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Virtual Desktop Infrastructure (VDI) Technology: impact of ICTs on the ecological footprint FI4VDI - SUDOE project

Redondo Gil, Carlos [(1) (2) (3)]

[(1)] Managing Director and Scientific Director, **Castile and León Technological Center for Supercomputing (FCSCL)**
Edificio CRAI-TIC, Campus de Vegazana s/n. University of León. E-24071-León (Spain).
carlos.redondo@fcsc.es http://www.fcsc.es
[(2)] Electrical Engineering & Systems Engineering and Automatic Control Department
Faculty of Industrial and Computer Engineering, **University of León**. E-24071-León (Spain).
carlos.redondo.gil@unileon.es http://www.unileon.es
[(3)] Research Group on Energy Efficiency in HPC environments FCSCL
GI EE / HPC-FCSCL • Efficiency and Energy Management in HPC environment

Abstract

This paper presents an analysis of the FI4VDI project, the goal of which was to develop an innovative model of service provision using cloud computing in order to create an infrastructure suite aims at large companies and SMEs alike, educational institutions, universities and/or research centres that would contribute to competitiveness and provide an efficient solution to reducing the carbon footprint derived from the use of information technology.

KEY WORDS

VDI - Smart Data Centre - SMART IT Infrastructure - Energy Efficiency - Carbon Footprint

Introduction

The aim of the *FI4VDI* project is: *to develop a federated infrastructure network for the creation of virtual desktop services*. Firstly, by evaluating the position and perception of public and private organisations in the SUDOE Space as regards the desirability of the virtualising IT operating environments, and secondly, by promoting the spread of cloud computing as a means to achieve savings, efficiency and simplicity with the primary objective of ensuring improved productivity.

The provision of cloud computing services by supercomputing centres has a positive effect on the ecological footprint; dependence on physical ICT infrastructures is reduced when these are replaced by virtual ones, and this in turn produces a marked reduction in energy consumption in these institutions.

With a federated cloud computing model, desktops can be connected to dedicated servers with high rates of effective utilisation, greatly increasing energy efficiency and reducing the carbon footprint associated with the service.

The provision of cloud computing services by supercomputing centres has a positive effect on the ecological footprint; dependence on physical ICT infrastructures is reduced when these are replaced by virtual ones, and this in turn produces a marked reduction in energy consumption in these institutions.

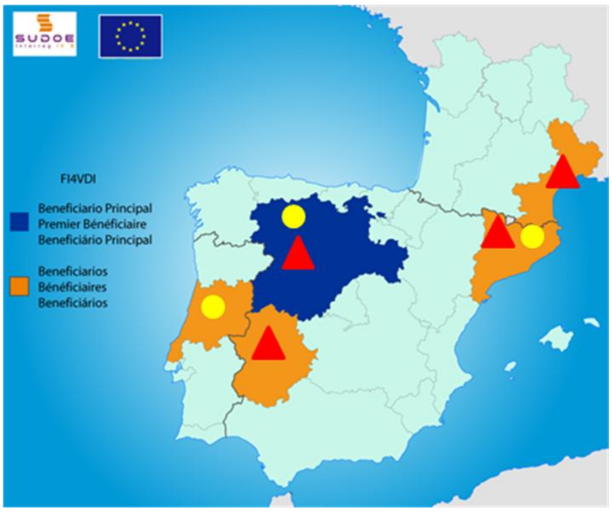


Figure 1. Scope of the FI4VDI project in the SUDOE Space[1 2]

Setting of the FI4VDI project: profile of the partners participating in the project.

Location of Centres providing the infrastructure

Location of business associations

The goal of the project was to develop a federated infrastructure network for the creation and management of energy efficient ICT services. Organisations that participated actively as infrastructure providers included the Supercomputing Centre in Castile and Leon [1] - Castile and Leon Region ES41 (Spain), the Computing and Advanced Technologies Centre in Extremadura - Extremadura Region ES43 (Spain), the University of Lerida Faculty of Arts Computer Centre in Ponent - Catalonia Region ES51 (Spain) and the University of Montpellier 2 *Sciences et Techniques* - Languedoc-Roussillon Region FR81 (France). Organisations actively

[1] www.sudoe.eu

[2] Relation of partners partakers in the project
Fundación del Centro de Supercomputación de Castilla y León (FCSCL) (ES)
Fundación COMPUTAEX (Computación y Tecnologías Avanzadas de Extremadura)
Centro CénitS (Centro Extremeño de investigación, Innovación Tecnológica y Supercomputación) (ES)
Universitat de Lleida Facultat de Lletres Centro de Computación de Ponent (ES)
Université Montpellier 2 Sciences et Techniques (FR)
Agrupación Empresarial Innovadora para la Seguridad de las Redes y los Sistemas de Información (ES)
Inova-ria – Associação de Empresas para uma Rede de Inovação em Aveiro Associação empresarial (PT)
Consorcio Parc Científic i Tecnològic Agroalimentari de Lleida (ES)

participating as business associations included the Innovative Business Association for Network Security and Information Systems (Spain), Inova-ria – Association of Companies for an Innovation Network in Aveiro - Central Region PT16 (Portugal) and the Science and Technology Park Agri-Food Consortium in Lerida - Catalonia Region ES51 (Spain).

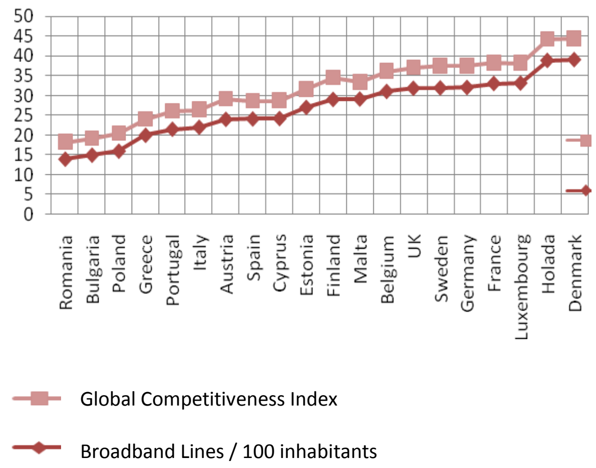
2. ICTs and competitiveness

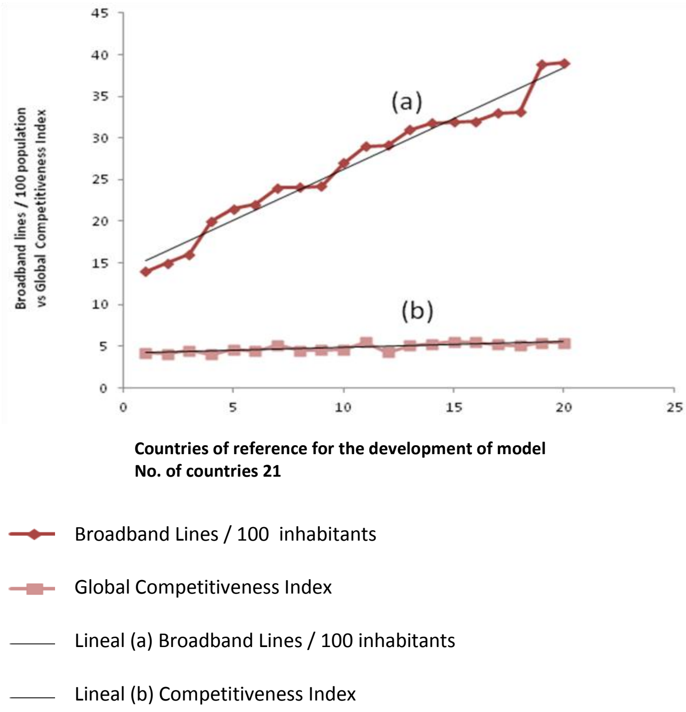
The positive effect of ICTs on competitiveness in the knowledge economy is an objective reality[3] [1], and one of the fundamental cornerstones of competitiveness is e-readiness, defined as the ability of an economy to adopt existing technologies in order to improve the productivity of its industrial sectors, with particular emphasis on the use of ICTs in daily activities and production processes to increase efficiency.

There is a strong correlation between the competitiveness a country attains and the use of ICTs in its production processes. This assertion is supported by a cross tabulation analysis of the 2010-2011 Global Competitiveness Index indicator, reported in the study cited above, and the 2010-2011 Networked Readiness Index indicator, calculated annually by the World Economic Forum in its Global Information Technology Report [2], which examines the impact of ICTs on development, economic growth and improvements in living conditions worldwide. This indicator combines aspects of national contexts related to the development and spread of ICTs, including regulatory issues, the business climate and infrastructure and the human resources necessary for growth in ICTs. It also focuses on the degree of e-readiness and interest in the use of ICTs shown by the main stakeholders (citizens, the business sector and public authority bodies) and the effective use they make of these technologies.

As can be seen in the graph following, the most competitive countries are those in which ICTs play a vital role in business and social processes.

Looking specifically at European Union member countries, for instance, a very close relationship is clearly evident between the competitiveness of the national economy and the extent to which the new information technologies have been adopted. By way of example, the following graph shows the correlation between broadband penetration in European countries and the level of competitiveness achieved. The most competitive countries are those that have achieved greater penetration of Internet access via broadband.

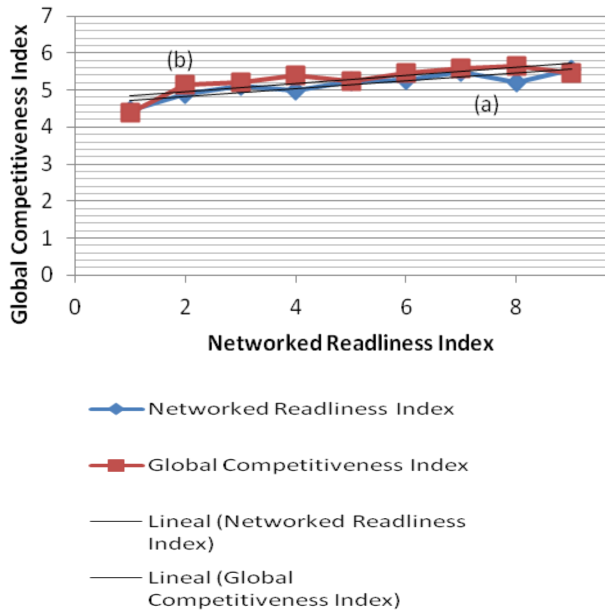




(a) $y = 1{,}2147x+14{,}071;\ R^2 = 0{,}9659$

(b) $y = 0{,}0701x+4{,}1;\ R^2 = 0{,}6507$

Figure 3. Broadband lines per 100 inhabitants · Relationship with Global Competitiveness · Broadband penetration by country. Source: World Economic Forum and the European Commission.



(a) $y = 0{,}1062x + 4{,}6049;\ R^2 = 0{,}7642$

(b) $y = 0{,}1092x + 4{,}7375;\ R^2 = 0{,}6442$

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[3] The 2010-2011 Global Competitiveness Report, World Economic Forum.

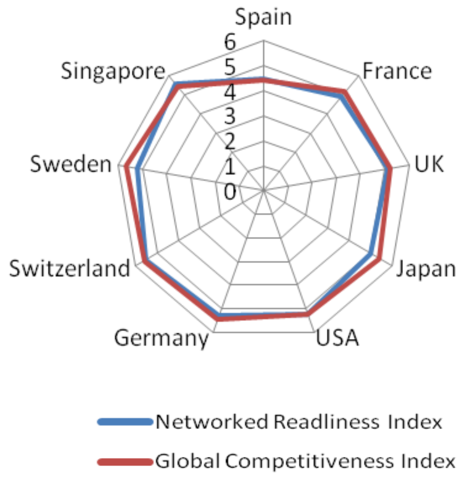

Figure 4. Global competitiveness Index. Relación Global Competitiveness – Network Readiness por países · Relación Global Competitiveness – Network Readiness por países. Fuente: World Economic Forum

3. ICTs and the environment

It has been estimated that the ICT sector is responsible for 2% of the global carbon footprint. More specifically, ICT sector activity in 2007 was responsible for the emission of 0.83 GtCO2e, and growth forecasts for the use of ICT products and services indicate that this figure will rise to 1.43 GtCO2e by 2020[4] [3].

Although the ICT sector is not in itself one of the most environmentally unfriendly sectors, nevertheless it should lead the way in the development and adoption of efficient technological solutions and the implementation of structural changes in operation (derived in part from the use of these technologies) that enable the sector to limit its carbon footprint, since there is scope for attempting to reduce the harmful impacts it generates.

Thus, the ICT sector should strive to become a benchmark for other sectors in terms of innovation and leveraging the benefits that accrue from use of green ICTs. To achieve this, the sector will need to make a firm and continuous commitment not only to research but also to the development of solutions that improve the energy efficiency of ICT components, systems and applications, and lead to technological innovations such as virtualisation and cloud computing, which can be applied in other sectors to optimise the configuration of their information systems.

It has been estimated that by 2020[5][6] cross-cutting and systematic application of *Green ICTs* in the various economic sectors could lead to a reduction of 7.8 GtCO2e in the total expected emissions of 51 GtCO2 - **a reduction equivalent to five times the sector's own footprint**. It has also been estimated that the energy efficiency provided by ICTs could even represent a saving in costs of as much as 600,000 million Euros by that date. Proyectos de eficiencia energética de la FCSCL [7] [8].

The ICT sector's carbon footprint is three parts due to the use of information and communication technologies, whilst the remaining 25% is associated with the ICT industry's production and manufacturing processes [4].

3.1. User computing

The main source [5] of greenhouse gases in the ICT sector is the energy required to operate personal computers and data monitors, which accounts for 40% of emissions. In second place are data processing centres, representing 23% of the total. Landline and mobile telecommunications account for approximately 24% (15% and 9%, respectively). Lastly, office communications, representing 7% of the total, and printers, worth 6%, complete the ICT industry's contribution to the emission of greenhouse gases.

A substantial proportion of the carbon footprint associated with information and communication technologies derives from the elements that comprise the workstation: computers, monitors, printers, etc. In additional, these components constitute a major source of waste: over 160 million desktop computers were discarded in 2007 alone. This effect is exacerbated by the ever shorter life cycles of these devices. In terms of energy consumption, a computer may consume between 200 and 300 W, but lower energy consumption solutions such as thin clients can reduce the carbon footprint by at least half.

In conclusion, workstations incorporate an increasing number of information and communication technologies, and thus possess considerable potential for reducing the carbon footprint associated with the use of these technologies.

3.2. Data processing centres (DPCs)

DPCs constitute the second largest source of greenhouse gases in the information and communication technologies industry, preceded only by workstations. The carbon footprint generated by DPCs is increasing rapidly, and it has been estimated that if the current rate is maintained, by 2020 there will be a total of 122 million servers located in DPCs worldwide, compared to the 18 million currently in existence.

The energy saving potential of DPCs is as high as 50%, distributed as follows:

- Improving energy supplies: 25%
- Use of more efficient processors: 5-10%
- Use of more efficient fans: 10-15%
- Direct current (DC) through rack-based systems: 10-15%
- Optimising cooling systems: 5-10%

All these values are reflected in power usage effectiveness (PUE) ratio [6], a measure of the energy efficiency of the facilities and equipment that make up data processing centres. PUE is the ratio between the total energy consumed by the data processing centre and the energy consumed solely by its component ICT equipment and devices. As a reference, the Government of Australia has established a PUE target of 1.9 for public administration data processing centres, to be achieved by 2015 from a baseline value of 2.5 in 2010.

Several strategies have been suggested for reducing the carbon footprint of data processing centres, including the following:

[4] SMART 2020 Report.
[5] Europe 2020 Strategy.
[6] European Digital Agenda and Digital Agenda for Spain
[7] Project CONTROL OF ENERGY EFFICIENCY
Foundation Supercomputing Centre of Castile and León FCSCL Period: 2012 - 2014, SmartTIInfrasture first *edition enerTIC Awards*, http://www.enertic.org/ Platform ICT companies to improve energy efficiency.
[8] Integral Monitoring Calendula MONICA Project: intelligent system monitoring and control of energy efficient Data Processing Centers
(FCSCL, http://www.fcsc.es/index.php/es/proyectos)
TSI Code -79 -080,500 to 2011. Call Avanza Green ICT, Ministry of Industry, Energy and Commerce, MINETUR, www.minetur.gob.es / energy

- Server virtualisation
- Use of cloud computing models
- Avoidance of duplicated storage of redundant information
- Thin provisioning

4. Virtual Desktop Infrastructure - VDI as a technology proposal [7] [8]

The term "desktop virtualisation" was introduced in the 1990s to describe the process of separation between the desktop, which encompasses the data and programmes that users employ for their work, and the physical machine. A "virtual" desktop is stored remotely on a central server rather than on the hard disk of an individual personal computer. This means that when users work on their desktop from their laptop or PC, all their programmes, applications, processes and data are stored and run centrally, allowing users to access their desktops from any device that can connect remotely to the central server, such as laptops, PCs, smartphones, or thin clients.

Through desktop virtualisation, the entire environment of an information system or the environment itself is encapsulated and delivered to a remote device. This device can be based on a completely different hardware architecture from the one used by the projected desktop environment. It can also be based on a completely different operating system.

Desktop virtualisation consists of the use of virtual machines to enable multiple network users to maintain their individual desktops on a single server or host computer. The central computer may be located in a residence, in the company or in a data centre. Users may be geographically dispersed and connected to the central computer via a local area network (LAN), wide area network (WAN) or via the Internet.

Desktop virtualisation offers advantages over the traditional model, in which each computer functions as a complete and independent unit with its own operating system, peripherals and applications. Energy costs are reduced because resources can be shared and allocated to users according to their needs, and the integrity of user information is enhanced because the data centre stores and safeguards all data and backups. Furthermore, software conflicts are minimised by reducing the total number of programmes stored on computers, and although the resources are distributed, all users can personalise and customise their desktops to meet their specific needs. Thus, desktop virtualisation provides greater flexibility than the client/server paradigm.

The limitations of desktop virtualisation include the possibility of security risks if the network is not well managed, the loss of user autonomy and privacy, the challenges involved in creating and maintaining drivers for printers and other peripherals, difficulties in managing complex multimedia applications and problems in maintaining the addresses of virtual machine users consistent with those held by the data centre.

Table 1. Benefits of VDI technology

Like any other technology, desktop virtualisation provides a number of key benefits that render this technology the first choice for a large number of users:

- Enhanced security and reduced desktop support costs [9]
- Reduced general hardware costs [10]
- Ensured business continuity [11]
- An eco-friendly alternative [12]
- Improved data security

Table 2. Advantages of VDI technology

The main advantages are [12] as follows:

- Instant implementation of new desktops and use of applications
- Virtually zero downtime in the case of hardware failure
- Significant reduction in the cost of new deployments
- Sound capacity for managing the desktop image
- The PC replacement cycle is extended from 2-3 years to 5-6 years or more
- Existing desktops include multiple monitors, bidirectional audio/video, video streaming, USB port supports, etc.
- Company employees can access their virtual desktops from any PC, including a PC in the employee's home
- Resources tailored to desktop needs
- Multiple desktops on demand
- Free provision of desktop computers (controlled by the policies of each corporation)

4.1. Review of the desktop virtualisation industry

According to Gartner Inc., the market for server-hosted virtual desktops (HVD) will rise to 49 million units in 2013, compared with just over 500,000 units in 2009]. The sector's global revenue will increase from around $1.3 billion to $1.5 billion in 2009, which corresponds to less than 1% of the professional PC market worldwide. The Gartner report "Emerging Technology Analysis: Hosted Virtual Desktops" also indicated that although company spending on hardware will fall, companies will require more servers, bandwidth and software to support new architectures.

The report also estimated that approximately 15% of current professionals worldwide will switch from traditional PCs to HVDs in 2014, equivalent to about 66 billion connected devices, and the U.S.A. will double the worldwide average, with over 18 million connected devices. Following an initially slow start, the HVD market is predicted to experience rapid growth in the immediate future.

Despite the new enhancements to performance and management capacity initially predicted for HVDs, the current economic recession has inhibited adoption of these systems in the short term because they require large initial investments in network and server infrastructures. Due to on-going budget cuts, a delay is expected in the initially envisaged implementation of HVDs.

5. VDI technology in the public sector [9] [16]

As large-scale consumers of information and communication technology, public authority institutions possess great potential for contributing towards a reduction in greenhouse gas emissions. It should be borne in mind that the relative weight of ICTs in the carbon footprint of governments is considerably higher than the 2% of global emissions they represent.

[9] *Study on cloud computing in the public sector in Spain* Spanish National Institute of Communication Technologies, July 2012. Study funded as part of the SERPLAGO project (cloud platform services for e-government and e-administration processes), funded by the 2011 INNPACTO sub-programme of the 2008-2011 National Plan of the Spanish Ministry of Economy and Competitiveness, and co-financed by the EU ERDF programme.

5.1. Knowledge about cloud computing in the Spanish public sector

Recently, Spain has undergone a transformation in its economic model and its position as regards the new technologies. Despite this, only 56.2% of public authority institutions have reported understanding the concept of cloud computing to a greater or lesser extent (15.6% claimed an in-depth knowledge and 40.6% had heard of it, but did not feel that they mastered it). Meanwhile, 43.8% of public bodies stated that they knew nothing about cloud computing

Base: Total public authority entities contacted (n=889).

In short, over 50% of Spanish public authority institutions knew about cloud computing, but only 15% claimed to have an in-depth knowledge.

Furthermore, there was greater awareness among state-level institutions than among the regional and local authorities.

An analysis by segment revealed that 91.5% of state-level public authority institutions knew about cloud computing (whether in depth or not), compared to 75.5% of regional bodies and 43.4% of local entities.

In addition to possessing a higher overall level of knowledge, state-level institutions also possessed a more in-depth understanding than their counterparts in regional and local areas. Thus, 53% of state government bodies claimed to have a thorough knowledge of cloud computing (compared with 38.5% who reported having a superficial knowledge), whereas at regional and local level, only 20% and 11.8 %, respectively, considered that they had an in-depth knowledge of this technology. A high proportion of regional and local authorities claimed to have a superficial knowledge of the cloud: 55.5% and 31.6%, respectively.

Knowledge of cloud computing, by public authority segment (%)

Base: Total public authority entities contacted (Local n=593, Regional n=179, State n=117)

5.2. Adoption of cloud computing

In general terms, Spanish public authority institutions make little use of cloud computing. Although 33.4% currently use some kind of cloud computing ICT service, 66.6% have not yet opted to incorporate a service of this kind in their systems map. Base: Total public authority entities contacted (n=500).

It is the local authorities that are the most active in incorporating cloud computing format solutions, with a proportion of 34.2%. The lower financial and resources capacity of many local authorities, and the development of cloud solutions and applications for municipal bodies by other, larger scale public administration institutions or the Spanish ICT industry itself, may help explain this result. Thanks to the infrastructures and applications that the regional or state authorities have offered to the local authorities in Spain in recent years, through programmes such as *Avanza Local* (Local Progress), many Spanish municipalities now use a considerable amount of ICT services and applications that are provided remotely in service mode. At regional level, the adoption rate is 28.7%, whilst at state level it is 23.4%.
Base: Total public authority entities contacted (Local n=257, Regional n=136, State n=107)

As regards the use of software solutions, not necessarily in the cloud, the rate of use from high to low is as follows:

Storage: technological resources offered by providers, the function of which is to store client data in their databases, 75.5%.

Email: a computer programme that allows clients to manage electronic mail (writing, sending, receiving, storing, organising, etc.), 74.1%.

Computing: computing resources offered by providers (computing capacity on provider's servers), 65.4%.

Backup: technological resources that allow temporary storage of client information, for recovery in the event of loss, 59.8%.

Office applications: collection of applications that enable clients to create, modify, organise, scan, print, etc., files and documents, 46.4%.

Virtual desktops: technology that enables clients to work on a computer using their desktop, from a terminal located elsewhere, 40.4%.

Database management systems (DBMS): systems used for storage and organisation of public authority data, 38.1%.

Collaborative tools: systems that provide access to certain services that enable clients to communicate and work together whether or not they are located in the same physical location, 34.2%.

Content Creation and Control (CCC): computer systems that enable the creation and management of content (text, images, video, etc.) and provide the option of sharing this content among members of a team, 33.6%.

Managed File Transfer (MFT): software that facilitates the secure transfer of data from one computer to another over a network, 32.1%.

Customer Relationship Management (CRM): software tools for integrated management of customer or citizen information, 28.3%.

Enterprise Resource Planning (ERP): set of tools which provide integrated management of processes and information corresponding to different business areas, 25.5%.

Application Lifecycle Management (ALM): process of managing the lifecycle of a software application through governance, development and maintenance of the same, 18.2%.

Project Portfolio Management (PPM): a process which incorporates analysis and collective management of a group of ongoing, envisaged or imposed projects, and **Supply Chain Management** (SCM): application of tools for improving and automating supply by controlling stock, delivery times and other aspects, 7.6%.

Base: Public authority users of cloud computing (n=152).

5.3. Reasons for adoption

Of all the reasons given for contracting cloud computing services, the most frequently cited was the saving such services represented in terms of the costs and time involved in the management of technology resources.

Ease of implementation and use, improved productivity and interoperability options were the other reasons mentioned.

Saving time managing IT resources	69,5%
IT resources management costs savings	68,4%
Improves productivity	55,5%
Simplicity systems usage	52,8%
Greater interoperability administrations	52,4%
Simplicity implantation systems	51,6%
Promotion e-Government	50%
Expansion of services	43,2%
Open government and greater participation	31,6%
Changing internal management models	25%
Internal staff reorganization	10%
Other	8,9%
The reasons are unknown	8,1%

Table 3. Reasons that influenced the decision to contract a cloud computing service (%)

Base: Public authority users of cloud computing (n=152)

5.4. Global benefits derived from use

Savings in time and costs are the main positive effects of cloud computing, followed by expansion of the services offered by the organisation and improvements in overall productivity.

	Quite/ Completely	Normal	Little/ Nothing	NS/NC
Saving time	66.5%	18.7%	14%	Rest
Saving costs	53.7%	30.0%	15.4%	Rest
Expansion of services offered by the agency	51.2%	12.8%	35.2%	Rest
Improving the overall productivity of the organism	47.2%	23.5%	21.7%	Rest
Changing models from internal management	23.5%	16.9%	58.2%	Rest
Promoting e-Government	23%	10.9%	63.9%	Rest
Promoting interoperability and cooperation between administrations	12.2%	19.5%	66.8%	Rest
Reorganization of internal staff	9.3%	11.3%	78%	Rest

Table 4. Degree to which the effects associated with the adoption of cloud computing have been of benefit to the public authority entity (%). Base: Public authority users of cloud computing (n=152)

5.5. Fulfilment of expectations and intention to continue using cloud computing systems

Three out of four public authority institutions, representing 75.8%, reported that cloud computing had fulfilled their expectations, and an additional 9.4% considered that their expectations had been exceeded. Only 6.4% of public authority bodies considered that the results fell below their initial expectations, whilst 8.4% did not know or gave no answer.

State and regional authorities were the most satisfied as regards considering that their expectations of cloud computing had been fulfilled

Fulfilment of initial expectations regarding cloud computing (%). Base: Public authority users of cloud computing (n=152)

Local administration	75%
Autonomic administration	82,1%
State Administration	88%

Table 5. Fulfilment of initial expectations of cloud computing, by public authority segment (%).

Base: Public authority users of cloud computing (Local n=88, Regional n=39, State n=25).

As regards intention to continue using cloud computing systems, 94.5% of public authority institutions using some kind of cloud service intended to continue using it in the future. Only 0.2% of public authority bodies reported that they would discontinue their current cloud computing use in the future, whilst 5.3% were undecided

This finding demonstrates the general satisfaction associated with the use of cloud technology.

Stated intention to continue using currently adopted cloud computing services in the future (%)

Base: Public authority users of cloud computing (n=152)

6. FI4VDI-SUDOE project

6.1. Objectives

The aim of the FI4VDI project was to develop a federated infrastructure network for the generation of virtual desktop services, and to promote sustainable development by leveraging the benefits deriving from transnational cooperation.

In brief, the project proposed the creation of a private cloud infrastructure using the resources available in various supercomputing centres located in different SUDOE regions, with the goal of ensuring protection of users' data and compliance with regulations pertaining to information security and the service-level agreements established. Implementation of this service would entail improved competitiveness and cost savings in the sectors targeted, where energy savings and efficiency are a distinguishing feature.

The problem addressed by the project was the need to determine the position and perception of public and private entities located in the SUDOE Space as regards the desirability of virtualisation of IT operating environments, and to promote the spread of cloud computing as a means to achieve savings, efficiency and simplicity with the primary objective of ensuring improved productivity.

Origin of the project: The provision of cloud computing services by supercomputing centres has a positive effect on **ecological footprints**; dependence on physical ICT infrastructures is reduced when these are replaced by virtual ones, and this in turn produces a **marked reduction in energy consumption in these institutions**.

Project objectives and results: With a federated cloud computing model, desktops can be connected to dedicated servers with high rates of effective utilisation, greatly increasing energy efficiency and reducing the carbon footprint associated with the service.

Project strategy and structure:

Task group 0. Preparation
Task group 1. Project coordination and management
Task group 2. Technical infrastructure development
Task group 3. Adapting applications to the cloud environment
Task group 4. Integration. Prototypes.
Task group 5. Project monitoring and evaluation
Task group 6. Publicity and information. Market capitalisation

6.2. Description of the technical task groups

Technical infrastructure development.

Design of a federated cloud infrastructure capable of providing the selected applications.

Actions focused on definition, implementation and deployment of the system architecture, considering the hardware and software of the different cloud servers as well as the most suitable middleware to interrelate it all.

Adapting applications to the Cloud environment.

Selection of different applications and environments.

Implementation of a federated infrastructure, optimising the resources and efficiency of the processes involved.

Adaptation focused not solely on computing implementation and functionality, but also on modelling functional paradigms and services that respond to the growing needs of these environments.

Integration. Prototypes.

Each of these involved the following actions:

- Prototype design
- Integration of prototypes into the federated infrastructure
- Functional implementation
- Validation
- Battery of functional tests
- Stress tests
- User training

- Dissemination and value enhancement

Performance indicators related to the ecological paradigm:

- R & D projects that provide improvements from an environmental perspective (No.)
- Degree of productivity enhancement
- Degree of fulfilment of expectations
- Cloud computing adoption rate
- Degree of cost savings in resource management

6.3. Results

Creation of a Platform as a Service (PaaS) for mass deployment of virtual desktops.

Federation of the participant supercomputing centres' infrastructures.

Creation of an innovative cloud computing service aimed at users in the public and private sectors.

Enhanced competitiveness and cost savings in the sectors targeted by the service created.

Establishment of strategic recommendations: definition of reliable models for cloud computing (service levels, system capacity, system restoration, interoperability through shared service infrastructures, migration models), identification of service areas and evaluate and promotion of cloud computing as a tool for achieving cost savings and technological optimisation.

Establishment of technological recommendations: identification of existing solutions and possibilities, assessment of the real capacity of suppliers, selection of an applications and systems map, initiation of a cloud computing strategy by adopting private clouds and infrastructure and platform services, establishment of system migration plans and identification of cloud computing as a model that fosters other technologies which are either emerging or in the process of expansion, such as energy sustainability in the area of IT or open source solutions.

Establishment of management recommendations: definition of systems for assessing investment returns, analysis of organisational impact and identification of change management models, development of new contracting models and practices, standardisation and organisation of common services and definition of risk analysis models.

Results of the project Control energy efficiency in HPC environments from implementation project Integrated Monitoring Data Processing Center of FCSCL:

(1) **Reducing consumption**: 29% reduction in electricity consumption during the first five months of 2013 compared to the same period last year. In this period the vacancy rate was 100%, the actions taken have not increased risks.

(2) **Reducing emissions**: in the first months of 2013 reduced 44,750 tonnes of CO2eq, which represents an annual saving of 106,729 tonnes of CO2eq.

7. Conclusions

The spread of cloud computing in the Spanish public sector is still limited, and is more common among local authorities than among regional and state institutions.

In general, the most common mode of deployment is private.

Savings, efficiency and simplicity are the reasons that have prompted public authority institutions to contract cloud computing services.

Those public institutions that decided to adopt cloud computing did so after carrying out a legal analysis focused primarily on data protection legislation.

According to the public authority bodies that have adopted cloud computing, the principle benefits of this model are the savings in costs and time it represents, whilst integrity of services and data was identified as the main difficulty.

The Spanish public sector perceived the cloud as a technological and, above all, operational advantage which has met their initial expectations regarding cloud computing.

Among the public authority bodies already using cloud computing, the future prospects are very bright: they intended to continue working in the cloud, they would recommend this technology to other institutions and they expected to continue to obtain future benefits from using the cloud.

However, those public institutions that are not yet using the cloud were more wary: few intended to incorporate technological solutions, and only a minority of these would consider cloud computing.

Acknowledgement

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Ref. SOE4/P3/E804-FI4VDI

Figure 5. Project FI4VDI-SUDOE Corporate Logo

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