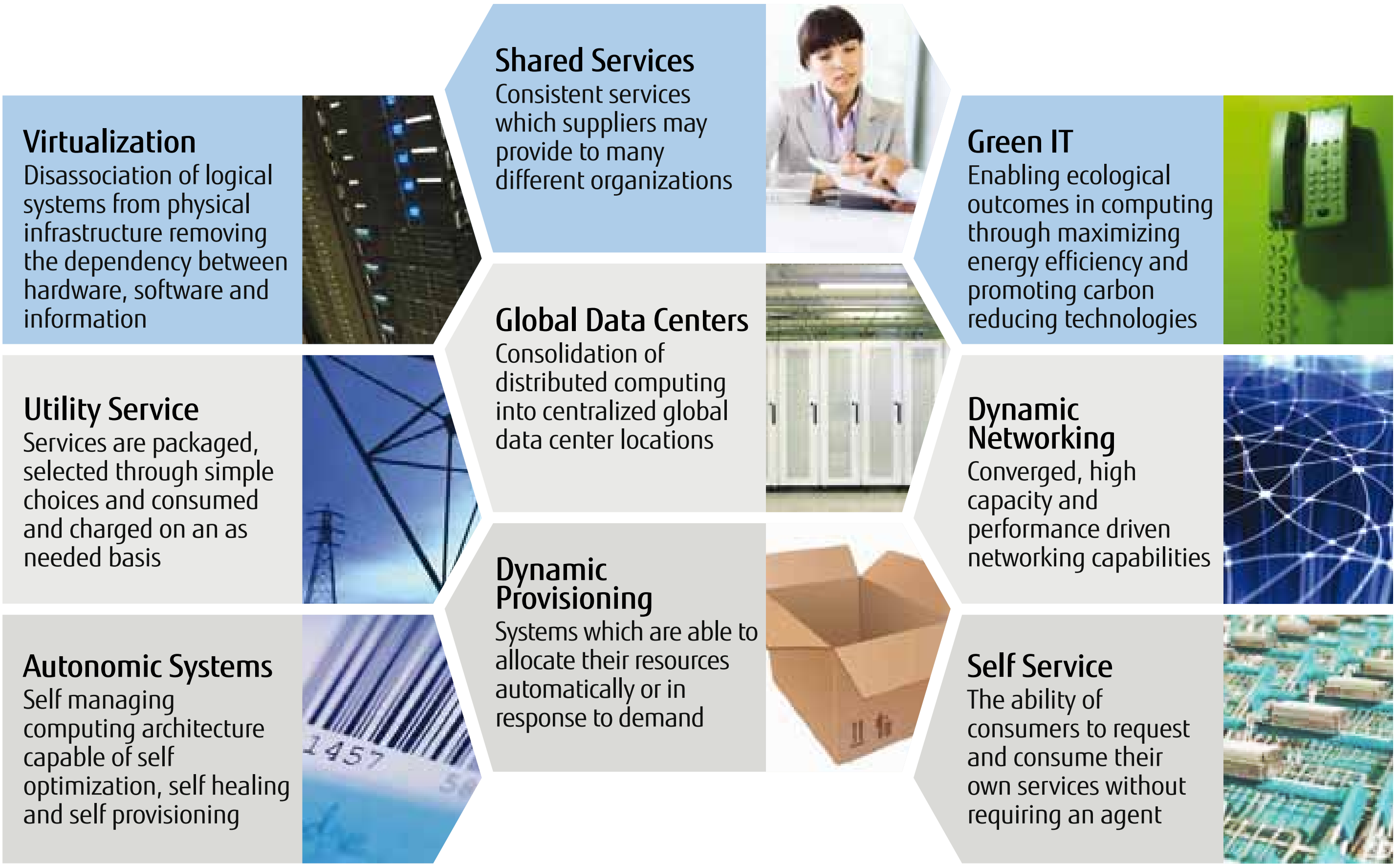
The diagram (below) illustrates this definition:



There is no single Cloud model, but rather many ways of designing, operating, selling and using Cloud services, based on different combinations and different degrees of the Cloud attributes. The table (below) shows how Cloud services form a rough continuum of increasing 'cloudiness' from non-shared Private Cloud through to fully-shared Public Cloud services.

	Traditional Infrastructure	Private Cloud	Community Cloud	Public Cloud
Technology Model	Customer-owned and dedicated on or off customer premise	Customer-owned and dedicated ICT run as a pooled resource and sold to customer departments (can be operated also as ICT outsourcing (ICTO)) in a provider's data center)	Run on a shared platform but for trusted use at an identifiable location	Shared and highly scalable platform with location unspecified
Cost Model	Customer-owned ICT or provided as an ICTO service	Customer-owned ICT or provided on ICTO-type commercials with scalability options delivered at an agreed price	Pay-per-use (minimum charge period applies): scalability confined to agreements	Pay-per-use per hour and rapidly scalable to demand

The diagram (below) provides another view of the Cloud, this time in terms of its defining functional and architectural elements.



It would appear intuitively then that a number of the inherent characteristics of Cloud – e.g. scalability, elasticity, sharing, dynamic provisioning, consuming according to need – would naturally mean more efficient computing, particularly from an energy consumption viewpoint, leading to a reduced environmental footprint.

From a sustainability perspective, an important broad distinction to make is between the Private and Public Cloud models. A Public Cloud, due to its economies of scale and inherent high degree of infrastructure sharing between many different customers, is likely to yield bigger energy/carbon savings than a Private Cloud.

These two basic models can each be further divided into sub-models, which can differ in their environmental characteristics.

For example, an Internal Private Cloud (hosted in the customers own data center) may be a less efficient option than a Hosted Private Cloud (hosted in the Cloud vendor's data center) as the latter data center would be expected to be more optimized.

The ratio of Private Cloud to Public Cloud implementations is likely to change over time in favor of the latter as customers' current security concerns over Public Cloud are allayed.

Cloud then is clearly a complex (and evolving) concept, which makes objective comparison, on virtually any grounds, between Cloud offerings from different vendors, or between Cloud and alternative computing models, not a simple exercise.

The Cloud can be Greener ...but it's not black and white

Let's examine some of the reasons why Cloud can be more sustainable than other computing modes and some circumstances when it may not be. We'll do this in terms of:

- Data centers
- ICT infrastructure
- Enablement effects
- Water and waste

Data Centers

The critical foundation for any Cloud solution is the data center which houses the servers, storage and network equipment which together deliver the total solution. The data center operator has the task of delivering continuous power to the ICT equipment whilst ensuring the ICT is kept within strict temperature and humidity thresholds. The impact of providing data center environments is indicated by a finding from the U.S. Environmental Protection Agency ENERGY STAR Program, which states that the average PUE (ratio is the total power entering the data center divided by the power used by the ICT equipment) in US data centers is 2.0[1]. So for every 1 kW of ICT, another 1 kW is consumed by the data center to provide the resilience and cooling.

According to Gartner, data centers account for 23% of global ICT emissions[2], and the ICT industry as a whole is accountable for 3% of global GHG emissions, placing it on a par with the aviation industry. The scale of these numbers indicates not only the challenge but also the opportunity faced by the data center industry with regards to reducing GHG emissions.

The industry's drive to increase energy efficiency across the data center can be seen by the significant number of initiatives launched to help data center operators measure and improve their operations, e.g. in the areas of standardization metrics and best practices.

Metrics

The Green Grid's initial and further definition of the PUE metric has enabled organizations to gauge the energy efficiency of a data center and more importantly a baseline for measuring the improvement month on month, year on year. Whilst it's acknowledged, PUE isn't perfect; it's a simple metric that has provided a stake in the ground for organizations to drive forward with improvements. Green Grid are formulating measuring and reporting data center efficiency including Carbon Usage Effectiveness (CUE) and Water Usage Effectiveness (WUE), reflecting the importance of measuring carbon and water as well as the efficiency of energy usage.

Best Practices

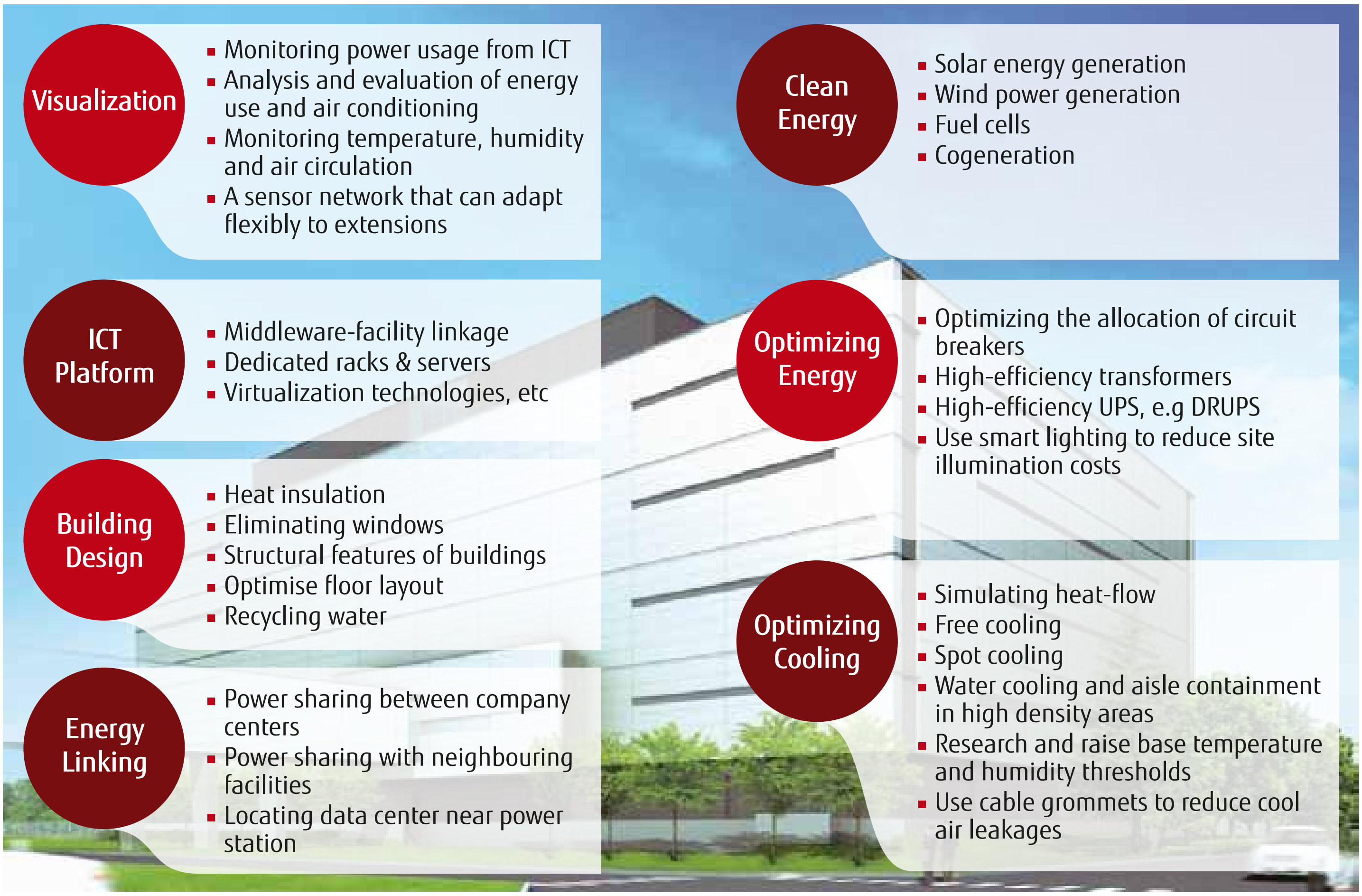
Further work has seen the development of guidelines for the operating and construction of data centers. The EU Data Center Code of Conduct and the Green Grid recently released the Data Center Maturity Model, providing an invaluable resource of guidance for data center operators, to continue to push the energy efficiency of their data center estate.

There isn't a single magic solution to reducing the GHG footprint of a data center but a combination of a number of elements across many areas. Some will only apply in the construction of new data centers whilst others can be easily implemented across existing data centers. The Cloud will provide an opportunity to integrate the ICT with the data center infrastructure, providing a highly energy efficient environment. For example, newer data centers allow cooling, the largest source of energy consumption within the data center after the ICT, to react to the dynamic nature of the Cloud. The data center grows or shrinks in direct response to Cloud utilization – optimizing energy consumption. Most importantly, every element of the data center needs addressing, from highly efficient cooling to water consumption. It's the combination of all of the individual elements which provide the ideal platform for the Cloud.

[1]U.S. Environmental Protection Agency ENERGY STAR Program, Report to Congress on Server and Datacenter Energy Efficiency Public Law 109-431, August 2, 2007

[2]Gartner's Data Center Summit 2007, 22-24 October 2007, London

The key areas for data center sustainability improvements are illustrated in the diagram (below).



Advantages of Scale and Design

The economies of scale of larger data centers justify the cost of the buildings, the research and development in new techniques and the more significant infrastructure investments required. It's essential that large data centers have a modular design in order to avoid waste. Internal modularization of data centers allows additional space to be brought into use only as required – there is no point in powering and cooling empty data halls. This modular design allows the data center to expand in line with demand and, once complete, means it is large enough to maximize return of investment on the efficiency of the advanced powering, cooling and facility design that has been deployed.

Like the ICT within them, data centers never reach 100% utilization, due to issues such lack of space, resilience and business growth. A data center could be "full" whilst only utilizing 60-80% of the design capacity. Multiply this across hundreds of data centers equals hundreds of megawatts of effectively stranded data center and grid capacity. The provision of Cloud solutions into a smaller number of large but scalable and modular data centers provides the optimum environment and can allow data center utilization of 90-100%.

Energy Efficiency versus Carbon Efficiency

Energy reduction does not necessarily equal a carbon emission reduction. A good example of this is where a company moves from hosting its ICT services in its own data center to using a public Cloud service. Whereas it might be fairly safe to assume (though not necessarily certain) that the migration would result in lower total energy consumption associated with those services, if the Cloud data center was in, say, Germany and the company's own current data center is in, say, France, then the carbon footprint of those services may actually increase due to the large difference in electricity energy generation carbon emissions factors between those countries (lower in France due to its high proportion of nuclear generation). If it were, say, Sweden and India, rather than France and Germany then there would be around a 20-fold emission factor difference, i.e. even if the new Cloud service were twice as energy-efficient as the existing ICT set-up then the carbon footprint (of the data center element) would rise 10-fold.

ICT Infrastructure

ICT infrastructure refers to the hardware, software, and network elements supporting Cloud services. The following table outlines the main Green benefits typically associated with the Cloud's ICT infrastructure.

ICT Infrastructure Aspect	Green Benefit
Multi-tenancy	Sharing infrastructure between customers means less overall energy, e.g. flattens load (fewer peaks/troughs).
Optimal Server Utilization	The utilization of in-house data center resources is typically very low because applications tend to be deployed in silos and systems are designed to allow for peak capacity. Likewise, storage levels sit at an estimated 25%, networks at 30% and server utilization within data centers is generally 10-15%. Traditionally, many servers sit idle 85-95% of the time yet use nearly as much power as they do when they are active.
Dynamic Provisioning	Reduces over-allocation of hardware as Cloud vendors provision according to intelligent demand analysis.
Minimization of 'embodied' CO_2	Cloud providers are more skilled at life cycle management of equipment (e.g. procurement, refresh, disposal) which means minimum 'embodied' carbon.
Cloud vendors can match equipment to purpose	By giving preference to equipment that is power efficient, has energy saving functions, is recyclable and has a smaller physical footprint.
Energy-efficient client devices	The Cloud model (Public in particular) works well with small (and possibly diskless), energy-efficient devices (e.g. thin clients), and will therefore naturally encourage their increasing take-up at the expense of bigger, more energy-hungry clients, thus reducing the embedded and in-use carbon footprint on the client side.
Application Optimization	Cloud providers more likely to assist with making application code and configuration optimally efficient.

Minimization of 'embodied' carbon – refers to the carbon emitted as part of the hardware manufacturing and distribution processes, which must be taken into account when measuring the Green benefits of any ICT system, including Cloud. There may be a negative effect when considering the carbon embodied in the existing infrastructure which the Cloud is replacing. For example, migration to the Cloud may necessitate retiring existing servers and other equipment before end-of-life, effectively incurring an additional embodied carbon burden (i.e. in the Cloud equipment which is 'prematurely' replacing them). This is a complex calculation but cannot be ignored.

Few hardware vendors either measure to any degree of accuracy or publish data on the embodied carbon of their products. Things are changing though. Fujitsu, for example, have recently carried out an exhaustive environmental Lifecycle Analysis (LCA) of certain products (including two server models) and have made the independently verified results publicly available. This is essential input to any robust measurement of Cloud's Green benefits.

The network element of Cloud may be expected to have a negative environmental impact, owing to Cloud's generally heavier reliance on networks than traditional computing models, particularly in the case of Public Cloud with its use of a small number of very large data centers supporting a user base dispersed across the globe. However, whether the impact is negative or positive, and the extent of that impact, will depend on how the Cloud services are distributed across data centers (e.g. high density of applications in a few data centers is better than low density spread across many), and how the existing services are deployed (e.g. if the existing network is highly sub-optimal then a move to Cloud may reduce network traffic).

The carbon footprinting of networks is clearly a complex process, not least because they normally contain a very large number of active components, spread over a wide geographical area (including globally) and which are shared between many customers. Telecommunications and network equipment providers are now, however, becoming active in the ICT carbon footprinting arena and therefore better quality data should soon start to be publicly available.

Cloud's Enablement Potential

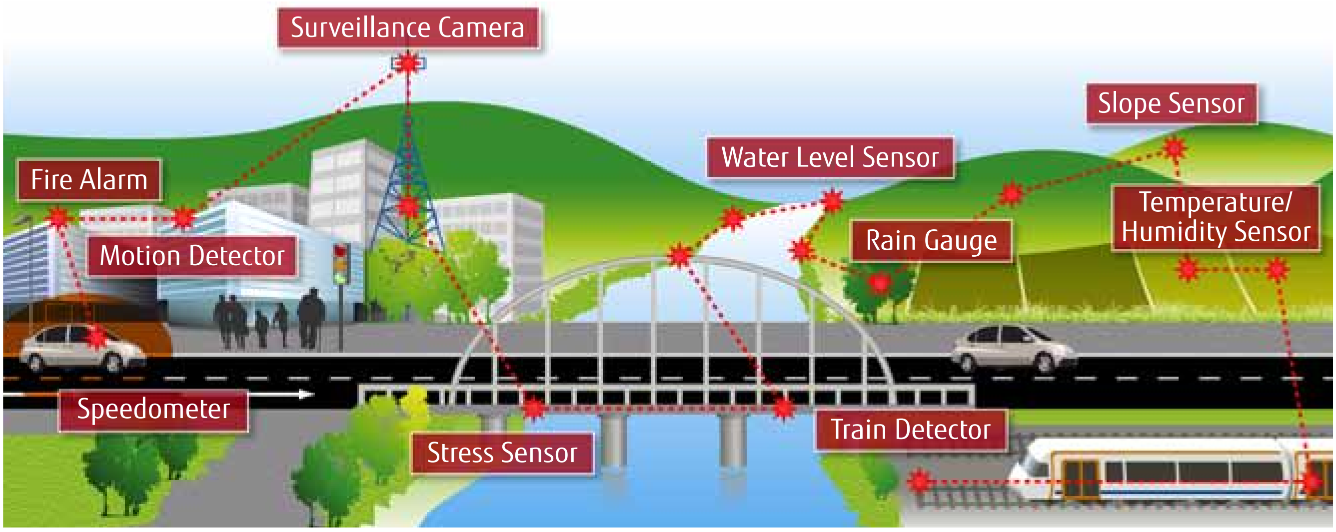
The generally cited Green benefits of the Cloud relate mostly to the ICT infrastructure, as these are normally the most obvious and immediate. However, the greatest potential environmental benefits of Cloud may well turn out to be not related to the ICT infrastructure, but rather to the way in which Cloud services can facilitate environmental improvements in the processes of the organizations using them, i.e. the 'enablement effects'. Large scale realization of these benefits will contribute greatly to reducing the 97% of global carbon emissions outside the ICT industry.

The enablement benefits tend to be subtle, take longer to realize and are perhaps harder to measure, than the ICT infrastructure benefits. They are largely made possible by the cost and agility advantages the Cloud brings, i.e. implementing certain solutions which generate environmental gains which may not be cost-effective now, become cost-effective in the Cloud. The range of potential solutions is extremely wide, and may be environmentally-specific solutions or, probably more commonly, solutions implemented principally for non-environmental reasons but which have indirect environmental gains.

Examples of environmentally-specific solutions include SAAS-based Carbon Accounting, and fully-fledged Sustainability Management systems. Solutions providing more indirect environmental improvement are very wide ranging and include Unified Communications and Collaboration (UCC), logistics optimization, and 'smart' transport systems.

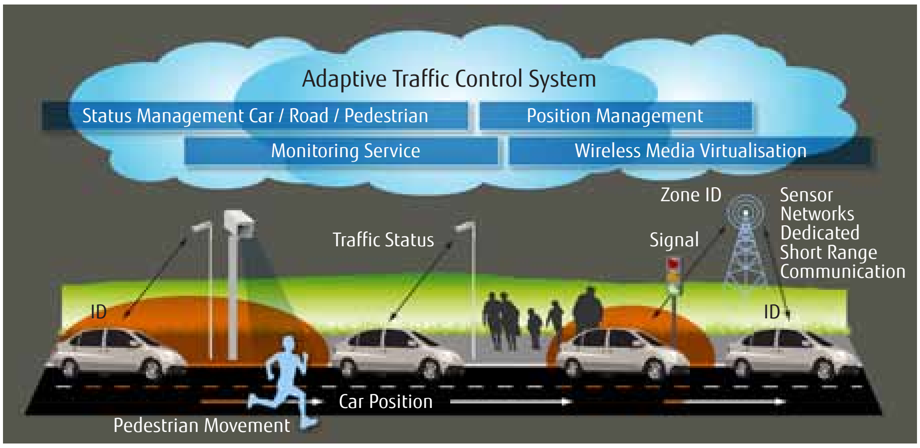
Examples of Cloud-based environmental enablement solutions are Fujitsu's sensor-based 'smart network' applications which support our vision of the 'Intelligent Society', and can deliver significant environmental benefits using sensing technologies, data networks and mobile solutions to transform how industries deliver their services. These solutions typically generate large amounts of data, and require a high degree of agility and elasticity in the processing and storage capabilities supporting them. As infrastructure projects, they may be uneconomic. As Cloud solutions they become cost-effective.

The diagram (below) highlights the 'Intelligent Society' scenarios in which the deployment of sensor networks provide additional environmental and societal benefits.

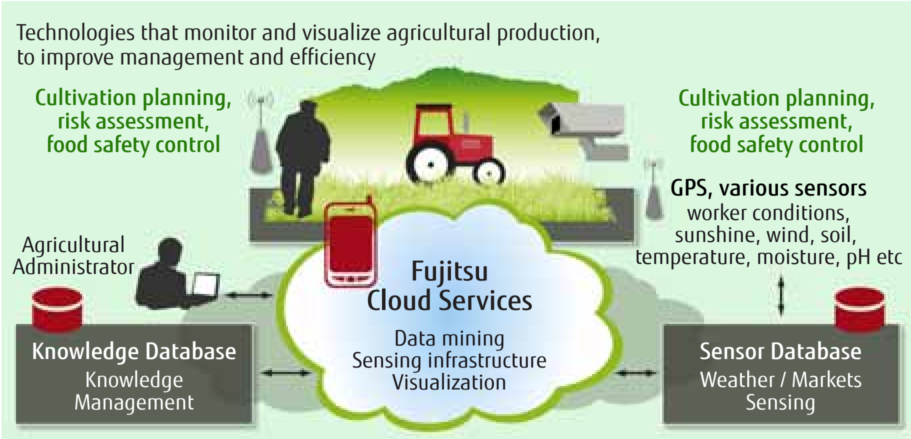


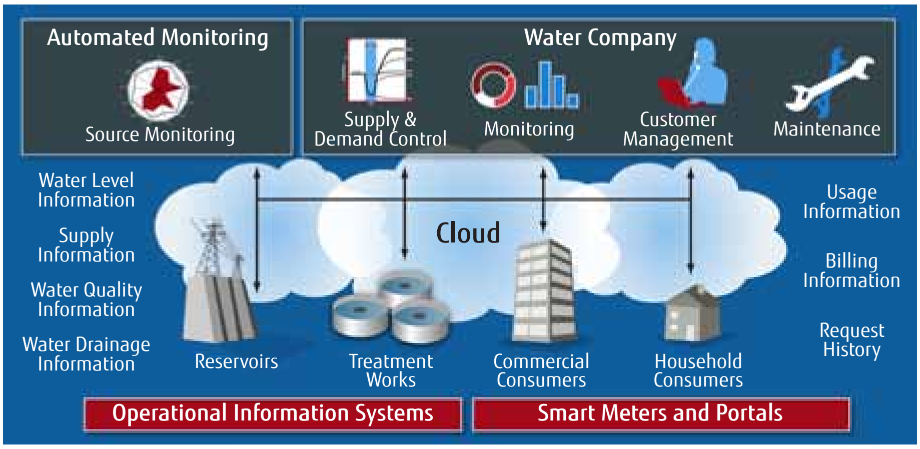
Examples of applications for the 'Intelligent Society' using Cloud-supported sensor-networks include:

Smart Traffic Cloud (right)
Sensor networks gather real-time information on road and traffic conditions allowing greater efficiency and safety of vehicle and pedestrian flows.



Smart Agriculture Cloud (right)
By capturing data on the climate, soil and water, as well as crop conditions through field located cameras and sensors, it is possible to devise new business models that secure better harvest yields with lower expenditures of labor and energy.





Smart Water Cloud (left)
Similar to Smart Grids for energy networks, this solution facilitates improved capacity management by building intelligence about the supply and demand of water. This allows the optimum efficiency of water production and usage through real time information gathering in the environmental aspects such as quality and drainage.

Water and Waste

Green ICT benefits, whether for Cloud or other ICT deployment models, are normally expressed in terms of energy and/or CO_2 savings, and those aspects are the focus of this paper. The reason being most customers' and national targets, and legislation, tend to major on these environmental dimensions, are somewhat measurable and have obvious cost impacts (i.e. on electricity bills and, increasingly, on carbon taxes).

Other environmental aspects, notably water usage and ewaste, are now rising up the agenda. At a very high level it is probably reasonable to assume that the volume of water used, and ewaste generated, would be less with the Cloud model than with other deployment models. The main reasons for this are that Cloud tends to optimize both hardware usage and energy usage, i.e. less hardware means less water required during manufacturing and less to dispose of creating less ewaste, and less energy usage means less water required in the electricity generation process. For example, it is estimated that the generation of 1kWh of electricity in the US uses 95 liters of water. This figure will vary in different countries, and with different methods of power generation, and has to take into account the fact that water is recycled (the process for which uses energy itself).

Calculating water consumption accurately for the ICT lifecycle is very difficult and an inexact science. Nevertheless, it would appear that Cloud has potential benefits in addition to energy and carbon savings, and it is likely in the near future that customers' buying decisions will also take these into account. The ICT industry will need to be ready to respond by measuring and making public the same type of objective and credible data on these as it is now doing for energy and carbon.

How do/will we know if the Cloud is Greener?

Claims by ICT suppliers, including Cloud vendors, about the environmental characteristics of their products and services carry little weight with customers unless they are supported by solid evidence, this evidence is quantified, and, increasingly, independently verified and measured in compliance with a recognized international standard. This allows accurate comparisons to be made between:

- The 'As is' and the 'To be' services;
- Services at various points in time, for the purposes of tracking progress against environmental targets;
- Services being proposed by competing suppliers, as input to buying decisions.

For Cloud services, perhaps the biggest difficulty in making comparisons is defining exactly what we mean by 'the Cloud'. This makes defining the 'As is' and 'To be' positions a problematic exercise. For example, if a company migrates its ICT services from its own data centers to a those of a Cloud vendor, is this a move to the Cloud or simply a good old-fashioned data center outsource? There is never likely to be industry-wide agreed definition so cross-vendor comparisons are always going to have to be examined with much care. The problem is exacerbated by the fact that most Cloud migrations, in common with most other major ICT service upgrades, almost always involve a degree of business transformation. The ICT post-migration is therefore normally different in usage and scale, making 'apples-with-apples' comparison difficult.

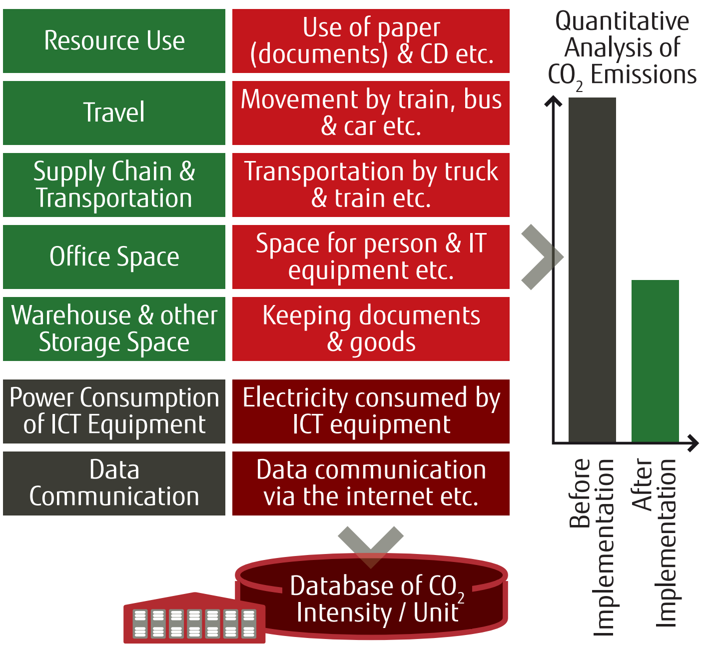
Even if those positions could be satisfactorily defined, there remains the further problem that organizations rarely measure to any degree of accuracy, if at all, the carbon footprint of their existing ICT services and rarely do Cloud vendors currently measure or publicly share theirs. Carbon footprinting of most types of ICT service is always likely to be an inexact science, Cloud services particularly so.

Despite the inherent difficulties, mindful of the demands of our customers for greater transparency and standardization on the environmental characteristics of our services, leaders in the ICT industry are now seriously addressing the problem.

Fujitsu, for example, has embarked on a range of internal and cross-industry activities, including:

- Systematic carbon footprinting of Cloud services comparing the 'As is' and 'To be' positions, and making available to our customers this information and relevant case studies;
- Participation on standards-making bodies and related initiatives aimed at achieving international agreement on the methodology for carbon footprinting defined types of ICT services. Fujitsu, for example, is a founding member of the GHG Protocol/Carbon Trust ICT Carbon Footprinting initiative which is developing ICT sector guidance, including for Cloud, on GHG Protocol standards;
- Formally measuring the enablement effects of adoption by organizations of various Cloud applications, using the Fujitsu 'Environmentally Conscious Solutions' certification process through which the enablement effects of over 200 solutions have so far been measured;
- Formal Environmental Lifecyle Analysis for our major products, including Cloud data center servers, verified by 3rd party specialists, and which include both the 'embodied' and in-use carbon;
- Influencing initiatives to better define ways of describing the environmental efficiency of data centers (as opposed to just the energy efficiency), e.g. Green Grid CUE.

The diagram (below) provides an overview of Fujitsu's Environmentally Conscious Solutions measurement methodology, showing the environmental aspects assessed in order to calculate an overall carbon impact of the introduction of a solution into an organization.



Applying the measurement methods outlined above will provide customers increasingly accurate and trustworthy information on the environmental benefits of Cloud services, which will better inform their buying decisions.

So, is the Cloud Green?

It should be apparent, from the opinions presented in this paper, that there is no simple answer to this question. It seems fairly evident at least that, ***per unit of computing work*** (however that is defined), Cloud will normally be Greener than alternatives.

The answer for any given Cloud implementation though will vary depending on a variety of factors. These include how efficient is the infrastructure pre-Cloud migration, whether the transition is to a Private or Public Cloud, and the geography involved (as the carbon emissions intensity of power generation varies so widely across countries).

It will also, of course, depend on the perspective being taken. For example, a company's move to the Cloud may reduce the direct carbon footprint of that company, as it has shifted a portion of its energy consumption (and therefore carbon emissions) to the Cloud provider. Therefore, it could be said that that company has become 'Greener'. In most cases, there will also be a net carbon reduction, due to the greater energy efficiency of the Cloud provider's ICT infrastructure and data center.

From the planet's perspective, 'Is the Cloud Green?' becomes a much bigger question. The anticipated large-scale take-up of Cloud services is likely to allow organizations and individuals to carry out more ICT activity – because the Cloud makes it cheaper and easier to implement than traditional computing models. It's the Jevons Paradox in action – the proposition that technological progress that increases the efficiency with which a resource is used tends to increase, rather than decrease, the rate of consumption of that resource. What was true for 19th century coal could well also be true for 21st century ICT.

The reality is that technological advances and increased computer demand are inevitable. Cloud provides greater access to computing power and is part of the reason that ICT will account for 6% of global GHG emissions by 2020[3]. On the positive side, it's estimated that enablement solutions such as Smart Grids, Smart Transport, Smart Agriculture and Smart Water, many of which are made possible by the advent of Cloud, have the potential to save 15% of global GHG emissions outside the ICT industry by 2020[4].

It is still early days in the evolution of Cloud, however there is the very real potential for Cloud to provide measurable sustainable improvements. To accurately determine the true extent of the net benefits being delivered we need industry wide agreement on what the Cloud actually is. and how to calculate the environment footprint of ICT services that are provided.

Whilst customers are currently moving to the Cloud principally for agility and cost reasons they are already seeing environmental benefits. For example, in December 2010 Fujitsu Limited and the Japan Advanced Institute of Science and Technology (JAIST) were awarded the 2010 Japan Minister of the Environment Award for the Prevention of Global Warming, for achieving significant reductions in the energy consumption of ICT equipment by building an advanced on-campus Private cloud. The award recognized the improved server operating rate and overall 48% reduction in power consumption achieved by consolidating what had been approximately 120 servers to 54 blade servers with superior energy efficiency from Fujitsu.

Published case studies from a number of other vendors and organizations also indicate that, in a variety of scenarios, migration to the Cloud can significantly reduce energy consumption and carbon emissions. They key question is what is the net saving? Over the coming months we will publish a suite of case studies utilizing our methodology to further increase the bank of knowledge on the Cloud sustainability bottom line, we welcome ongoing discussion and feedback from you.

[3]SMART 2020 Report
[4]SMART 2020 Report

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