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Final report from the JISC Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education

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Executive Summary

Cloud computing – where elastic computing resources are delivered over the Internet by external service providers – is generating significant interest within HE and FE. In the cloud computing business model, organisations or individuals contract with a cloud computing service provider on a pay-per-use basis to access data centres, application software or web services from any location. This provides an elasticity of provision which the customer can scale up or down to meet demand. This form of utility computing potentially opens up a new paradigm in the provision of IT to support administrative and educational functions within HE and FE. Further, the economies of scale and increasingly energy efficient data centre technologies which underpin cloud services means that cloud solutions may also have a positive impact on carbon footprints. In response to the growing interest in cloud computing within UK HE and FE, JISC commissioned the University of Strathclyde to undertake a *Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education* [19].

The objectives of the review were: to review the current evidence for the environmental costs and benefits of cloud computing; to review the organisational and environmental implications of cloud computing for institutional activities outside the research area; to review the changes to institutional governance, policies, procedures and skills required by adoption of cloud computing; and to make recommendations to the JISC for further areas for development. This was achieved using a four-stage approach consisting of (i) a literature survey and activity review of current activity relating to cloud computing within the sector; (ii) a PESTLE analysis to explore the political, economic, social, technological, legal and environmental factors which will influence uptake of cloud computing within the sector; (iii) the development of four scenarios of near-future use of cloud computing within the sector; and (iv) a cost, benefit and risk analysis of adopting cloud computing. This last stage also included development of some high-level advice and guidance for institutional and IT managers relating to environmental impact and changes to governance, policies, procedures and skills sets.

The findings from the activity review concur with recent JISC surveys of the use of and attitudes to ICT within the sector [20-21]. Typically institutions show a great deal of interest in cloud computing although there is a range of levels of involvement. The most common current use of cloud is for email followed by storage, web services and virtual learning environments. The most common reason for uptake was the provision of a better service, followed in descending order by a reduction in costs, better collaboration and a reduction of hardware overheads as part of a green IT strategy. Despite this considerable interest and more limited use, the review revealed that few institutions have formal policies on adoption or use of cloud computing. While there was a general consensus that the use of cloud computing would lead to lower energy use, there was some cynicism about the actual 'greenness' of cloud computing. The most common concerns related to jurisdiction issues, uptime of services, security of services, lock-in and the strength of service level agreements (SLAs). Lack of trust in commercial cloud services was also raised with some respondents favouring more focused regional or academic clouds. Finally, respondents felt that if true efficiency benefits were to be realised, a centrally managed approach to contracting cloud computing services as part of an overarching institutional information systems strategy was required.

Looking to the future, the PESTLE analysis identified a wide variety of political, economic, social, technological, legal and environmental factors that are likely to affect the sector over the next five

years. The main drivers are economic, relating to the reduction in funding and the need to increase competitiveness through better student and staff experiences. The need to replace aging institutional infrastructures is also a timely influence as is the increasing emphasis on greening ICT. Significant barriers, however, do and will continue to exist. Not least are socio-cultural issues relating to perceived, but not necessarily well-founded, risks associated with cloud computing. In particular, an assumption that the security of data and applications in the cloud is more likely to be compromised than with in-house storage, concern over jurisdiction and privacy of data, and a worry that commercial cloud providers do not sufficiently understand the business requirements of HE and FE are each likely to negatively impact the uptake of cloud computing for core institutional services. However, two key unknowns remain - the impact that the new government will have on the education sector is unclear, as is the impact of the current trend for institutional restructuring.

Four near-future scenarios of the use of cloud computing in HE and FE were developed. In the *Cloud Workspace* scenario institutions contract with commercial cloud providers to offer a range of institutionally branded cloud-based communication, collaboration and productivity tools to their students and staff. In the *Large-Scale Cloud Storage* scenario, institutions move their educational resource repositories, institutional repositories, institutional archives, corporate datasets, data backup, archiving and disaster recovery, and research datasets into the cloud. This may be achieved through simple hosting of repositories, block storage solutions or a multi-tenancy cloud storage solution where the data is access through sophisticated APIs. In the *Cloud-Enabled Learning Environments* scenario two types of cloud-based learning environments can be expected initially, cloud hosted institutional Virtual Learning Environments (VLEs) and Personal Learning Environments (PLEs). While hosted VLEs will be contracted out by the institution, PLEs will be constructed by individual learners from a variety of communication, collaboration, productivity and pedagogical tools available in the cloud or on their desktop. In time, hybrid 'Cloud' Learning Environments may evolve, where the loci of control moves away from institutions to a partnership model where both academics and learners can equally share choice and control of the learning environment through cloud-based services. In the final scenario, *Academic Clouds* are introduced to counteract concerns regarding privacy, security and understanding of the academic sector needs. There are three forms – *public academic cloud*, *private academic cloud* and *private institutional cloud*. In the public academic cloud, the cloud infrastructure is accessible to the academic sector only, although it is built from publicly available cloud services, while in the private academic cloud, the computer processors, data centres and networking applications are based solely within the JANET network. In contrast, in the private institutional cloud, an individual institution fashions its own internal IT provision on the flexible utility based infrastructure used by the commercial cloud providers. Of these three forms of academic cloud, it is the public academic cloud that offers the most advantages.

Given the early stage of adoption and limited scope of cloud computing within the academic sector, it is too early to determine exactly what advice or guidance is required in the longer term. Rather, the report brings together the lessons learned from the review by focussing the advice and guidance on how to explore the costs, benefits and implications – i.e. the business case – of adopting cloud within individual institutional contexts.

Finally, four areas of future work are recommended: (1) JISC continues to review the use and potential use of cloud computing in line with its ongoing sector monitoring and horizon scanning. This should include a review of early adopters of cloud computing; (2) an investigation of the legal

issues surrounding cloud computing be commissioned, covering the possibility of joint negotiation and the development of SLA templates appropriate for HE and FE institutions; (3) JISC commission a set of bolder, more extreme scenarios which explore how, in the next 20 years, the emerging cloud computing paradigm and related technologies might significantly change how HE and FE institutions undertake teaching and learning, research, business community engagement and administrative activities; (4) JISC investigate how cloud computing can best be exploited in order to make institutional processes and data more green and produce an overall reduction in carbon footprint.

Table of Contents

Acknowledgments.....	3
Executive Summary.....	4
1 Background and Overview	9
1.1 Background	9
1.2 Aims and Objectives of the Review.....	10
1.3 The Approach Adopted	10
1.4 Scope and Contents of the Report.....	11
2 Cloud Computing in HE and FE	12
2.1 History.....	12
2.2 Definitions and Variations.....	13
2.3 Models of Use	15
2.4 Activity Within HE and FE.....	17
3 PESTLE Analysis of the Uptake of Cloud Computing within HE and FE.....	19
3.1 Political Influences	19
3.2 Economic Influences	20
3.3 Social Influences.....	22
3.4 Technological Influences.....	23
3.5 Legal Influences.....	24
3.6 Environmental Influences	26
3.7 Reflections on the PESTLE Analysis.....	27
4 Scenarios for Use of Cloud Computing within HE and FE	29
4.1 The Cloud Workspace	29
4.2 Large-Scale Cloud Storage.....	31
4.3 Cloud-enabled Learning Environments.....	33
4.4 Academic Clouds	35
4.5 Reflections on the Service Scenarios	37
5 Advice and Guidance on Cloud Computing	39
5.1 Drivers	40
5.2 Costs.....	42
5.3 Benefits	43
5.4 Issues.....	45
5.5 Risks	48

6	Conclusions, Implications and Recommendations	51
6.1	Conclusions	51
6.2	Implications of Cloud Computing for Institutional Activities outside the Research Area	53
6.3	Recommendations for Future Work	54
	Appendix A: References	57
	Appendix B: Technical Glossary	64
	Appendix C: Survey Findings	65

1 Background and Overview

1.1 Background

Cloud computing – where computing resources are delivered over the Internet by external service providers – is becoming increasingly prominent with Google, Amazon and Microsoft offering varying services. In the cloud computing business model, organisations or individuals contract with a cloud computing service provider to access data centres, application software or web services from any location. As JISC's ITTs relating to cloud computing [22-24] note, there is already significant interest within HE and FE regarding the potential of cloud computing to support education, research and administrative activities. For example, Google Docs is used by many research teams for collaboration and Amazon's shared services are used by Oxford University's Malaria Atlas project to store and analyse data [25]. Further, as JISC's briefing paper on email outsourcing [26] and the project team's recent JISC-funded Greening Information Management project [27] highlight, there is significant interest from the community in the provision of institutional email through cloud computing services provided by Google and Microsoft. Cloud computing also enables specialised software and applications that were previously too costly to be made available for teaching. Similarly, cloud virtual servers enable simulations or data processing that cannot currently be supported by institutional hardware. Finally, many cloud providers offer Web Service interfaces that allow applications to be built, which seamlessly and invisibly integrate a range of subservices from different cloud providers.

This interest from institutions has arisen because, as JISC recognised in commissioning this review, cloud computing offers many advantages over more traditional institutionally hosted and managed computing services. For example, as it is based on scalable and elastic external services which may support usage by a range of organisations and individuals, cloud computing offers significant efficiency and cost savings through economies of scale. Further, the scale of these services means that they can be based on high-specification data centres with the latest cooling systems and service optimisation techniques, which individual institutions are unlikely to be able to afford. As the Greening Information Management project has recently investigated, this coalescing of storage, virtualisation and optimisation also brings the potential for significant reduction in the embedded and consumption energies associated with data usage [28]. This is increasingly likely to be of significant interest to institutions as they seek to reduce the environmental impact of their ICT usage in line with Government and funding councils' carbon reduction policies.

While the exploration of educational applications of cloud computing is already underway [29-30], commercial cloud services also open up the potential for a new paradigm in the provision of administrative computing. Of particular interest is the elasticity of services which could allow institutions to contract in spare capacity in times of peak demand such as clearing or student enrolment. As well as delivering a more reliable service due to the in-built redundancy, this also potentially affords significant financial savings as costs are based on actual usage rather than peak capacity required. However, the implications of storing personal and sensitive business data on external services need to be explored. For example, should certain data remain internal to institutions? Are there appropriate loss of service penalty clauses? Is there a danger of becoming locked into one service provider? More generally, the business continuity implications, new shared services models, Service Level Agreements (SLAs), governance requirements and potential competitive advantages for institutions need to be explored.

While cloud computing offers many potential advantages, the impact for HE institutions is yet to be investigated. Like the current move towards Web 2.0, the introduction of such ‘utility-based’ computing will have significant impact on the existing ICT service provision and support within institutions. For example, the need for support and management of storage arrays or application servers within institutions and the associated staff roles may disappear. However, new support implications will emerge – e.g. supporting staff using externally provided services and management of cloud services provider relations. As the project team’s JISC-funded Work-with-IT project [31], examining the evolution of working practices, has found, such changes in technology can significantly impact upon staff, affecting attitudes and efficiencies where not well-managed. Significant change management needs to be undertaken to ensure that staff have the correct skills and confidence to work effectively in the new technological environment and that holistic organisational strategies, policies and procedures are developed to support them in new ways of working.

In response to the growing interest in cloud computing within UK HE and FE, JISC commissioned the University of Strathclyde to undertake a *Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education* [19]. This was complemented by two sister reviews – a *Technical Review of Cloud Computing for Research* [32] and *Using Cloud Computing for Research* [33].

1.2 Aims and Objectives of the Review

The aim of this review was to explore the environmental and organisational implications of the move to cloud computing. Specific objectives were:

- To review the current evidence for the environmental costs and benefits of cloud computing;
- To review the implications of cloud computing for institutional activities outside the research area;
- To review the changes to institutional governance, policies, procedures and skills required by adoption of cloud computing;
- To make recommendations to the JISC for further areas for development.

1.3 The Approach Adopted

The project began with an orientation phase consisting of desk research, establishing contact with key stakeholders and conducting stakeholder interviews. A survey and activity review was then conducted in order to survey the range of cloud computing activities already used within HE and FE, the institutional implications of these activities, the assessment of associated environmental and institutional impact and areas where further advice and guidance is required. The survey and activity review targeted institutional ICT managers, administration managers, e-Learning managers, financial directors and estates managers by contacting JISC Announce, JISC RSC’s and sector professional bodies (including Association of University Administrators (AUA), Association of University Directors of Estates (AUDE), British Universities Finance Directors Group (BUFDG), Scottish Association of University Directors of Estates (SAUDE), Society of College National and University Libraries (SCONUL), Universities and Colleges Information Systems Association (UCISA)). In total, sixteen stakeholders from HE and FE were interviewed. The interviews consisted of a set of survey questions to assess the current cloud computing activity followed by more open-ended questions designed to

illuminate the implications of current activity and gaps in knowledge. While no firm conclusions can be inferred about the sector as a whole, these activity review interviews provide an indicative picture of current activity and trends.

The survey and activity review were complemented by a facilitated workshop which explored the PESTLE (political, economic, social, technological, legal and environmental) issues surrounding cloud computing within HE and FE. Having identified and prioritised the key PESTLE issues the workshop then focused on exploring their implications. Group A discussed how environmental impact might best be maximised and assessed, and how 'ownership' of carbon accounting might be achieved. Group B identified and discussed the potential institutional implications of cloud computing, including types of provision, educational and business functions that could be supported and likely risks.

Leading sector experts and key institutional managers were then invited to attend a 'scenarios' workshop, which explored the likely demand and uptake of non-research cloud computing within the sector. This was achieved through the exploration of potential services scenarios of applications of cloud computing to support the non-research needs of institutions, the barriers and enablers to their uptake, the implications of these services for institutional policies and for staff, and the business case(s) for the service scenarios.

Areas where high-level guidance is required were then identified from the activity review, although the workshops also informed this process. As most HE and FE institutions are only beginning to investigate the potential of cloud computing in their own contexts, and most adoption to date has been for low risk, non-core services, it was deemed most appropriate to give guidance that allows institutions to investigate the business case for cloud within their own contexts. Finally, drawing on the issues identified in the course of all project work carried out, recommendations have been scoped to advise JISC on potential further work in this area.

1.4 Scope and Contents of the Report

This report presents the findings from the JISC-funded a *Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education* [34].

This report proceeds as follows. In Section 2, cloud computing and its use in the HE and FE sectors is examined. This is followed by a full PESTLE Analysis in Section 3 which details the political, economic, social, technological, legal and environmental factors affecting the uptake of cloud computing within HE and FE. Section 4 explores the potential future use of cloud computing in HE and FE by presenting a series of scenarios that institutions can review and reflect upon in their own contexts. Section 5 contains high-level advice and guidance to allow institutions to investigate the potential business case for adopting cloud computing, taking into account the associated costs, benefits, issues and risks. Finally, Section 6 summarises the conclusions drawn from the review, outlining the implications of the findings and highlighting a series of recommendations for future work. Three appendices are included – References (A), a Technical Glossary (B) and Survey Findings (C).

2 Cloud Computing in HE and FE

While cloud computing is presented by service providers and some industry commentators as a radically new way of delivering high quality and cost-effective IT services, the term cloud computing is not without controversy. In order to clear ambiguity surrounding the term *cloud computing* for HE and FE, the literature review began with a brief study of the history leading up to the emergence of the cloud computing phenomenon which is presented below. This is followed by a discussion of the range of definitions, including the NIST definition of cloud computing, which was adopted by the project team. General models of the use of cloud computing are then briefly presented. The section ends with a summary of the range of current activity revealed by the activity review.

2.1 History

Cloud computing has its roots in the ideas of networked computing where computers are clustered together to increase capacity and resilience. Subsequent developments such as grid and utility computing, Application Service Provision (ASP), and Software as a Service (SaaS) have all influenced the more recent emergence of cloud computing [35]. Academia was particularly influential in driving grid computing forward. In grid computing [36] multiple independent clusters spread across the Internet can be called on as required, akin to plugging into utility services such as the electricity grid. This led to development of distributed grid services such as GridPP [37] where software is used to distribute processes across many potentially heterogeneous and widely geographically distributed computers in parallel. While significant use of grid computing has been made in certain areas of academia, little use has been made within the commercial sector or within HE and FE corporate systems. Lack of uptake can be attributed to the fact that organisations would, in effect, be migrating their applications and data to a third party solution which, given the inherently distributed nature of grid applications and data, are geographically spread [38]. For commercial organisations this reliance on third parties to ensure data security and service levels appropriate to business needs in a distributed environment proved a significant stumbling block.

By contrast, cloud computing has developed primarily from within the commercial sector. Mohamed [35] traces the provision of cloud computing services back to Salesforce.com [39] who, in 1999, pioneered a service that delivered enterprise applications via a simple website. Amazon became the first big player to offer cloud-based services in 2002 when after upgrading their infrastructure, they realised they had a great deal of spare capacity [35]. So Amazon Web Services [40] was born and subsequently in 2006 Amazon launched its Elastic Compute Cloud (EC2) service [41]. While these services are provided by a third party, they differ from grid computing services in that they are offered through large data centres rather than being dispersed throughout the Internet. Thus, in general, cloud computing actually constitutes a centralisation of computer processing in terms of geographic location, although the services are provided in real time over the Internet. For commercial organisations, already familiar with large in-house data centres, migration to such pay-per-use utility computing services based on large but remote data centres has proven more acceptable.

The rise of virtualisation, where many individual physical servers are accommodated onto a much smaller number of virtual servers [42], has also proved to be a key enabler in the emergence of cloud computing. Virtualisation has allowed huge storage and processing capacity to be concentrated in

server farms and has also allowed for the sharing of the physical resources (e.g. processing and storage). Individual users of cloud-based services may share physical servers but use different virtual servers or virtual machines, thus keeping their details separate and private. The use of virtual machines also enables the rapid scalability of resources which is an essential characteristic of cloud computing [8]. Although the roots of virtualisation are in 1960s mainframes [43] this current form is less than ten years old.

The emergence of ‘killer apps’ such as Google’s Google apps [44] and Gmail [45] and Microsoft Dynamics [46] are further expanding the uptake of cloud-based services to companies, institutions and individuals. It is this emergence of killer apps combined with more business oriented services with high levels of reliability and data security which potentially offer new means of providing scalable, secure and reliable corporate and educational applications for HE and FE.

2.2 Definitions and Variations

While the literature and IT industry forums confirm that cloud computing is currently a hot topic, as Armbrust et al [8] note in their report *Above the Clouds: A Berkeley View of cloud Computing*, there is a great deal of confusion about exactly what it is. According to Geelan’s [47] comparison of industry experts’ definitions, the definitions all vary; however, he identified scalability or elasticity, virtualisation and on-demand computing as common features attributed to cloud computing. Armbrust et al go as far as to say that as a research group, they are unable to agree on exactly what cloud computing is, although they do highlight three features that they believe makes cloud computing new:

- The illusion of infinite computing resources available on demand, thereby eliminating the need for Cloud Computing users to plan far ahead for provisioning;
- the elimination of an up-front commitment by Cloud users, thereby allowing companies to start small and increase hardware resources only when there is an increase in their needs; and
- the ability to pay for use of computing resources on a short-term basis as needed (e.g., processors by the hour and storage by the day) and release them as needed, thereby rewarding conservation by letting machines and storage go when they are no longer useful.

From *Above the Clouds: A Berkeley View of Cloud Computing* [8].

There is some cynicism relating to the term *cloud computing* and Larry Ellison, Oracle CEO, notes that much of the confusion arises from the term being used to re-badge (and encourage the sale of) a wide range of services [48].

Comparing different definitions of cloud computing, there is alignment between definitions from the National Institute of Standards and Technology (NIST) [49], JISC CETIS [30], and Gartner Inc [50], whereby key features of cloud have been identified as on-demand, broadly accessible, using pooled resources, elastic and metered, and paid for according to use.

In accordance with the two sister reviews funded by JISC into cloud computing [32-33], this review of the environmental and organisational implications of cloud computing used the following definition of cloud computing from NIST [49]:

“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**.”

Essential characteristics: On-demand self-service, broad network access, resource pooling, rapid elasticity, measured service.

Service models: Software as a Service (SaaS); Platform as a Service (PaaS); Infrastructure as a Service (IaaS);.

Deployment models: Private Cloud; Community Cloud; Public Cloud; Hybrid Cloud.

The essential characteristics that NIST associate with cloud computing are expanded below.

Essential Characteristics

On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service’s provider.

Broad network access: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g. mobile phones, laptops, and PDAs).

Resource pooling: The provider’s computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or data centre). Examples of resources include storage, processing, memory, network bandwidth and virtual machines.

Rapid elasticity: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale up capacity. The capabilities can then be rapidly released when additional capacity is no longer required. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

Measured service: Cloud systems automatically control and optimise resource use by leveraging a metering capability at a level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported on, providing transparency for both the provider and consumer of the service utilised.

2.3 Models of Use

The service models and deployment models generally associated with cloud computing are expanded below.

Service Models

The wide range of cloud computing services on offer can be divided into four categories [51] that include three service models (IaaS, PaaS, SaaS) defined by Mell and Grance [49] plus a category for services that don't easily fall under infrastructure, platform or application:

- Applications – Software as a Service (SaaS)
- Platform – Platform as a Service (PaaS)
- Infrastructure – Infrastructure as a Service (IaaS)
- Services – general services not IaaS, PaaS or SaaS

The descriptions of each of these service models below are followed by examples of these services derived from a snapshot of cloud computing services established in May 2009 [51]. The examples are further divided into useful categories taken from Peter Laird's Cloud Vendor Taxonomy [51].

Software as a Service (SaaS): In this service model the capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, and application capabilities. An exception might be for limited user-specific application configuration settings, however the consumer does not have responsibility for maintaining applications.

There is a huge range of SaaS applications available including Google Apps [44], Netsuite [52] and Concur [53]. Some level of customisation is usually possible e.g. user-specific configuration settings such as display and accessibility options.

Platform as a Service (PaaS): In this model the capability provided is to deploy consumer-created or acquired applications onto the cloud infrastructure created using programming languages and tools supported by the cloud provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage. They will have control over the deployed applications and possibly application hosting environment configurations.

There are business user platforms and developer platforms which differ in the way applications are developed. In business user platforms non-programmers will develop applications using visual tools without the ability to use custom code. On developer platforms, developers are free to code applications using their own programming code. Current business platforms include: Caspio [54], Intuit QuickBase [55] and WorkXpress [56] and developer platforms include Google App Engine [57], Apprenda SaaSGrid [58] and Salesforce.com force.com [39].

Infrastructure as a Service (IaaS): In this model the capability provided is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to

deploy and run arbitrary software, which may include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components, for example, the hosting of firewalls.

Cloud infrastructure can be broadly divided into public and private clouds (see the following subsection on cloud deployment models). Laird [51] includes other related infrastructure services including compute grids, data grids and virtualisation services. Cloud examples include public clouds such as Amazon EC2 [41], Microsoft Azure [59] and Rackspace Mosso Cloud [60], and private clouds such as Eucalyptus [61], Nimbus [62] and Enomaly [63].

Other Cloud Services: The main services currently offered which do not readily fit into SaaS, PaaS or IaaS models are storage, integration, metering and billing, security and fabric management. Cloud storage vendors offer hosted storage that is API accessible with current vendors including Amazon S3 [64], Google BigTable [65] and Microsoft SQL Data Services [66]. Integration solutions provide integration between multiple cloud applications or between cloud and non-cloud applications. Current vendors include Amazon SQS [67], Boomi [68] and Microsoft BizTalk Services [69]. Metering and billing are outsourced billing and invoicing solutions with vendors that include Aria [70], eVapt [71] and Vindicia [72]. Although cloud vendors will have a base level of security built in, there are vendors specialising in add-on services like encryption or single sign on capabilities (across multiple applications). Current vendors include Enstratus [73], Ping Identity [74] and Symplified [75]. Fabric management vendors help organisations manage and deploy their application in the cloud. Their services include server monitoring and auto scaling of server loads. Current vendors include 3Tera [76], Cloudkick [77] and Rightscale [78].

Deployment Models:

NIST split deployment methods into 4 types [49]:

Private Cloud: In this model the cloud infrastructure is operated solely for one organisation and managed by that organisation or by a third party. An example of private cloud software is Eucalyptus [61] and instances of private clouds are Hosts Unlimited [79] in the UK and NASA Nebula [80] and Rice University cloud [81] in the USA.

Community Cloud: The cloud infrastructure is shared by several organisations and supports a community that has shared interests. It can be managed by the organisations or by a third party, for example, the Google Government cloud in the USA [82].

Public Cloud: In this model the cloud infrastructure is available to the general public or a large industry group and is owned by a cloud vendor who sells the services. Amazon EC2 [41] is a prime example of a public cloud.

Hybrid Cloud: The hybrid cloud infrastructure is a composition of two or more clouds (private, community or public) that remain unique entities but are bound together by technology that enables data and application portability.

Cloud versus Web 2.0

Given the various definitions for both Web 2.0 [83] and cloud computing, it is often difficult and confusing to disentangle the two. Taking the NIST definition of cloud computing used for the purposes of this review [49], there is some crossover between the essential characteristics of cloud and those of Web 2.0 applications. Web 2.0 applications will fulfil some of the essential characteristics of cloud, for example - on-demand, self-service and broad network access, but not always the others - resource pooling, rapid elasticity and measured service. Web 2.0 applications are often collaborative, interactive, and tend to rely on user generated content such as blogs, wikis, tagging, social bookmarking, multimedia sharing, podcasts and RSS feeds [84]. These can often also be provided by cloud applications; for example, Google Apps [44] is a cloud application from Google which allows collaborative office applications (word processor etc.) accessible from a browser. Some cloud computing services (cloud applications) can also be Web 2.0 applications, for example, such as Google Apps. Many are not, however, such as developer platforms like Google App Engine [57] or Salesforce.com force.com [39].

2.4 Activity Within HE and FE

The JISC Key Audience Survey 2008/9 [20] reported that the use of cloud computing, at least at the institutional level, was relatively low, with most use relating to outsourcing of student email. The appetite for institutions to consider using cloud, however, appeared to be much higher. The Key Audience Survey also found that while awareness of cloud computing is fairly high, the depth of knowledge among head and senior ICT/network staff appears less so. The main obstacles that are reducing the uptake of cloud computing appear to derive from lack of information and clarity of the issues and implications of adopting cloud services. Interestingly, the survey revealed that the enthusiasm for institutions to consider using it appears much higher than its current actual use suggests. Lastly, the survey noted that it was not clear how much cloud computing was used on a more informal basis by staff within institutions, but that few institutions had any policy or guidance in place for staff [20]. The results of an earlier JISC Attitudinal Survey of Head and Senior Learning and Library staff in 2008 [21] indicated that usage of cloud computing in HE/FE libraries was very low, although there was considerable interest in its potential use.

The activity review conducted as part of this review complements the JISC's surveys, providing a more focused exploration of activities in 16 HE and FE institutions. Nine out of 16 institutional stakeholders interviewed indicated that their institution is using cloud computing at some level. It can be assumed that those who volunteered to be interviewed for the activity review already had an interest in cloud computing; therefore the activity review cannot be taken as a representative sample of the sector. However, the findings provide an informative snapshot of interest and use in HE and FE. A brief summary follows, with a full breakdown of the survey results from the Activity Review presented in Appendix C: Survey Findings.

Of the 16 institutions covered in the activity review, over half (10 in total) are using cloud computing at some level with 6 currently not using cloud computing services. Of the 6 institutions currently not using cloud computing, only 2 are not currently considering cloud services. The most common current use of cloud was for email (6 institutions), with the next most common cloud services being storage, web services and VLEs. The most common reason given for using cloud computing services was the provision of a better service, with 8 out of 10 cloud users citing this as their motivation. Cost

was the next most common reason given (6 of 10) followed by better collaboration (3 of 10) and a reduction of hardware overheads as part of a green IT strategy (3 of 10).

Regarding implications of the use of cloud computing, the general consensus was that the use of cloud computing would lead to lower energy use, less servers, energy savings from reduced need for cooling and lighting, and also reduced digital and physical storage requirements within the institution. However a few respondents were cynical about the 'greenness' of cloud computing and felt that energy consumption is simply shifted to the cloud rather than reduced. Further, some of the institutions represented by interview had not considered the environmental implications of cloud computing at all. The most common concerns relating to the use of cloud included jurisdiction issues, access to services (uptime), security of services, and the strength of SLAs. A number of respondents indicated local or regional private clouds tailored to HE and FE would be a more attractive prospect and would be trusted more than large commercial offerings.

A centrally managed approach within institutions for cloud computing services was favoured; it was felt that duplication and inefficiency could result if services are developed in isolation by different departments and/or faculties within an institution. With regards to evaluating the environmental impact of the use of cloud computing, power consumption and billing were reported as being handled at institutional level with difficulties expected if attempting to isolate the effects of decommissioning particular hardware equipment. Interoperability was cited as important in relation to allowing movement of institutional data between vendors if a change of vendor was required. There was a recognition that lock-in could be an issue, a concern also voiced in the literature [8, 85].

The trends, influences and issues relating to cloud computing, which were identified by the literature and activity reviews, fed into the PESTLE analysis of factors affecting the uptake of cloud computing in HE and FE. This analysis is presented in the next section.

3 PESTLE Analysis of the Uptake of Cloud Computing within HE and FE

Current industry marketing argues that cloud computing offers an effective, elastic and cost-effective way to meet the varying computing demands of organisations. While value for money is a key driver given the current economic climate, as discussed in section 2.1, the key issues relating to uptake of cloud computing within commercial organisations have been concerned with the reliance on third parties to ensure data security and service levels appropriate to business needs. Evidence from the activity review suggests similar concerns are currently concerning senior IT managers within HE and FE. However, as with any change, there are a number of competing factors that will influence particular institutions' choices. The PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis present below highlights the drivers and barriers which are likely to affect the uptake of cloud computing within HE and FE over the next 5 years.

3.1 Political Influences

Within HE and FE political influences typically include government directives, funding council policies, national and local organisations' requirements and institutional policy [86]. The PESTLE analysis identified three broad categories of political influences relating to cloud computing in HE and FE – government policies, institutional policies and JISC.

Government Policies

Government directives and funding council policies are not expected to directly affect the uptake of cloud computing within HE and FE. However, the development of the proposed private government cloud – G-Cloud [87] – may significantly influence the academic sector's uptake. G-Cloud represents the first large public-sector cloud project and given the poor track record of many large-scale public IT projects it will be watched carefully. If and when the G-Cloud is implemented, the hope is that it will provide a number of benefits including cost savings, improved agility, standardisation and consolidation, greener ICT, reduced commercial risk, and reuse (of applications) [88]. Successful implementation of the likes of G-Cloud is likely to provide practical evidence of the feasibility of using cloud computing to support key business applications within the non-commercial sector. However, whether a private academic cloud is the best solution is questionable and is discussed further in Section 4. It is also important to note that it is currently unclear how the change in government will affect either the G-Cloud or the policy directives to institutions.

Institutional Policies

Internal politics and institutional policies were identified as more immediate political influences. Interestingly, while some researchers and other non-IT staff suggested that IT departments would be firmly against any move towards cloud computing, the activity review and workshops revealed that IT Directors are increasingly examining the potential of cloud computing solutions as part of overarching information systems strategies. Indeed, the IT Director at Royal Holloway, University of London, reported that their IT strategy consisted of preparing for cloud computing models of service provision and compared the current set up to an internal cloud [89]. While the respondents were perhaps biased towards early adopters, current interest within the sector and JISC indicates a general trend. However, as senior IT staff reported, corporate systems owners such as registry or

finance managers are much more concerned about the potential risks and business impact that might arise from migrating corporate applications and data to a third party solution.

JISC

As is evidenced in other areas such as eLearning and Web 2.0 [90], timely and well chosen funding council and JISC initiatives can significantly influence sector uptake. The Shared Service and Cloud Computing Pilots [5] within JISC's *Flexible Service Delivery Programme* [91] and subsequent initiatives are expected to significantly influence sector uptake.

3.2 Economic Influences

The review highlighted that economic influences are the primary drivers for cloud computing in HE and FE. According to JISC infoNet [86], economic factors pertaining to HE and FE are likely to include funding mechanisms and streams, business and enterprise directives, internal funding models, budgetary restrictions, and income generation targets. The PESTLE analysis identified four broad categories of economic influences relating to cloud computing in HE and FE – economic downturn, cloud computing business models, institutional budgetary mechanisms and business community engagement.

Economic Downturn

As is already evident in England, the recent financial crisis will lead to reduced direct and indirect funding streams within the HE and FE sectors. As is already beginning to emerge, this is likely to lead to institutional restructuring, reductions in personnel, and a push to radically rethink aspects of how an institution works. For example, as a recent PESTLE review [92] carried out for the sector identified, institutions may increasingly move towards lean thinking approaches [93] – where the focus is on the prevention of unnecessary and ineffective activities or resources whilst adding value for the customer in a flexible and responsive way to sustain and improve organisational competitiveness. Thus, a reduction in funding streams combined with an increasing need to illustrate value for money is likely to drive many institutions to consider cloud computing within their overall information systems provision. For example, a move to replace an institutional email service by a free cloud-based solution such as Google's Gmail [45] or Live@edu from Microsoft [94] will result in a reduction in hardware and support costs. More generally, as utilising the cloud may allow for a reduction in investment in IT infrastructure and local support [95-96], cloud-based services should provide a leaner and cheaper alternative than the traditional institution-based computing services.

Increased competitiveness within the sector may also drive the uptake of cloud computing. Institutions may perceive a competitive advantage [97] in moving parts of their information systems and services to cloud services as it will enable them to provide a standard of service which they otherwise would not be able to afford due to lack of in-house staff or technology resources. Such cloud services have the added advantage that they can easily be adjusted as demand dictates, due to the flexibility and pay-as-you-go nature of cloud service provision.

The adoption of cloud computing may not necessarily result in cost savings. Instead, cloud services may be adopted to enhance resilience or to provide an elastic expansion of core capacity as and when required. For example, there are a number of processes within institutions, both in

administration and teaching, where extra computer processing or storage capacity may be periodically required. One example might be in clearing; another student workspace for practical classes or workshops. However, while the use of cloud computing can improve an institution's key services, it may result in additional costs. As respondents argued [98], this may actually mean that less cash rich institutions will be less likely to utilise cloud computing as it may be a 'nice to have' add-on.

Cloud Computing Business Models

The cloud computing services market and business models will also strongly affect uptake. For example, the provision of 'free' cloud services such as webmail from Google or Microsoft is leading to some FE institutions ceasing to provide student email and commissioning cloud-based email for students. For example, New College Worcester has recently adopted Google Gmail [99] and Cheadle and Marple College have adopted Microsoft's Live@edu [100] to extend their institutional email provision to students. Institutions need to be aware of the full implications of such changes to the business models of their traditional IT provision. For example, cloud computing challenges the traditional software business model [101] as organisations will no longer need to purchase and locally install software to the same extent. Removal of these in-house services and associated support resources will make it difficult to migrate back to in-house services, potentially locking institutions in to cloud solutions. Review participants were particularly concerned that an institution could rapidly lose the skills to host in-house email services – skills which would be extremely expensive to buy back in [98]. This is a potentially serious issue as business models for free cloud services may change in future to recoup software development or other costs. If these free services were to start charging, institutions may no longer be able to afford them, although they could be effectively locked in due to lack of retention of internal skills.

Institutional Budgetary Mechanisms

Indirect funding mechanisms and internal budgetary mechanisms will also affect uptake of cloud computing within institutions. As the JISC review *Using Cloud Computing for Research* [33] has found, academics in control of their own research grant budgets commission cloud computing services directly, independent of any institutional policy or of existing cloud services. Of more relevance to this review of environmental and organisational implications of cloud computing is the move towards making energy and other service and utility costs explicit within an institution's local budget centre [102]. Full breakdown of centrally allocated costs could lead to academic departments and professional services areas opting out of central provision and commissioning their own cheaper cloud services.

Business Community Engagement

Finally, in their article on cloud computing, Jaeger et al argue that due to the large and growing market (\$160 billion US in 2008) for cloud computing, the location and placement of cloud computing data centres will have clear economic ramifications [95]. This suggests that HE and FE consortia, together with commercial partners, have the potential to significantly impact upon local/regional economies through the development of regional cloud computing centres. Given the increasing focus on Business Community Engagement [103] within the sector, and in particular the impact that institutions may have on regional economies [104], this potential wider economic influence should not be forgotten.

3.3 Social Influences

The social PESTLE dimension relates to external societal and cultural aspects which could influence an organisation. JISC infoNet advises that within the HE and FE sector these are likely to relate to attitudes to education, general lifestyle changes, changes in populations, distributions and demographics, and the impact of different mixes of cultures [86]. In the case of cloud computing, social influences pertain mainly to student and staff preferences although cultural aspects and changing demographics may also influence uptake.

Student and Staff Preferences

Usage trends and expectations of students and staff may influence the uptake of cloud computing. While students and staff are unlikely to request that institutions support cloud services per se, their use of services such as external storage solutions (e.g. Microsoft SkyDrive [105] and Amazon EC2 [41]) or free cloud applications (e.g. Google Apps [44] and Gmail) is influencing institutional decisions. For example, keen to ensure good ratings in the National Student Survey [106], some institutions are seeking to integrate students' favourite applications, some of which are cloud-based, into the student experience.

Student and staff preferences could also potentially hinder uptake. For example, institutions may have to limit the use of proposed cloud services if they are not able to be delivered on a variety of different devices such as iPhones or other smart phones.

Culture and Attitudes

The culture within different areas of an institution can also affect uptake. For example, while the elasticity of cloud computing might provide an ideal and cost-effective solution for dealing with the peaks in demand during clearing or student registration, workshop participants argued that professional services areas such as registry were currently highly unlikely to agree to outsourcing part of their services in many institutions [107]. This attitude arises from a prevailing perception that cloud computing is inherently risky for institutional systems, although it should be noted that the same stakeholders who cite the high risk may consider internet banking to be secure. Some institutions may even ban certain cloud computing services because of security fears or as a result of other negative perceptions of cloud-based services.

Key review participants from JISC [108] were not convinced of increased security concerns for cloud and actually referenced the huge implications for commercial suppliers of failures or security breaches, which could actually be more detrimental to a vendor than an institution with in-house provision. These stakeholders felt that the (perceived) security risk would decrease as more institutions take up cloud provision, i.e. after a 'tipping point' is reached, there would be collective ownership of risk and the corresponding consequences of failure [108].

Changing Demographics

Increases in student numbers, especially in times of financial constraint, combined with potential shortages in skilled IT staff could also drive institutions to move towards cloud computing rather than in-house solutions.

3.4 Technological Influences

JISC infoNet suggests the technological factors which influence HE and FE are the major current and emerging technologies of relevance for teaching, research or administration [86]. Clearly cloud computing is a prime example of an emerging technology and business model. The technical developments and standardisation, reliability and maturity of services and current institutional infrastructure will all affect uptake.

Technical Developments and Standardisation

Enabling technologies that underpin the cloud computing business model include server virtualisation, energy-efficient data centres, load balancing techniques, network infrastructure and bandwidth. Without development of these technologies cloud computing would not exist. However, there are still several limitations within the cloud computing model which are limiting uptake.

Lack of standardisation of virtualisation and APIs and interoperability issues are delaying more general uptake. For example, as discussed in sections 2.4 and 3.2, institutions are concerned about lock-in where a user or institution is unable to easily change cloud service provider due to the lack of interoperability of software or data formats used in one or more parts/layers of the cloud service [8, 85, 109]. Interoperability is clearly important if institutions are to be able to move data between vendors [109] and although there are no currently widely adhered to industry standards there are organisations championing this issue. The Open Cloud Consortium (OCC) [110] and the Cloud Computing Interoperability Forum (CCIF) [111] which has a number of significant supporters including IBM, Sun, CISCO are working in this area. However since not all the big providers in cloud computing (e.g. Google, Microsoft and Amazon) support one of these initiatives it is questionable whether a standard will be widely adopted anytime soon. Recognising these issues, the European Commission is also attempting to encourage interoperability standards and open source approaches [112].

Ease of use will also impact upon uptake. For example, if users need to use a number of identities to access different cloud services this is likely to impact uptake negatively. Integrated access to services via the UK academic community's federated access management service [113] will greatly increase usability and hence uptake of cloud services.

Increases in the efficiency of data centre technologies will both reduce the cost of the service and the carbon footprint – two aspects increasingly high on institutional agendas. Improved security, fabric management (for monitoring cloud services) and graphical user interfaces (GUIs) will also aid usability and reliability. Finally, new killer apps, especially Web 2.0 technologies which lie in the cloud will also further increase uptake.

Reliability and Sector Maturity

The availability and reliability of cloud-based services will shape how well the services are viewed, and also what types of information are outsourced into the cloud. Services in which even a small amount of downtime could be damaging to an institution's reputation or where 'mission-critical' data/processes are involved are currently unlikely to be outsourced to cloud computing. On the other hand, services that are simple to use and do not require expertise to adopt or support are likely to be adopted more quickly. Institutions are also likely to be more favourable to cloud

computing services which allow easy monitoring of the service – in particular, its security, storage and processes performance.

The maturity of vendor offerings and of the experience of the sector may also affect the uptake of services. Currently many institutions in the academic sector lack experience of cloud computing services and may be holding back to see how the ‘early adopters’ fare with cloud-based services.

Current Infrastructure

Current institutional infrastructure will also affect uptake. While lack of appropriate hardware to run new applications or services may encourage IT managers to look at utilising cloud-based solutions, inappropriate network architecture may dissuade against such a solution. In particular, institutions may need to move towards dual load sharing connections to the JANET infrastructure rather than the current primary connection and backup arrangement [108]. Such changes are not required by cloud computing alone and JANET(UK) is currently investigating the implication of a range of emerging technologies and computing models on both the core JANET and local institutional networks [108]. Finally, inherent network latency may mean that it is inefficient to put some functions such as transaction intensive data in the cloud although emerging networking technologies and data centre technologies may help to reduce latency in future [114, cited in 115].

3.5 Legal Influences

Legal PESTLE factors, described by JISC infoNet as European and national proposed and passed legislation [86], also impact upon uptake of technology in HE and FE. As JISC Legal [18] advise, areas of consideration include Copyright/IPR, Data Protection, Freedom of Information, Human Rights e-Commerce, Accessibility Law, Defamation, Harassment, Computer Misuse, Terrorism, Interception and Monitoring, Hosting Liability, Employment Law. The PESTLE review highlighted two key related legal areas likely to influence uptake of cloud computing - perceived legal and security issues surrounding data storage, and contractual and service level agreements.

Perceived Legal and Security Issues and Surrounding Data Storage

The review illustrated that perceived legal and security issues can act as barriers, preventing institutions from adopting cloud computing solutions. Such issues are unlikely to prevent adoption of cloud computing per se; rather they will influence the decision regarding what types of services are adopted and the types of data involved. The issues raised include jurisdiction issues, security risks, subcontracting, data ownership issues, lock-in, service level agreements (SLAs) and reliability.

A major concern for those taking part in the review was that data held in cloud vendors’ servers would be under foreign jurisdiction and hence accessible to a foreign government, for example in the USA. Some participants indicated they would not move data into cloud services unless there was a guarantee that it would stay within the European Community. For example, one IT Director said they only decided to use Microsoft as a student email provider when the cloud hosting was confirmed as being within Europe [89]. They also noted that the significant risk was for personal or financial data and that most data they would store would be of little interest to anyone and not pose a significant legal or security risk. Concerns over government acts that give access to data, for example, the USA Patriot Act [116] and the Homeland Security Act [117] miss the point that governments could potentially access data held within their country or that of their allies whether

there are laws allowing it or not [85]. For others, the risk of their data being accessed by government officials is largely theoretical and not a significant concern [118].

In the cloud it is also not always clear under whose jurisdiction data, software and hardware lie. Many commentators feel that legal disputes are likely to arise from issues surrounding jurisdiction and location [85]. Due to lack of clarity surrounding jurisdiction, some educational institutions have only outsourced student email to cloud vendors, preferring to hold back on staff email to see how this works out. Running two email systems (cloud, non-cloud), however, is unlikely to be cost-effective in the long run. This may prevent some institutions from using cloud solutions at all, while it may persuade others that the cost-saving benefits outweigh any risks relating to jurisdiction. This decision may, in some cases, be dictated by external funders or partners. For example, the University of St Andrews commented that some external research funders (particularly military or commercial) are unwilling to correspond via cloud-based email [119].

Jaeger et al, [95] suggest that rapid technological change has been too fast for legislative and policy-making processes to keep up with, leading to a number of legal issues (e.g. confidentiality, legal jurisdiction privacy and liability). Lack of clarity arising from a deficit in appropriate legislation or established precedence can dissuade institutions from change, and uptake of cloud computing is no exception. Jaeger et al suggest that this could be addressed through intergovernmental collaboration on cloud computing standards. At present this seems unlikely due to differences between nations (particularly between the EU and USA) on many factors including legal definitions (privacy, data protection etc). However, a recent official report for the European Commission examined cloud computing and its relevance to the future of Europe [112]. Key recommendations from the report include that the European Commission, together with Member States, should set up the right regulatory framework to facilitate the uptake of cloud computing. As Jaeger et al note, *“the manner chosen to address these [legislative and security related] issues must not be allowed to place disproportionate control over the capabilities of the Internet firmly in the possession of corporations or governments”* [95].

The size of some commercial cloud providers may also prove a more lucrative target due to the large volumes of potentially exploitable data. However, commercial cloud vendors have a great deal to lose if their security is too lax and are likely to employ more skilled staff and institute more stringent security than many smaller educational institutions can afford.

There may be additional security risks posed by using cloud computing services, for example, the use of shared resources, where many clients are using the same physical server potentially increases the risk that the different clients may be exposed to each other's data. Further, even where data is stored in an encrypted form, it needs to be decrypted to be processed. As the processing is likely to take place in the cloud, it still may be exposed to potential theft or misuse by a rogue employee at a cloud service provider or subcontractor. As Mowbray summarises, *“Cloud services can provide considerable opportunities for legitimate businesses, but carelessly or maliciously designed cloud services may also offer entrepreneurial opportunities for tax evaders, industrial spies, data thieves and denial-of-service extortionists. These opportunities are a potentially fertile source of future legal cases”* [85].

Contractual and Service Level Agreements

Concern over the terms of contractual agreements will affect uptake of cloud computing. For example, as Mowbray notes some agreements do not always make clear what rights the cloud service providers have to use customer related data, including the circumstances under which they can sell it [85]. There may also be instances where an organisation signs up to a cloud-based service, unaware that the provider is actually a subcontractor who has an agreement with a larger provider. This adds another layer of contractual and legal complexity to the service which may be completely invisible to the organisation but does nevertheless add risks to the provision and security of the service. Such complexity and lack of transparency leads to a lack of trust. These issues may lead to a focus on private UK-based clouds tailored to HE and FE.

Institutions may also worry that commercial cloud service providers do not understand the business needs of academic institutions or provide suitable contractual terms. The fact that commercial services providers are showing significant interest in working with the academic community to develop and refine their commercial offerings for the academic sector [108] suggests that many of these worries can be allayed.

Unsatisfactory service level agreements (SLAs) may also dissuade institutions from adopting cloud computing services. Institutions adopting 'free' services feel the SLAs are weak [107] and that they are not in a position to negotiate better agreements (for paid or free services). For example, there is a concern amongst HE/FE stakeholders that current user agreements or SLAs are not strong enough to guarantee a good level of service or to provide compensation if levels are not met [107]. A sector approach to contract and SLA negotiation could improve this position by bringing the weight and expert advice to bear.

3.6 Environmental Influences

The environmental (or ecological) dimension relates to the physical environment in which an institution operates. As JISC infoNet's PESTLE overview advises, these are likely to include local, national and international environmental impacts, and outcomes of political and social factors. The PESTLE investigation identified two broad environmental factors – global warming and the green agenda, and the availability and fitness of estate.

Global Warming and the Green Agenda

As the JISC TechWatch report "Low Carbon Computing" notes, educational institutions are working within the context of the UK being the first country in the world to introduce a legally binding framework for tackling climate change [120]. At a time when institutions are being asked to reduce energy consumption there has been a rapid growth in both the requirement for data/information storage and of online services [120]. The government recognises cloud computing as a possible remedy for this dilemma and, as discussed earlier, plans to rationalise government and public sector data centres through the proposed private government cloud 'G-Cloud' [88].

Until recently, the possible energy savings and reduced environmental impact afforded by cloud computing have not been high on the list of drivers for its adoption by educational institutions. Indeed, as the activity review illustrated, many institutions have not considered the environmental implications of cloud computing at all. However the recent linkage, by HEFCE, of capital funding to

performance against institutional carbon management plans [121] is expected to focus institutional interest on methods of reducing the carbon footprint. As cloud computing effectively shifts energy consumption, and hence carbon footprint, to the data centre of the cloud service provider, institutions are expected to become increasingly interested in replacing in-house provision by external cloud computing solutions. While a significant shift to outsourcing of a range of IT services in educational institutions to cloud vendors will greatly reduce the carbon footprint of IT in HE and FE it could be argued that the carbon footprint is just shifted into the cloud. Indeed as cloud computing resources are increasing all the time – Jaeger et al note that Google alone had over one million servers in 2007 [95] – claims to environmental benefits should be carefully examined.

There is some evidence, however, to suggest that using cloud computing services does not just shift energy consumption - it does reduce it. The server farms run by the cloud computing vendors are becoming more energy efficient all the time with some vendors that have 'state of the art' energy efficient data centres. For example, Google may be able to attract academic institutions based partly on their green credentials [122]. However, evidence from the literature is not clear-cut. Singh and Vara argue that modern data centres can consume and waste enormous amounts of electricity [123]. Others point out that a data centre server utilisation is typically only 5-15% although this can be increased to 60-70% using virtualisation and up to 100% for some servers used in cloud computing [124].

Availability and Fitness of Estate

Increasing shortages of estate that is fit for purpose and the potentially higher cost associated with the scarcity of estate were identified by the JISC *Study into the Evolution of Working Practices* [90] as important environmental issues for some institutions, particularly those located in city centres or those with aging buildings. The ever-increasing hardware and cooling systems required to run corporate applications are therefore putting pressure on scarce resources and in some cases institutions are running out of appropriate space for new servers. The introduction of virtualised servers can reduce server numbers and hence both space requirements and energy consumption. However, this requires a significant up-front investment and a more viable option for institutions lacking the capital to invest in virtualising their services locally, may be to adopt a cloud computing strategy.

3.7 Reflections on the PESTLE Analysis

PESTLE analysis is by nature an exploratory tool designed to help identify key influences from the external environment which may impact upon an organisation. It does not provide a definitive answer regarding what will happen; rather it identifies potential key drivers and barriers.

As the analysis illustrates, political, economic, social, technological, legal and environmental factors will all influence the uptake of cloud computing within HE and FE. The main drivers are economic, relating to the reduction in funding and the need to increase competitiveness through better student and staff experiences. The need to replace aging institutional infrastructures is also a timely influence as is the increasing emphasis on greening ICT. Significant barriers, however, do and will continue to exist. Not least are socio-cultural issues relating to perceived, but not necessarily well-founded, risks associated with cloud computing. In particular, an assumption that security of data and applications in the cloud is more likely to be compromised than with in-house storage, concern

over jurisdiction and a worry that commercial cloud providers do not sufficiently understand the business requirements of HE and FE are likely to negatively impact uptake of cloud computing for core institutional services. However, two key unknowns remain; the impact that the new government will have on the education sector is unclear, as is the impact of the current trend of institutional restructuring.

The positive and negative influences uncovered by the PESTLE analysis are next used to explore four potential near-future scenarios for the uptake of cloud computing within HE and FE.

4 Scenarios for Use of Cloud Computing within HE and FE

Key objectives of this review were to explore the implications of cloud computing for institutional activities outside the research area and the potential impact of the adoption of cloud computing on institutional governance, policies, procedures and skills. Given the developing nature of cloud services, it is difficult to state definitively how cloud will be used within the sector. The exploration of potential usage was therefore undertaken by using sector experts to develop a range of future services scenarios which are likely to emerge over the next five years.

The services scenarios were developed and explored in a Workshop held in Birmingham in late March 2010. The methodology used was adapted from the project team's prior work on scenarios for the evolution of working practices [31] which drew on JISC's *Scenario Planning Guidelines* [125] and JISC Netskills' *Working in the education sector in 2020* scenarios [126]. During the workshop, the experts were divided into two teams – *Institutional Managers* and *Service Providers*. The Institutional Managers team was asked to adopt an institutional perspective, assuming the role of IT Services or senior management in the discussions. The Service Providers team was asked to assume the role of providers of cloud services. This included consideration of the perspective of commercial providers such as Amazon, Google or Microsoft etc. and also that of an organisation running a non-commercial private academic cloud. By encouraging the teams to live their roles, the workshop explored the different perspectives on what constitutes cloud computing followed by the services desired by institutions and the services likely to be marketed by cloud providers. This led to identification of four cloud services scenarios – *The Cloud Workspace*, *Cloud Storage Solutions*, *Cloud-Enabled Learning Environments* and *Academic Clouds*. These scenarios were then further explored by the two teams. In particular, the types of contracts and SLAs likely to be offered and the likelihood that these will meet institutional requirements were considered, followed by the business case for adopting cloud computing within institutions and for a private academic cloud. The four cloud services scenarios and their implications were then further refined and peer reviewed by the project team, in conjunction with a number of additional key experts who could not attend the workshop.

This section presents the resultant scenarios for the use of cloud computing within HE and FE. This is followed by reflection on the scenario exploration process.

4.1 The Cloud Workspace

Cloud workspaces consisting of institutionally branded cloud-based email services, collaboration and productivity tools are likely to become increasingly common within UK HE and FE. Typically users will connect via the web to an environment which offers access to web-based email, on-line chat facilities for synchronous communication, sharing and collaborative editing of a range of standard but limited document types. Examples of such cloud workspace tools include Gmail [45], Google Apps [127] and Microsoft's Live@edu [94]. The key feature of these tools is that they are hosted in the cloud, replacing the need for users to install common desktop productivity and communication applications such as Microsoft Office or Lotus Notes on their local hard drives. However, it should be noted that the cloud-based tools may provide more limited functionality than local desktop applications.

In general, basic cloud workspace tools are offered for free to the academic community. While in many cases individuals may simply sign up to create a user id and gain instant access to a range of free cloud-based tools, more typically institutions will contract with the cloud provider to access a free but institutionally branded service. This will allow institutions to control the look and feel of the interface to the various tools and also to present the service to its staff and students through a local URL, making the service appear as an integrated part of the institution's own internal network domain. A prime example of such an approach is the Open University's recent agreement with Google to provide Google Apps [128].

Evidence from the USA suggests that institutions will target these services at students in the first instance in order to help embed enhanced communication, collaboration and peer review within the student experience [129]. However as Educause reports, there are an increasing number of institutions who are overcoming staff or institutional reservations regarding the perceived security risks associated with storing staff materials and emails in the cloud. Thus, it is expected that institutions will increasingly migrate to cloud workspace tools for both staff and students [129]. This migration will be dictated by the diminishing returns in cost savings and efficiencies presented by dual solutions. Research staff, in collaboration with colleagues outside the institution, are likely to pioneer this staff use, with adoption by the rest of the institution following as institutional and service managers become more reassured regarding the security and reliability of these services and as the cost of supporting dual systems outweighs the business case for their retention.

The big players such as Microsoft and Google are likely to continue to dominate the educational market for cloud workspace communication collaboration and productivity tools in the near future. However, as is already the case, many other companies, both small and large, will offer competing cloud workspace services – e.g. the latest Lotus notes software from IBM [130] or Fronter [131], a teaching and learning platform from a smaller Danish company. Uptake of cloud workspace tools beyond of the big players will depend on their compatibility with Microsoft Office, OpenOffice [132] and other open source applications and the degree of innovation in workspace models that they provide.

The business model for these cloud workspace tools is that by hosting the applications within large data centres which service a multitude of different customers, cloud service providers can achieve considerable economies of scale and therefore offer pay-as-you-go solutions at a more competitive rate than in-house solutions. These significant economies of scale allow the cloud providers to offer special, free but limited, educational services based on the premise that educational usage will expose students – the future workforce – to their products. The service limitations – typically email and document storage restrictions – may mean that institutions will need to contract a premium service rather than standard educational provision to meet staff requirements. Even taking this cost into account, as the Forrester report into the cost of cloud email services illustrates, cloud-based solutions which relieve institutions of support and maintenance overheads are likely to be more cost effective where staff numbers are less than 15,000 [133].

While most cloud providers will advertise standard contractual and SLAs, there will be room to negotiate sector-wide agreements suitable for UK HE and FE. Contracts may or may not specify where in the world that the hosted emails or documents will reside. Typically, guarantees of location will be offered on premium services only. Similarly, encryption of transiting data will be a costed

extra – one which is only likely to be purchased for highly confidential or business-critical emails and documents. Contracts will not involve any transfer of ownership of data to the cloud service provider. For costed services, the key SLA terms will relate to monthly uptime of the suite of tools, scheduled downtime, and service credits which would be accrued should the service level fail to meet agreed targets. However, breaks in services may not be counted unless the break results in the service being unavailable for more than 10 minutes. So while a SLA may have a guarantee of 99% uptime this might exclude very short episodes of downtime. Free services are unlikely to provide meaningful SLAs. Large institutions or consortia may be able to enter into additional contractual agreements, although different SLAs will be much more difficult to negotiate.

The key influence in adopting cloud workspace tools will be financial – both in terms of reducing existing costs relating to hardware, software, maintenance and support, and to the ability to develop additional services effectively for free. Functionality and existing student and staff personal use of particular free solutions are likely to influence corporate decisions regarding uptake and the selection of commercial cloud providers. The benefits afforded to institutions will therefore be related to cost savings and improved services and student experience – key benefits in the increasingly competitive and cash-strapped education market. For example, the Open University contract with Google provides a SLA with higher levels of availability than the University itself could offer [134]. For students and staff the key advantage will be that they can work more collaboratively, from any web-enabled computer, without having to worry about having compatible software installed locally [129].

Criteria for selecting cloud workspace tools

- When seeking to reduce hardware and software costs
- When seeking to reduce maintenance costs
- When aiming to improve student services and experience
- When seeking to work more collaboratively
- When aiming to work more flexibly

4.2 Large-Scale Cloud Storage

As institutions amass ever more data, large-scale data storage, management and preservation is increasingly becoming a major concern. Cloud storage solutions offer a way to outsource these problems to a third party. Potential datasets that could be moved to the cloud include educational resource repositories, institutional repositories, institutional archives, corporate datasets, data backup, archiving and disaster recovery, and research datasets.

Institutions will be able to choose from a range of large-scale data storage solutions within the cloud infrastructure. At the most basic level cloud hosted solutions will offer virtual server hosting or block storage. Hosted solutions will suit institutions who have limited technical skills sets. For example, the University of Southampton already offers a hosted institutional repository service [135] which provides institutions with their own branded ePrints repository of research literature, scientific data, student theses, project reports, multimedia artefacts, teaching materials, scholarly collections, digitised records, exhibitions and performances. The repository hosting service includes customisation to satisfy an institution's metadata requirements. On the other hand, block storage

solutions such as Amazon's Elastic Block Storage (EBS) service [136] will offer storage volumes which behave like raw hard drives and can be used by institutions to effectively add new disk capacity. Finally, a more sophisticated model of 'cloud storage' or 'storage as a service' will enable institutions or individuals to store their data in a multi-tenancy cloud storage solution which they then access through sophisticated APIs. The cloud storage solution itself may be spread over a number of storage arrays in different locations and access is load-balanced using data location virtualisation or other data management techniques [137]. Amazon's S3 service [64] is a prime example of such a cloud storage solution.

The business rationale for cloud-based storage solutions is that they offer the advantage of an elastic, highly scalable, reliable, inexpensive data storage infrastructure which is shared by many users. This means that institutions contracting such services are freed from the burden of managing large-scale data service in-house – an area where relevant skills are lacking [108] – and gain from the economies of scale afforded by the cloud. However, whether cloud storage is a reasonable option depends on the anticipated use of the data. For example, whether cloud-based solutions can currently reliably handle highly transactional files or databases that require consistently fast network connections is questioned [138]. This is, in the main, due to the inherent latency which arises due to the transfer of data over the Internet. While network bandwidth and reliability is continuing to increase, commercial companies are still not ready to move highly transactional data to the cloud. Indeed, according to Forrester Research, business users are not yet ready to move to cloud storage as reliability, service levels, share tenancy and long-term pricing all present significant barriers [114, cited in 115]. While it is possible that some academic institutions may experiment by putting the likes of customer relationship management data on the cloud, many others will await the outcome of such early adopter studies and the experiences of G-Cloud before considering moving highly transactional data to the cloud.

Most cloud providers will provide a range of standard contractual and SLAs for their various data storage solutions. Contracts will ensure that institutions or commercial clients retain full ownership of their data. Given the potentially sensitive and commercial nature of the data stored, contracts may include options which specify both the regional location of the host data centres and the jurisdiction under which the contract and provider operate. Providers are also likely to offer encryption of stored and/or transiting data on their premium services – a facility which may be bought by institutions storing key corporate data. Level of effort relating to data security may also be specified; however there can be no guarantee against a breach of security. Capacity and level and rate of expandability will also be specified. Standard SLAs will focus on monthly uptime, error rates and service credits. Institutions accessing the cloud data as part of corporate applications will look to third party cloud service companies similar to DuraSpace [139] to overlay improved accountability and quality of service guarantees on top of standard commercial cloud data services.

The key influences in adopting large-scale cloud storage will relate to scalability, cost effectiveness and the nature of the data itself. The nature of the data will dominate, at least in the short to medium term. Of the large datasets which might be considered within the scope of this review – educational resource repositories, institutional repositories, institutional archives, corporate datasets, and data backup, archiving and disaster recovery – data which is either infrequently accessed or which is mainly accessed over the network anyway are most likely to be put onto the cloud. Thus, data backup, archiving and disaster recovery, institutional repositories and open

educational resource repositories are the most likely candidates. However long-term preservation will be of concern and therefore the business standing of the supplier will be an important factor. Data which is highly sensitive – either commercially sensitive data – or personal data – is less likely to be stored in the cloud due to perceived increased security risks and the fact that additional safeguards such as encrypting traffic over the Internet may further increase latency and costs. For cloud storage solutions, lock-in will also be of prime concern. This is primarily due to the lack of standardisation of APIs which means that it is difficult to move to a new cloud storage provider without starting from scratch [137].

Looking further to the future, new usage models may develop where institutions share data in the cloud. For example, consortium customer relationship management (CRM) solutions may emerge where groups of institutions collaborate by storing institutional CRM information in a cloud private to the consortium. While each institution would still have confidential access to the commercially sensitive material, the use of a private cloud could afford data mining opportunities at the consortium level.

Criteria for selecting Large-Scale Cloud Storage Solutions

- When a cost effective solution to more storage capacity needed
- When a highly scalable resource is required
- When data is infrequently accessed – e.g. repositories, archiving, data backup, disaster recovery
- When data is **not** “highly transactional” – lots of data transfers

4.3 Cloud-enabled Learning Environments

The provision of learning environments within HE and FE is likely to spread to the cloud. Two types of cloud-based learning environments can be expected initially – Virtual Learning Environments (VLEs) and Personal Learning Environments (PLEs). In the first case, traditional institutional VLEs will be remotely hosted by commercial VLE specialists. For example, Blackboard already offers a Managed Hosting Service [140] where an institution’s Blackboard VLE is hosted on the company’s servers. While such hosted services currently tend to be employed by smaller, commercial learning providers, this may increasingly become a preferred option for smaller FE colleges struggling to resource staff to support in-house VLEs. Cloud hosted solutions are also beginning to emerge for non-commercial VLEs. For example, Unicorn Inc. [141] now offers hosting services for both Sakai [142] and Moodle [143] open source VLEs. Given the core educational focus, the business models of these providers will generally be compatible with the needs of UK HE and FE.

Students and staff using cloud-based VLEs should not, in principle, experience any difference compared to institutionally hosted VLEs. Student and staff preferences are therefore unlikely to influence the move to the cloud of institutional VLEs; rather, the decision will be based on evaluation of reduced costs and in-house support requirements versus the degree of configurability and flexibility afforded by cloud hosted VLE services. This means that where institutions wish to undertake significant customisation, a locally hosted VLE may still be more appropriate given that the institution will require local VLE developers. The general institutional culture towards using the cloud will also affect uptake. As VLEs are increasingly viewed as core and mission critical services,

uptake can be expected to lag behind that of student email or collaboration tools. Institutional and VLE managers will need plenty of evidence relating to the reliability and quality of cloud hosted VLE services before committing to commissioning such a cloud-based system. Contractual agreements will be concerned with the cost of the service, resilience, upgrade schedules and expandability of provision. Anything above a very basic support level will come as a costed extra. For those institutions without in-house support staff, this could add significantly to the cost of the service. SLAs are likely to include monthly uptime, error rates, latency and service credits.

Personal Learning Environments (PLEs) are educational systems which allow individual learners to take control of and manage their own learning [144]. As JISC CETIS [144] suggests, in a PLE scenario institutions would provide educational content via repositories and assessment activities etc; however learners would access these institutional facilities using a PLE which each individual learner constructs from his or her preferred tools and ways of working. As students increasingly turn to cloud-based workspaces using communication, collaboration and productivity tools, PLEs are likely to draw heavily on these free to education cloud services. Use of cloud workspace tools has the advantage that much of the learning environment constructed by the student will remain available to him or her on completion of their course, paving the way for a lifelong PLE which evolves over time as technology and business models changes. As PLEs are built by students from their preferred tools, there will be no contractual arrangements or SLAs directly relating to PLEs. The resultant lack of service guarantees and support is something that institutions will need to be aware of and manage the implications of. This may result in institutions advocating preferred PLE solutions built from their standard communication, collaboration and productivity tools with users warned that they will not receive support for different tools, although online forums could be used for informal support mechanisms.

Malik [145] argues that the availability of cloud-based plug and play user 'apps', repositories and even cloud hosted VLE components will lead to the emergence of personalised Cloud Learning Environments (CLEs). Such CLEs will move the loci of control away from institutions to a partnership model where both academics and learners can equally share choice and control of the learning environment and share content etc through cloud-based services. This vision perhaps derives from the changing loci of control afforded by Web 2.0 technologies [31] rather than the elasticity and economies of scale at the core of cloud computing per se. Indeed there is disagreement regarding the usefulness of the term cloud in this context and regarding what advantages this distinct vision provides over simply the evolution of existing VLEs or PLEs [145]. However, the easy to use plug and play nature of cloud computing combined with the free educational services models could be a significant enabler of new collaborative, student-centric ways of learning. While such a collaborative approach would require a significant shift from the culture of institutional provision of learning environments, it is strongly in line with current constructivist approaches which seek to empower learners through collaboration, self-regulation and co-curriculum. However, academics who are unfamiliar with emerging Web 2.0 and cloud technologies are much less likely to embrace such a radical approach. Further, given the lack of institutional control, such approaches may have significant implications for quality assurance and enhancement procedures relating to the student experience. New approaches would therefore be required. Whether contractual arrangements and SLAs could be brought together under some kind of overarching third party cloud service, which allows pick and mix solutions but guarantees acceptable levels of service, would need to be explored.

The key influences relating to the adoption of cloud-based learning environments vary depending on purpose. While cost savings and resilience will be key influencers, particularly in moving to directly hosted solutions, pedagogical objectives should be the primary motivator – something which should not be lost in efficiency drives. Care must be taken to fully investigate the additional cost associated with support, be it in-house or through the cloud supplier as part of the business case. Student preferences and lifelong learning requirements will also be key influences in PLE and CLE type solutions. Considerable barriers to uptake are to be expected at first. These will be related to a perceived loss of control over a core part of an institution's business, potential service breaks and network latency in the case of the host VLE solution. CLE solutions are likely to be viewed as much more experimental and therefore latency may not be such an issue in the short term.

Criteria for selecting Cloud-based Learning Environments

Cloud-Based Virtual Learning Environment (VLE)

- When there is a need to reduce costs
- When less customisation is required

Cloud-Based Personal Learning Environment (PLE)

- When more student control of learning is required
- To enhance and support life-long learning

Cloud Learning Environment (CLE)

- Collaborative student-centred learning supporting a co-curriculum

4.4 Academic Clouds

In contrast to the specific tools, applications and utilities discussed in the preceding scenarios, in the *Academic Cloud* scenario institutions or individuals may purchase scalable, elastic pay-as-you-go access to a range of computer processing, storage, networks, and other fundamental computing resources which they can employ to run arbitrary software. This academic sector specific *Infrastructure as a Service* (IaaS) type solution could be provided in three forms – *public academic cloud*, *private academic cloud* and *private institutional cloud* – distinct from general public IaaS solutions which can be purchased from the likes of Amazon, Salesforce.com etc.

In a *public academic cloud* scenario, the cloud infrastructure is accessible to the academic sector only, although it is built from publicly available cloud services. This could be achieved through a sector-level deal with a single large-scale cloud supplier or through an overarching academic cloud management service which integrates the provision from a range of commercial suppliers to provide a branded academic cloud. There are two key features of this public academic cloud. Firstly, as it uses commercial cloud infrastructure it gains from massive economies of scale, it is infinitely scalable (in theory) and benefits from the resilience and load balancing which the global cloud providers can offer. Secondly, it offers a branded academic sector cloud service tuned to the sector's business needs. This includes sector-wide contracts and SLAs through which institutions or individuals can purchase a range of cloud-based services. By purchasing such bulk deals the sector will have sufficient leverage to negotiate contracts and SLAs tuned to meet the business needs of the academic sector. Indeed, as respondents and workshop participants felt that this is an area where institutions lack appropriate skills, such negotiation is likely to be warmly welcomed in the sector.

The feasibility of a public academic cloud depends largely on the interest of the sector in buying in to such a service and the willingness of commercial providers to engage in a bespoke academic solution. JISC's ongoing industry liaison discussions suggest that commercial cloud providers are keen to investigate the academic market [108]. While institutions and individuals who took part in the review did not specifically identify with the need for a public academic cloud, the enhanced contractual leverage, quality of service and SLAs which this could bring were viewed as key enablers required if uptake of cloud computing was to move beyond provision of student email and become a central part of core institutional IT strategies. However, this public - albeit restricted - cloud is still exposed over the Internet and therefore the data and processing may be subject to external security attacks. As discussed in section 3, while some may be concerned with the security, the cloud providers are likely to have more extensive in-house security measures and expertise than that within academic institutions. Latency may also be an issue; however JANET(UK) is already having discussions with commercial data centre and application providers regarding improved connectivity to JANET [108].

In a *private academic cloud* scenario, the cloud infrastructure – the computer processors, data centres and networking applications are based within the JANET network rather than via the Internet in general. While the idea of a dedicated (private) academic cloud service might appeal, this scenario has the disadvantage of much more limited scalability and therefore elasticity than a truly global cloud solution. Further, as the cloud is limited to JANET, peaks in demand are likely to coincide across large parts of the sector. For example, many institutions may wish to purchase additional computer processing power from the cloud to cope with processing peaks relating to clearing or student registration. The processing and data storage capacity of the private academic cloud will need to be constructed to accommodate such peaks; however, for the majority of the year the cloud will run significantly under capacity and therefore not be as cost-effective as a global cloud solution which can absorb such peaks. Further, while resilience could be built with multiple cloud data centres on JANET, global cloud players will be able to offer better resilience guarantees. Thus while the contractual and service level agreements relating to a private academic cloud will also be designed to meet the business needs of academia, the costs, resilience and elasticity terms are likely to be less favourable when compared to those of a public academic cloud.

In the *private institutional cloud* scenario, an individual institution fashions its own internal IT provision on the flexible utility-based infrastructure used by the commercial cloud providers. Rice University in the USA has developed such a private cloud [146]. The advantages of this approach are twofold. Firstly, an institution retains full control over its personal and commercially sensitive data and its security infrastructure. The latter is a double-edged sword, as commercial suppliers are generally viewed as having a superior infrastructure as their core business depends on reputation in this area [107-108]. Secondly, the institution can rationalise its IT infrastructure while introducing new costing models where departments or individuals are accurately charged for the resources they use. However, this private institutional cloud scenario does not offer the same key benefits of economies of scale, and infinite elasticity that non-institutional solutions provide. Institutions may be able to capitalise some limited economies of scale due to coalescing IT provision which was previously distributed across many different departments; however, the cost of sourcing sufficient infrastructure to offer reasonable elasticity is likely to outweigh any benefits. Although some industry analysts claim there may be a general move towards reorganising an organisation's IT

provision in this way [147], such solutions will require significant investment and are not really cloud solutions according to the NIST definition of cloud computing.

Other hybrid or regional models may also emerge. For example, a consortium based on region or institutional focus could develop its own smaller scale private cloud. Alternatively, a private academic sector cloud could call on resources from public cloud providers to deal with peak demands. However, the business case for such models would need to be carefully examined.

Criteria for selecting:

Public academic cloud

- When massive scalability required.
- When demand for resources is extremely variable.
- When there is no expertise for negotiating SLAs within your institution.

Private academic cloud

- When security is an issue.
- When scalability is less of an issue.

Private institutional cloud

- When the highest levels of security are required.
- When there is a desire to avoid service level agreements (SLAs).

4.5 Reflections on the Service Scenarios

The scenarios developed here are near-future scenarios designed to help explore the institutional and environmental implications of cloud computing. The scoping of the scenarios, based on the findings of the PESTLE analysis and activity review, has facilitated the exploration of important characteristics, influences and impacts of how cloud computing might be used over the next five years within HE and FE. Two key points are worth highlighting. Firstly, while cost-effectiveness will undoubtedly drive much of the move into the cloud, the move towards user-led technological innovation, driven by the advent of Web 2.0 technologies, will indirectly influence uptake as many Web 2.0 technologies are based in the cloud. Secondly, while a private academic cloud has been suggested as a way to minimise many of the perceived risks associated with institutional use of cloud, more detailed consideration revealed that many of the benefits of the cloud would be lost. A public academic cloud is a more viable scenario.

It had been the intention to consider further the viability of an academic cloud within the context of this review through a more detailed impact analysis based on the academic cloud scenario. Investigations by JANET(UK) into the implications of large-scale data centres and discussions by JISC industry liaison regarding the cloud industry's interest in such an arrangement were ongoing during the period of this review. It was therefore not possible to fully integrate the results of these investigations into a deeper impact analysis of the viability of an academic cloud. The forthcoming

internal JISC workshop on cloud computing should provide an excellent setting to further explore the viability of an academic cloud.

As the sector begins to gain experience in cloud computing, it will be worthwhile revisiting the scenarios to explore what might happen in the next 10-20 years. Indeed, there are researchers who feel that cloud computing provides an opportunity to rethink the whole model of higher education as a more open-content, inter-university, collaborative vision. In their article “Above-campus services: Shaping the promise of cloud computing for higher education” Wheeler and Waggener suggest that cloud computing offers “a new capability and an opportunity to rethink approaches for delivering IT services” [148]. They go on to describe a meta-university model in which services are provided at a level above an individual campus/university. In “The Tower and The Cloud”, Richard Katz suggests that there are a number of factors that are leading to the democratisation and industrialisation of IT and that this has consequences for education. The unbundling of educational offerings may lead to competition as it can be relatively easy to re-bundle and “mash-up” educational materials that are online and this will have positive and negative aspects [149]. Thus, exploration of how the emerging cloud computing paradigm and related technologies might significantly change how HE and FE institutions undertake teaching and learning, research, business community engagement and administrative activities is recommended.

The outputs of the PESTLE analysis and the scenario developments together fed into the development of advice and guidance on cloud computing which is presented in the next section.

5 Advice and Guidance on Cloud Computing

The advice and guidance presented in this section is aimed at decision-makers in HE and FE who are responsible for the provision of institutional IT Services. It provides a summary of areas to be covered when investigating the business case for the use of cloud computing for IT service provision in HE and FE and recommends further resources to enable investigation where appropriate.

The advice and guidance is based on the issues relating to cloud computing which were uncovered during this review of the environmental and organisational impact of cloud computing within HE and FE. The activity review with key representatives from 16 UK HE and FE, the PESTLE and scenario development workshops outlined in subsection 1.3, subsequent discussions with key HE and FE stakeholders and a supplementary review of relevant literature all contributed to the advice and guidance presented here.

Activity review respondents indicated that the uptake of cloud computing at an institutional level is not progressing as quickly as the vendor hype might suggest. Some respondents that have only just started exploring the possibilities of adopting cloud-based computing services were unsure of what methods would be used to assess the resultant impacts to the institution. Most institutions in the activity review already using cloud computing services have piloted one service first, usually student email, with a view to determining how successful this was before deciding whether to move other services into the cloud.

Given that institutions are currently proceeding, but with caution, many stakeholders consulted did feel that it was perhaps too early to determine exactly what advice or guidance was required as they were only just beginning to investigate cloud computing, although most did comment that guidance was required from a legal perspective and also with regards to security, energy efficiency, institutional policy and staff issues. Security concerns and alignment with institutional IT strategy were the most common reasons given in the activity reviews for not adopting cloud computing. The advice and guidance in this section therefore presents a structure to allow decision makers to investigate the potential business case for adopting cloud computing at this early stage in sector adoption; examining the potential drivers, costs, benefits, issues and risks associated with cloud provision of IT.

“The Business Case presents the optimum mix of information used to judge whether the project is (and remains) desirable, viable and achievable, and therefore worth investing in.”

Office of Government Commerce [1]

Each of these aspects of the business case is covered in the following subsections. This project has been carried out as part of JISC’s Greening ICT Programme; consequently there is a focus on environmental areas for each aspect. Note that in order to make a decision, institutions must examine these aspects in relation to a cloud solution and for other alternatives, including the status quo, in order to compare and contrast options and to make an informed decision. While there is not currently any academic cloud services as scoped in Section 4, should these be developed, institutions should also consider the business case for an academic cloud solution as well as for the more

commercial services currently on offer. Further, other possibilities should be considered too. For example, consortia of educational institutions, perhaps in the same region, could effectively pool resources to provide shared computing services. This is certainly something suggested in literature [150] and also during the activity review. There are joint data centres being built in the USA that allow a number of academic institutions to share costs and resources [151]. This is a viable option also considered by the Universities of Derby, Salford, and Sheffield Hallam who recently completed a feasibility study on the possibility of a shared cloud computing data centre [150].

Note also that an appropriate timescale for any investigation must also be considered; for example, one which considers the time required in order for any change to realise expected benefits and one which allows changed regular costs to be compared in addition to reviewing the one-off costs required to make a change. The business case may need to be examined for the short, medium and long term in order to determine whether cloud computing is the most appropriate option for services.

5.1 Drivers

Drivers for considering cloud computing solutions for institutional services should be identified in the context of the institutional strategy and how well they align. As the PESTLE analysis of section 4 identifies, the main drivers are economic, relating to the reduction in funding and the need to increase competitiveness through better student and staff experiences. The need to replace aging institutional infrastructures is also a timely influence as is increasing emphasis on greening ICT.

The PESTLE analysis provides a broad overview of the drivers and their implications. Consideration of this analysis within the context of an individual institution's vision and goals and current operating environment is the recommended starting point for an institution exploring the business case of cloud computing.

Political Drivers

Government policies, the economic and political climate and the influence of the funding councils should be considered in light of how they will influence institutional strategy and the service provision required to meet its vision.

Economic Drivers

The financial climate and expected income from an institution's funding streams should be considered in addition to the preservation of competitive advantage i.e. does the institution benefit from keeping particular services in-house and therefore distinct from direct competitors?

Social Drivers

From the project activity review, one of the most frequently cited reasons for not adopting cloud computing was the need for cloud computing to fit into institutional IT strategies. In general, HE and FE are considering 'chore' rather than core services for cloud computing, for example email and file storage, rather than distinct specialist or customised services which are more difficult to move to cloud. Although generic systems may indeed be business critical, the nature of their provision is typically rather uniform between organisations and therefore easier to outsource. Many activity review participants had taken the step of seeking advice from other institutions who were already

using cloud services; for example Royal Holloway University of London consulted with University College London (UCL) before negotiating their student email service with Microsoft [89].

Technical Drivers

Clearly any business case must be developed within an institution's own unique context; the optimum path for service provision will depend on the size and profile of an institution and other individual factors. For example, if the institution has successfully implemented cloud computing solutions previously it will be more knowledgeable about what issues might arise. In addition, a service cannot be considered in isolation. If most other services are cloud-based it would not be a great leap for an institution to make a decision to opt for a cloud-based solution for another service.

Legal Drivers

Legal issues will be a major factor determining an institution's decision on whether to adopt cloud computing. There may be cases where legal issues associated with cloud could inhibit an institution's progress. However, conversely, the adoption of cloud may also offer institutions a solution to existing legal issues; for example outsourcing the storage of data to an organisation who can actually provide an increased level of security.

Environmental Factors

With regards to environmental drivers, Low Carbon Computing notes that "the UK is the first country in the world to introduce a legally binding framework for tackling climate change and the implications of this are likely to be far reaching for the public sector" [120] (p1). This JISC TechWatch report "Low Carbon Computing: a view to 2050 and beyond" is a substantial report that seeks to explain that HE/FE will face tough targets for reducing energy emissions and discusses factors and technologies affecting the sector in the long and short-term. In recent years the rapid growth in both the requirement for data/information storage and of online services has fed the rapid rise of cloud computing services. These services have significant implications for our energy consumption as Anderson et al note:

"In 2007, the EPA predicted a 75% growth in data centre energy use in the USA over a 5-year period (from 2006) under the "current energy efficient trends" scenario but their estimates already look like they are being exceeded: the Uptime Institute reports that when surveying the top tier of data centres, they have recorded a 20–30% annual rise in energy consumption" [43] (p16).

Jaeger et al found that Google alone have over one million servers (2007) and it is a safe assumption that all big internet players (Google, Microsoft, Yahoo, Amazon, IBM) run vast server farms [95]. Some experts are suggesting HE/FE should be moving IT out into cloud-based services. For example, a key recommendation from Low Carbon Computing [43] is that: "More consideration needs to be given to the issues involved in a move towards shared services and third party 'cloud' services". The report also indicates that the emerging government plans for G-Cloud [88] need to be watched closely. G-Cloud represents the first large public-sector cloud project and given the poor track record of many large-scale public IT projects it will be of great interest. If and when the G-cloud is implemented the hope is that government IT services will reap a number of benefits including cost savings, improved agility, standardisation/simplification/consolidation, green ICT strategy, reduced commercial risk, reuse of applications and virtualisation [88].

From the activity review undertaken by this project, the general feeling from respondents was that the use of cloud computing would lead to lower energy use, less servers, energy savings from a reduced need for cooling and lighting, and also from less digital and physical storage within an institution. Many institutions have already virtualised servers leading to a reduction in server numbers and energy consumption. Other energy savings noted were from cloud computing use leading to more flexible working and teaching practices and a reduction in the need to be physically at the institution. In at least one institution the former email servers have not been decommissioned but re-used for other services. Most of the points raised by the activity review participants were also brought up by those participating in the PESTLE workshop.

A few activity review respondents were cynical about the greenness of cloud computing and feel energy consumption is just moved rather than reduced. Workshop participants also raised the issue of 'greenwash' where some cloud computing vendors overstate the green credentials of their services and indicated that it was difficult to completely trust their claims. Some institutions in the activity review have not yet considered environmental implications or feel they are very small (particularly some colleges). For some institutions the adoption of a cloud-based service such as student email is an additional service for the students and has not led to any equipment reductions or energy savings.

Workshop participants cited energy savings and greater sustainability (lowering institutions' carbon footprint) as being seen as drivers to adopt cloud computing services. This is also linked with the institutional profile - is it seen as green or not? It was suggested that there may be rewards for institutions that appear green, and penalties for those that do not, from government and research funding bodies.

In addition to considering how cloud computing solutions could help an institution to achieve its strategic vision, it should also be considered that the existence of cloud computing could also affect strategy development. As discussed in subsection 4.5 the emerging cloud computing paradigm and related technologies might significantly change how HE and FE institutions undertake teaching and learning, research, business community engagement and administrative activities. Even if the whole HE/FE model does not change in light of cloud computing, many researchers feel cloud and other IT trends will have a significant impact. Young suggests that "in the next five years, web-based computing will likely bring important changes in how students study, how scholars do research, and how college information-technology departments operate" [151].

5.2 Costs

In order that a fair business case be considered for investigation, the full costs of cloud computing and its alternatives must be identified and compared. This should include direct costs, e.g. for hardware and staff time, as well as indirect costs to cover estates costs and network infrastructure. It is often difficult for institutions to accurately cost individual services due to the nature of the finance systems used and further resources to assist with this process are given at the end of the section. The following advice should be taken into consideration when investigating costs.

- Institutions must be cautious when analysing the cost of cloud solutions as marginal costing is often used internally. As the true costs of providing an ICT service may therefore be unknown,

direct comparison with cloud services which make explicit the full cost to the user are difficult to undertake.

- Although many institutions have cited cost savings as a benefit of using cloud computing, in other cases costs may not decrease but other benefits, such as an improved level of service, may be the reason for adoption. A true cost comparison should be made to enable options to be realistically compared, even if a decrease in cost is not expected.
- Once a new solution is implemented, costs must be monitored to ensure that expected cost savings are actually made.
- The cost of change must be considered in addition to comparing annual running costs for different service options. This may include the costs of running parallel services (old and new) during a system changeover, additional staff training costs and estates costs to repurpose rooms or buildings.
- Several stakeholders reported adoption of free cloud computing services, for example student email. However the costs associated with enabling and supporting uptake of such 'free' services must be considered. In this case, costs may include staff time required to liaise with the supplier and additional hardware, software, maintenance and estates costs required due to student expectations of a means by which to use the 'free' service. Increased use of the institutional helpdesk may also need to be accounted for to cover enquires related to the service and the staff time taken to help resolve user issues. Furthermore, it must be considered that a currently free service may well incur charges from the supplier in the future. In reality, there is probably no such thing as a completely 'free' service.
- Any reductions in staff time may be calculated as a cost saving for cloud computing, not just centrally but in devolved faculties or departments as well. In addition to any reduction in capital expenditure on IT equipment and a reduction in costs of maintenance and power usage, there are other areas where costs can be reduced by using cloud services. For example, Kambil indicates that the business implications of a move to cloud computing include a change from purchasing software and installing it locally, challenging the traditional software business model [101]. It also means a potential cost saving to the end users of the cloud-based software because the users (or their IT support staff) do not need to purchase software and install and maintain it.

Further Resources for Investigating Costs

The Insight Model and framework for calculating costs and benefits of ICT [3]

The Joint Costing and Pricing Steering Group's Transparent Approach to Costing (TRAC) Guidance [7]

5.3 Benefits

From the project literature review, activity review, workshops and stakeholder interviews, the potential benefits of adopting cloud computing are wide and varied. The list of benefits that follows in this subsection is not exhaustive, but represents typical aspects of service provision that can be improved via use of cloud. Note that all benefits related to the provision of a particular service being examined must be considered, even if a cloud solution would not realise them. Ideally, institutions

should identify potential benefits that apply to any of the service solutions being compared (cloud computing and its alternatives) and compare if, and to what extent, each of the solutions contributes towards achieving these. Benefits could be scored for each solution and perhaps even weighted according to importance to the institution and its strategy, to allow the most relevant comparison possible. Further resources at the end of this subsection are referenced to help with the identification and comparison of benefits.

- If a business case being investigated relates to the provision of new functionality or to a new service, then there is obviously no baseline comparison to be made. Benefits of potential solutions alternative to cloud should still be investigated, for example in-house provision.
- Section **Error! Reference source not found.** discussed the fact that ‘chore’ services are often deemed highly suitable for cloud provision. The corresponding benefit for institutions is that resources may be freed up to do more innovative work, buying in more utility-type services such as email.
- Depending on the size, wealth and strengths of a particular institution, cloud computing solutions may offer a better level of service that can be provided in-house, with greater reliability, robustness, security and functionality.
- This improved level of service may contribute towards meeting the expectations of stakeholders, e.g. staff, students, industry partners, etc. This may translate into specific benefits for particular stakeholder groups, e.g. a better student experience, improvements in teaching and learning processes, improved availability of management information.
- Some institutions consider cloud computing to be a new and Innovative approach and that using it helps to stay aligned with technological advances.
- Improved efficiency, i.e. more efficient or effective use of staff time.
- Cloud computing may allow more appropriate use of the institutional estate.
- Cloud computing may in some cases be adopted to facilitate collaboration and information exchange with other institutions, i.e. to provide a service that is available to users beyond its own staff and students. Young [151] notes that the benefits of using cloud computing will include ease of collaboration between students, researchers and academics and also the availability of high performance computing to a much wider audience.
- Reduced power consumption is a potential green benefit of cloud computing, although it was noted from the activity review and workshops that power consumption and billing are often handled at institutional level and so it can be difficult to obtain detail on power consumption within different areas of an institution. One potential solution for this is to use estimates using an appropriate method or toolkit (see further resources below). A number of project participants reported that they had calculated the real costs in terms of energy, money, space and other ancillary aspects of ICT, sometimes as part of bigger green initiative. Institutions must proceed with caution, however, if making green claims. It is often tacitly assumed that cloud computing is more green by its efficient and streamlined nature; however calculations or estimations would have to be compared with cloud-related figures which are often difficult to source. Some stakeholders did feel that energy consumption was being moved rather than reduced when opting for cloud. Jaeger et al note that “*data centers consumed one percent of the world’s electricity in 2005, and the carbon footprint of data centers will surpass that of air travel and many other traditional industries before 2020. By that time, networked computing may consume half of the world’s electricity*” [95]. Although exploiting economies of scale via cloud

would appear to enable the ‘greening’ of provision, these figures have yet to be truly proven [152] (p14). There seems to be a great deal of positive claims from industry literature but much less hard evidence. In their workshop paper, Singh and Vara note that modern data centres consume and waste enormous amounts of electricity for different reasons [123] (p67). Given the continuing increase in demand for energy to run institutional computing infrastructure, it is imperative that their energy use is optimised. A data centre server utilisation is typically only 5-15% but this can be increased to 60-70% using virtualisation and up to 100% for servers used in cloud computing [124] (p5-7). A large proportion of the power used in a data centre is used for cooling 60-70% [153] (p2).

Most industry players are focusing on optimising IT infrastructure for energy usage. A recent example is an IBM experiment (project BlgGreen) where they virtualised large numbers of individual data centre servers onto a single, back-office mainframe, which IBM argue can save as much as 80% of the power consumption [43, 154]. The Low Carbon Computing report indicates that the greenhouse gas (GHG) emissions associated with the cloud are becoming increasingly important [43, 153] but the potential for energy savings should be focused on system operations and networking aspects as well the hardware aspect that have already been investigated. This is an area where further work needs to be done to continue to optimise the energy used in cloud-based computing services.

Further Resources for Measuring Benefits

To assess the energy efficiency of cloud services there are some tools to guide assessments. For example, *Leveraging the Cloud for Green IT* from Spellmann et al lists key attributes (and other factors) for both institution-based and cloud-based computing and describes a methodology to identify IT components that can be moved to the cloud [6]. This methodology provides a way of quantitatively evaluating how cost effective and energy efficient moving institutional IT provision to cloud-based services might be.

The SustelIT footprint tool [10] was developed to aid estimations of in-house IT energy use.

Other tools that may aid the assessment of costs and changes to IT provision are the Benefits of ICT Investment Landscape Study’s (BIILS) Evaluation Framework and Toolkit [13] and the JISC infoNet Impact Calculator [15].

5.4 Issues

When considering cloud computing as an option for provision of services in HE and FE, there are potential issues which may require to be resolved in order to exploit the benefits.

5.4.1 Policies and Procedures

Some activity review respondents reported that cloud computing had not been adopted primarily because it did not currently fit with institutional IT policy and strategy. JISC’s 2008-9 Key Audience survey also found that few institutions had any policy or guidance in place for staff relating to cloud computing [20]. Furthermore, some workshop participants indicated that current institutional

policies often meant personal use of some cloud computing services was blocked, having been deemed a security or legal risk by the institution.

- It is strongly advised that strategies for cloud computing are developed centrally at institutional level. If services were to be adopted separately by a number of discrete departments or faculties there may be great inefficiencies and a high risk of duplication of effort.
- The choice of cloud computing vendor should also take into account the vendor's position on standards, interoperability of data and the use of proprietary software. Adopting cloud computing solutions that use proprietary data formats, software and application programming interfaces (API) risks data lock-in and makes any move to an alternative vendor more difficult.
- The implementation of cloud solutions to replace existing services must be managed and monitored to ensure that the decommissioning of old services actually happens and that an institution is not paying for a dual service. Conversely there may be instances where the original service is scaled down rather than shut down – one activity review participant reported this scenario for the institutional email system – most staff use the cloud-based email service, however a small number of research staff conducting military work must remain using the in-house system as stipulated by the funder. Despite having to maintain a scaled down in-house system, the institution has determined that it is still worthwhile to opt for cloud for the majority of users. Note the importance of managing this situation; ensuring that only those specifically required to use the in-house system do so, and that anyone expected to have this requirement is identified and that funding conditions are never breached. Note also that for this example, end users are unaware of any difference at the point of use as provision is seamless to the end user.
- It is important to ensure that cloud services are used appropriately – it has been suggested that the lack of involvement in provision by internal staff and a perceived reduced responsibility for ICT services could lead to poor housekeeping. For example, if the use of cloud-based services at an institution results in some locally based storage also being used and this is not managed effectively by any staff (ICT or otherwise) it could eventually pose a problem, both in terms of local storage capacity and also the ability to find local data/information.
- There is a trend and expectation for many types of information and media to be delivered on a variety of different devices, for example, mobile phone, computer, internet-enabled TV. This puts pressure on services from universities and colleges to be able to deliver services via these devices. This may in turn result in an expansion of roles for staff within institutional ICT. As staff or students are able to access cloud-based data and applications from anywhere then their working arrangements, patterns and locations may change and become more flexible. A consequence of this could be that students may have less in-person interaction with staff and other students and that some staff could work from home regularly. Institutional policies need to be updated to take into account flexible working and care must be taken to ensure there is enough face-to-face interaction between staff and students.

5.4.2 Roles and Responsibilities

The move to using cloud computing services by educational institutions will have a number of implications for staff and students. This is likely to include changes to methods of working and how ICT is supported, both for ICT staff and end users. Institutional adoption of cloud computing services may change the organisational structure of ICT support, as much of the support function may be transferred to the cloud service provider. Some ICT staff in our activity review expressed concerns

about staff reductions due to the outsourcing of services to the cloud; however most senior IT staff consulted claimed that existing staff roles would change rather than cease to exist.

- In addition to the actual level of service agreed and achieved via cloud computing, the *nature* of service provided to end users should also be considered. For example, would an internal helpdesk still field calls from end users and in turn act as a liaison with external service providers? Or would end users be expected to contact external service providers directly? Changes in organisational structure may well be required.
- Stakeholder discussions revealed the expectation that some existing ICT staff roles would evolve to focus less on technology and more on contract negotiation, developing and monitoring SLAs and tracing faults. Training and staff development support will need to be provided as part of an overarching holistic change management strategy. Further, care needs to be taken to minimise the loss of skills and expertise that are valued by the institution. Concerns from ICT staff relate not only to numbers of staff but also depth of experience [155].
- Changes in ICT services and their delivery may increase training requirements, at least in the first instance. New support material will also need to be developed (user guides, help on web pages). This may be provided externally or in-house, but will have implications for immediate and ongoing staff roles with an institution as old systems are de-commissioned and new systems are introduced.

5.4.3 Working Practices

When considering how cloud computing will affect roles and working practices in HE and FE institutions, a number of activity review respondents felt that significant moves to use cloud computing services would lead to changes in working practices, roles and responsibilities. The flexibility of working afforded by being able to access applications and data from anywhere is generally viewed as a positive change by staff [92, 156]. However, not all institutions have established flexible, location independent working policies and tensions may arise.

Resistance to new working practices afforded by cloud computing may occur. Respondents noted that lack of adoption may arise from a general resistance to change and to using ICT in general. A concern raised at the PESTLE workshop was that once in-house ICT capacity was lost it could be very difficult to revert back. This may be particularly true if buildings are designed for thin-client technology with no cooling systems in-house and no building infrastructure for server rooms.

Further Resources for Overcoming Issues

The JISC-funded Work-with-IT project which examined the evolution of working practice, roles and responsibilities in HE and FE has developed advice and guidance for Staff Development and Change Managers [4].

The framework from the Embedding Work-with-IT project which is seeking to help institutions and professional bodies embed effective practice relating to changing working practices, staff roles and responsibilities will also be of assistance as will the interactive toolkit which is currently being developed [9].

JISC's Information Systems Management and Governance (ISMG) framework and interactive toolkit [12] can be employed to help institutions to reflect on the management and governance of their information systems by thinking in a structured way about what they want to achieve from strategic investments in cloud computing and whether current structures and practices need to be realigned.

JISC infoNet's infoKit on change management [16] also provides a range of useful information and tools.

5.5 Risks

Institutions must consider risks associated with the use of cloud solutions, the risks of staying with the current solution and the risks of other alternatives; i.e. the risks of *not* adopting cloud if an informed assessment is to be made.

- There was in-depth discussion with stakeholders during the project relating to perceived risk versus real business risk. Although the conclusion was that much of the perceived risk is unjustified, the negative perception of institutional stakeholders is itself a real risk; even if fears are unfounded, perceived risk relating to cloud computing could hinder the buy-in required to consider it as a real option and make it a success. While business decisions relating to cloud computing should be based on impartial, factual advice, appropriate communication and change management strategies must be put in place to mitigate against lack of buy-in and other potential socio-cultural risks.
- Business criticality – obviously the more business critical a system or service, the greater the consequences of failure. Institutions must ensure that SLA terms are appropriate, i.e. different services may have different agreed levels of service and penalties for failure, and correspondingly different costs to the institution as a customer.
- Lock-in was identified throughout the project as a major risk of third party provision of any service. This relates not only to contractual lock-in, but circumstantial and/or technical lock-in where an institution's processes have been set to accommodate a particular service provider and it becomes difficult to change them. In particular, loss of in-house skills and capacity were highlighted. There is a potential risk of a huge time and cost investment required to resurrect these if a decision is made in error or if the landscape changes and cloud is no longer the optimum solution. It is interesting to note, however, that some institutions saw the loss of

particular in-house skills as a benefit since the institution no longer had to be responsible for maintaining them and could concentrate more on its preferred areas of growth.

- Security was the top concern for all activity review participants in this study. As above, there has been much discussion of perceived versus actual risk. In the first instance, finance systems were frequently identified as one considered to be unsuitable for cloud-based provision. However during the workshops, discussions developed about the acceptability of internet banking and the fact that security is only as strong as ‘the weakest link in the chain.’ Furthermore, as discussed in subsection 3.3, there has been expert comment [108] that cloud services could actually offer an increased level of security for some institutions, depending on how secure their in-house provision of services and institutional network has been.
- There are risks associated with a changing operating environment and, as with all major business decisions, the business case for any solution must be regularly re-examined in light of the changing landscape to judge its validity on an ongoing basis.
- Legal risks, as discussed in previous sections, are a major issue for cloud computing acceptability and uptake in HE and FE and this was an area identified by most project stakeholders as one where guidance is required. There may be issues relating to jurisdiction, data protection, data ownership, and SLAs. Jurisdiction issues include concerns over government acts that give access to data stored on foreign machines, for example, the USA Patriot Act [116] and the Homeland Security Act [117]. SLAs do not always make clear what rights third party service providers have to use a client’s data and information derived from it (e.g. operational data), including the circumstances under which they can sell it [85]. The legal issues surrounding cloud computing is an area where there is little legal precedent at the moment and caution is recommended. It is recommended that institutions do query where data will be held geographically and whether this is guaranteed. For example, one activity review participant did not enter into a contract with a third party supplier until they had provision to store data within the European Union. Institutions must also check whether they have obligations to fulfil themselves, if mission critical data/information is to be stored in the cloud, institutions must have clear contractual arrangements to allocate responsibility for backup and disaster recovery mechanisms. Institutions must also ensure that they have checked the track record and processes of any supplier, for example that they have multiple sites if providing a core service or storage key data. Definitions in SLAs are equally critical. For example, is the cloud provider’s definition of downtime – service unavailable at all, for 5 minutes or more, for 30 minutes or more, etc – acceptable to the institution?
- As discussed above, the perception of security risk must be managed; however realistically there may be real security risks that must be considered. There are perceptions that cloud computing services are inherently more risky than in-house computing systems, partly due to cloud services being a bigger target. The top threats to cloud computing identified by the CSA in their report in March 2010 [11] are: abuse and nefarious use of cloud computing services, insecure APIs, malicious insiders, shared technology vulnerabilities, data loss/leakage, and account, service and traffic hijacking. Institutions must consult appropriate guidance and liaise with potential service providers regarding their security measures and their adequacy.

Further Resources for Managing Risks

The Cloud Security Alliance (CSA), a non-profit industry body, has produced guidelines for security for those moving services to the cloud [2]. The guide provides practical recommendations and poses key questions to make the transition to cloud computing as secure as possible, on one's own terms. This advice is likely to prove invaluable to those considering using cloud computing services and in their report in March 2010 the CSA claim it has become the industry standard catalogue for best practices.

The CSA have also published a top threats document to *"provide needed context to assist organizations in making educated risk management decisions regarding their cloud adoption strategies"* [11].

Security guidance and recommendations are available in a further report produced by the European Network and Information Security Agency (ENISA) [14].

More generally, JISC infoNet provide a Risk Management infoKit designed to help institutions evaluate their approach to risk and give some practical suggestions on how to manage the risks which they take [17].

Finally, the JISC Legal Service publishes regularly on legal issues for HE and FE and is currently developing a briefing paper on cloud computing. [18]

6 Conclusions, Implications and Recommendations

Having presented the PESTLE analysis of uptake of cloud computing, scenario for future use of cloud computing and high-level advice and guidance for institutions wishing to consider cloud computing, the conclusions of the review and its implications for JISC, institutions, and IT staff briefly considered. This is followed by four recommendations for future work.

6.1 Conclusions

6.1.1 Current Activity within the Sector

While there is much market hype surrounding cloud computing, uptake of cloud computing at an institutional level is not progressing as quickly as the vendor hype might suggest. However, interest in its potential to enable cost-effective improvements in institutional IT services is significant. The most common adoption is cloud-based email for students. In general, institutions are awaiting the results of early adopters foray into cloud computing before committing to moving its more core business processes into the cloud.

6.1.2 Drivers For and Barriers To the Adoption of Cloud Computing

The main drivers for adoption of cloud computing within institutions are economic, relating to the reduction in funding and the need to increase competitiveness through better student and staff experiences. The need to replace aging institutional infrastructures is also a timely influence as is increasing emphasis on greening ICT.

Significant barriers, however, do and will continue to exist. Not least are socio-cultural issues relating to perceived, but not necessarily well-founded, risks associated with cloud computing. In particular, an assumption that the security of data and applications in the cloud is more likely to be compromised than with in-house storage, concern over jurisdiction and privacy of data, and a worry that commercial cloud providers do not sufficiently understand the business requirements of HE and FE, are likely to negatively impact uptake of cloud computing for core institutional services.

Four near-future scenarios for use of cloud computing in HE and FE can be extrapolated from the PESTLE analysis – *The Cloud Workspace*, *Cloud Storage Solutions*, *Cloud-Enabled Learning Environments* and *Academic Clouds*.

While these key drivers, barriers and the scoped scenarios will help institutions decide on the optimal business case for the adoption of cloud computing within their own context, there are two key unknowns which may affect future trends. The impact that the new government will have on the education sector is unclear, as is the impact of the current trend for institutional restructuring.

6.1.3 The Environmental Costs and Benefits of Cloud Computing

The literature survey suggests that cloud computing may reduce the impact of ICT through the coalescing of computing resources in state of the art, energy efficient data centres. Backing up this claim is much more problematic given the difficulty in obtaining figures on energy consumption. Independent analysis of commercial cloud providers' claims is required, as are better methods of attributing energy use to particular IT services within institutions.

Analysis of overall energy consumption relating to a service also needs to take into account system operations and networking contributions, as well the hardware aspect that is typically used. Further, institutions need to take care that the cost-effectiveness of cloud computing does not mean that wasteful and energy inefficient processes are simply being moved to the cloud rather than being reviewed and redesigned.

6.1.4 The Changes to Institutional Governance, Policies, Procedures and Skills required by Adoption of Cloud Computing

As cloud computing offers a new way of sourcing an institution's IT infrastructure, institutions will need to carefully reflect on the management and governance of their information systems. As part of the business case, careful consideration is required regarding whether the strategic investment is compatible with institutional aims and whether current structures and practices will need to change. For many institutions there will be little change required in policy. For example, institutional procurement policies should relate to all IT provision and therefore purchasing a pay-per-use cloud service should be covered by normal consumable policies and procedures. Similarly, acceptable use policies are unlikely to require change.

Where change will be required is if cloud computing is being introduced as part of an overall initiative to reduce inefficiencies. In this case, institutions will need to ensure policies are aligned with this object and prevent individuals or groups circumventing the initiative by procuring duplicate or competing solutions.

New skills will be required. In particular, contract negotiation and servicing will replace more technical systems support for those involved in managing and supporting the IT infrastructure.

6.1.5 Advice and Guidance

Given the early stage of adoption of cloud computing within the academic sector, which is very cautious in scope, it is too early to determine exactly what advice or guidance is required in the longer term. Providing institutions with advice and guidance on how to explore the costs, benefits and implications – i.e. the business case – of adopting cloud within their own institutional context was therefore seen as the most practical way of bringing together the lessons learned from this review.

However, advice on legal issues and the implications relating to data ownership and reuse full implications of cloud contracts is required. As institutions feel ill-equipped to negotiate satisfactory contracts and SLAs, guidance needs to be developed. Similarly, targeted guidance on using the cloud as part of a green ICT strategy is required if sector-wide carbon reduction targets are to be met.

6.1.6 The Business Case for an Academic Sector Cloud

Academic clouds could conceivably be constituted in three ways – *public academic cloud*, *private academic cloud* and *private institutional cloud*. While a private academic cloud has been suggested as a way to minimise many of the perceived risks associated with institutional use of cloud, more detailed consideration revealed that many of the benefits of the cloud would be lost. A public academic cloud is a more viable scenario. However, a more detailed analysis is required before JISC, and the HE and FE sectors, commit to developing such a solution. This decision would have to be

informed by ongoing investigations by JANET(UK) into the implications of large-scale data centres and discussions by JISC industry liaison regarding the cloud industry's interest in such an arrangement. The forthcoming internal JISC workshop on cloud computing should provide an excellent setting to further explore the viability of an academic cloud.

6.1.7 Timeliness of the Review

As the project team has observed in the course of its investigations, the outcome of this review into the environmental and organisational implications of cloud computing within HE and FE, and its sister cloud reviews relating to research, is eagerly awaited by many in the sector. However, as discussed above, given the early and developing nature of cloud usage within the sector, this report cannot answer all the questions. The review has, however, developed a sound basis upon which future work can be built.

6.2 Implications of Cloud Computing for Institutional Activities outside the Research Area

The implications of cloud computing for institutional activities that have been examined throughout this report are summarised below

6.2.1 For Institutions

Institutions and their IT and service managers will need to:

- Better understand their existing ICT costs and how such costs might be apportioned back to cost centres and potentially individual users;
- Develop and then enforce as appropriate a holistic IT strategy which potentially contains in-house and outsourced cloud components;
- Establish the governance and stewardship requirements of their data and information systems;
- Be aware of socio-cultural influence in assessment of benefits and risks;
- Adopt an informed approach to analysing and managing the actual risks associated with cloud computing based on impartial factual advice;
- Manage the change brought about by any move towards cloud effectively;
- Evolve the institutional ICT support structure to accommodate cloud outsourcing as required;
- Be open to exploring how cloud computing could be used to help implement radically different ways of supporting teaching and learning, research, business community engagement and administrative activities.

6.2.2 For IT Staff

IT staff may need to:

- Retrain to develop new skills.

6.2.3 For JISC

Recommendations to JISC are as follows.

- Continue to monitor this evolving computing paradigm;
- Help the academic community to move from limited early adopters to intelligent integration of cloud computing into overall ICT strategies;
- Integrate findings from differing JISC initiatives relating to cloud computing.

6.3 Recommendations for Future Work

Having concluded this review of the environmental and organisational implications of cloud computing in higher and further education, the following recommendations are made to JISC.

6.3.1 Updated Synthesis of Cloud Computing

The advice and guidance contained within the previous section is suitable for the current stage of development of cloud-based services in HE and FE. Earlier sections of this report have given an overview of the current landscape of cloud computing usage within the HE and FE sector; however it should be noted that this landscape is continually changing. Service provision in HE and FE will evolve, particularly in the current difficult economic climate where the landscape of HE and FE may change unpredictably.

In light of this, it is recommended that JISC continues to review the use and potential use of cloud computing, in line with its ongoing sector monitoring and horizon scanning. In particular, a review and synthesis of early adopters of cloud computing is required. It is expected that this will involve a synthesis of work that is already underway and work expected in the near future, such as projects funded by JISC's Grant Call 05/10 [5].

This is in line with workshop and activity review feedback where vendor information was reported to be treated with caution and the most common request was for honest, detailed case studies. Several stakeholders had already consulted with other institutions who are using cloud computing and valued the information from those with experience. Of most benefit would be case studies of institutions that have made the transition to cloud-based services at an institutional level and where green benefits are expected. Case studies would provide a detailed description of an institution's transition to cloud-based provision of a service, including the associated issues in practice and how they are resolved, and the benefits realised by making the transition, including improved greening of ICT.

It is recommended that JISC 'follows the journey' of cloud computing; i.e. it is too early, for example, to develop a JISC infoNet infoKit on cloud computing, however it may be appropriate in the future as its use evolves in HE and FE.

6.3.2 Resolving Legal Issues for Cloud Computing

Many stakeholders participating in this review have suggested that a joint negotiating service may be feasible; one which could jointly negotiate academic provision of cloud computing similarly to the many joint purchasing consortia that exist in HE and FE. It must be considered if the joint negotiation of cloud services is something that can be covered by these existing purchasing consortia, or whether a new model for this is required specifically for cloud, working on behalf of the HE/FE sector or discrete groups within it. The potential for a 'kite mark' system for approved vendors should also be considered

SLAs are a particular potential issue for institutions who have not yet built up expertise in negotiating and enforcing them for cloud services. Again, feedback from the activity review and workshops indicates that advice on developing realistic and reasonable service levels is required, with particular interest in a template for SLA development. Consideration would have to be given to whether any template developed matched with what vendors are willing and able to supply. It is expected that SLAs should include 'green' criteria; the availability of real measurements and data from cloud vendors that proves their green credentials is to be encouraged. Some vendors, for example Google, already do this to some degree [122] and this could prove a selling-point for many vendors. However vendor buy-in will be required for this to be ubiquitous and this will require pressure from HE/FE in conjunction with funding organisations, professional bodies and perhaps even central government.

In addition to the development of SLAs, institutions will also require advice on monitoring and enforcing these agreed levels of service, imposing appropriate penalty clauses as and when necessary.

It is therefore recommended that an investigation of the legal issues surrounding cloud computing is commissioned, covering the possibility of joint negotiation and the development of SLA templates appropriate for HE and FE institutions. This work should be taken forward in conjunction with JISC Legal, who are currently preparing a briefing paper on cloud computing.

6.3.3 Longer Range Cloud Computing Scenario Development

The scenarios developed for this review were extrapolated from the scenario development workshop attended by key sector stakeholders. As noted, throughout this report, current use of cloud in HE and FE is mainly for low risk, standard services such as provision of email. As discussed in section 3, as the sector begins to gain experience in cloud computing, it will be worthwhile revisiting the scenarios to explore what might happen in the next 10-20 years. Indeed, there are researchers who feel that cloud computing provides an opportunity to rethink the whole model of higher education, as a more open-content, inter-university, collaborative vision.

It is recommended that JISC commission a set of bold scenarios which explore how, in the next 20 years, the emerging cloud computing paradigm and related technologies might significantly change how HE and FE institutions undertake teaching and learning, research, business community engagement and administrative activities.

The use of bolder, more extreme scenarios is beneficial as it allows issues to be explored, even if the sector is not (yet) experiencing these radical changes. This is in line with more traditional Scenario Planning techniques; there is great benefit in investigating completely new approaches to which the sector has not yet been exposed.

6.3.4 Enabling the ‘Green Cloud’

As reported in this review, there is often a tacit assumption that cloud computing, by its very nature, is a green solution due to economies of scale. However, it has also been claimed that energy use may simply be moved rather than reduced as a whole. From the consultation work carried out, it is also clear that when moving services to the cloud, existing capacity is often re-purposed rather than de-commissioned, hence a reduction in energy use is not achieved. Furthermore, to enable cloud computing, an organisation’s network capacity may actually increase which will have an implication for energy use, thus use of cloud computing does not make IT greener by default.

A more fundamental issue also needs to be considered. As the recent JISC report on *The ‘greening’ of ICT in education* [157] highlights, the energy usage associated with the data centres and other storage facilities makes a significant contribution to the overall carbon footprint of ICT, and one which is continuing to increase. According to the Green Data Project, “collective failure to apply *data discipline* to our business information system storage – to purge junk data and to archive data with little chance of re-reference onto greener archival media – is what drives the acquisition of more and more energy consuming hardware year after year, increasing exponentially the carbon footprint of IT in the process.”[158]. The danger is that the affordable scalability offered by cloud computing simply enables institutions to keep increasing data without any recourse to its negative environmental impact. As the Green Data Project argues, “Green IT begins with Green Data” [158]. Further, as the JISC-funded study of *Greening Information Management* concluded, implementation of ‘Greening Information Management’ options within an overarching Information Lifecycle Management and stewardship strategy could contribute to a positive environmental impact, provided they are incorporated into institutional policy and endorsed by senior management [159].

It is recommended that JISC investigate how cloud computing can best be exploited in order to make institutional processes and data more green. This work would ideally include an initial scoping study which examines how institutions could use the move to cloud computing to significantly changes their practices in order to produce an overall reduction in carbon footprint, followed by more detailed implementation pilots.

Appendix A: References

1. Office of Government Commerce (OGC), *Managing Successful Projects with PRINCE2: 2009 Edition*. 2009 edition ed. 2009: Stationery Office Books.
2. Cloud Security Alliance (CSA), *Security Guidance for Critical Areas of Focus in Cloud Computing V2.1*. 2009, Cloud Security Alliance. p. 1-76.
3. Nicol, D., M. Coen, and C. Breslin, *INSIGHT : A Framework for Evaluating the Costs and Benefits of ICT Investments in Teaching and Learning*. 2004, JISC/University of Strathclyde.
4. McDonald, D., D. Cullen, and A. Comrie, *Technology-enhanced working: Advice and Guidance for Staff Development and Change Managers*, in *JISC Study into the Evolution of Working Practices*. 2008, University of Strathclyde.
5. JISC. *Grant 05/10: Flexible service delivery programme: Call for projects*. 2010 10th May 2010]; Available from: http://www.jisc.ac.uk/fundingopportunities/funding_calls/2010/04/510fsd.aspx.
6. Spellmann, A., Gimarc, Richard., Preston, Mark.,, *Leveraging the Cloud for Green IT: Predicting the Energy, Cost and Performance of Cloud Computing*, in *CGM 09*. 2009: Dallas, Texas. p. 1-17.
7. JCPSG. *JCPSG:TRAC Guidance* 2010 17th May 2010]; Available from: <http://www.jcpsg.ac.uk/guidance/>.
8. Armbrust, M., et al., *Above the Clouds: A Berkeley View of Cloud Computing*. 2009, Berkeley p. 1-23.
9. University of Strathclyde. *Embedding Work-with-IT*. 2010 15/05/10]; Available from: www.work-with-it.org.uk/embedding.
10. SustelT, *ICT Energy and Carbon Footprinting tool*. 2009.
11. Cloud Security Alliance (CSA), *Top Threats to Cloud Computing V1.0*. 2010, Cloud Security Alliance (CSA). p. 1-14.
12. Coen, M., Cullen, D., Breslin, C., Kelly, U., *A Framework for Information Systems Management and Governance (ISMIG) - Self Assesment Toolkit*. 2007, University of Strathclyde. p. 1-36.
13. University of Strathclyde, *BIILS: Benefits of ICT Investment - Landscape Study: An Evaluation Framework and Toolkit (V 2.2)*. 2008. p. 1-17.
14. European Network and Information Security Agency (ENISA), *Cloud Computing: Benifits, Risks and Recommendations for Information Security*, D. Catteddu, Hogben, Giles.,, Editor. 2009, ENISA. p. 1-125.
15. JISC infoNet. *JISC infoNet - Impact Calculator*. 2009; Available from: <http://www.jiscinfonet.ac.uk/records-management/measuring-impact/impact-calculator>
16. JISC infoNet. *JISC infoNet - Change Management infoKit - Overview and Introduction*. 2007 07/01/10]; Available from: www.jiscinfonet.ac.uk/infokits/change-management.
17. JISC infoNet. *JISC infoNet - Risk Management infoKit*. 2007 13/05/10]; Available from: <http://www.jiscinfonet.ac.uk/InfoKits/risk-management>.
18. JISC Legal. *JISC Legal: Legal Guidance for ICT Use in Education and Research*. 2009 18/01/10]; Available from: <http://www.jisclegal.ac.uk>.
19. University of Strathclyde. *Web Page - Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education* 2010 21 April 2010]; Available from: http://www.strath.ac.uk/learningservices/innovation/innov_projects/cloud/.

20. JISC, *JISC Key Audience Survey 2008/9*. 2009. p. 1-41.
21. JISC, *JISC Attitudinal Survey 2008: Head and Senior Learning and Library Staff*. 2008, JISC. p. 1-72.
22. JISC, *Invitation to Tender: Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education*. 2009. p. 1-19.
23. JISC, *Invitation to Tender: Using Cloud Computing for Research*. 2009. p. 1-14.
24. JISC, *Invitation to Tender: Technical Review of Cloud Computing for Research*. 2009. p. 1-14.
25. Kolowich, S. (2009) *Amazon Offers Educational Grants for 'Cloud Computing' Access*. The Chronicle of Higher Education.
26. JISC and UCISA. *Outsourcing Email and Data Storage briefing papers*. 2010; Available from: <http://www.jisc.ac.uk/publications/documents/bpoutsourcingv1.aspx>.
27. University of Strathclyde. *Greening Information Management - Home page*. 2009; Available from: <http://www.greeningim.org.uk/>.
28. McDonald, D., et al., *Greening Information Management: a focussed literature and activity review*. 2009, University of Strathclyde. p. 1-42.
29. JISC CETIS. *Cloud Computing*. 2010; Available from: http://jisc.cetis.ac.uk/topic/cloud_computing.
30. Kraan, W. and Yuan. Li. *Cloud Computing Briefing Paper*. 2009; Available from: http://docs.google.com/View?id=dgssm42h_13gm33jfdg.
31. University of Strathclyde. *Work-with-IT:JISC Study into the Evolution of Working Practice*. 2010; Available from: <http://www.work-with-it.org.uk/Home.aspx>.
32. University of Southampton. *TeciRes: Technical review of using cloud for research - website*. 2010; Available from: <http://tecires.ecs.soton.ac.uk/index.php>.
33. JISC. *Using Cloud Computing for Research - Web Page*. 2009 April 21, 2010]; Available from: <http://www.jisc.ac.uk/whatwedo/programmes/researchinfrastructure/usingcloudcomp.aspx>.
34. University of Strathclyde. *Review of the Environmental and Organisational Implications of Cloud Computing in Higher and Further Education*. 2009-2010 13/05/10]; Available from: http://www.strath.ac.uk/learningservices/innovation/innov_projects/cloud/.
35. Mohamed, A., *A history of cloud computing*, in *ComputerWeekly.com*. 2009.
36. Delic, K.A. and M.A. Walker, *Emergence of the Academic Computing Clouds*. Ubiquity, 2008. 9(31).
37. O'Neill, N. *GridPP - UK Computing for Particle Physics*. 2010; Available from: <http://www.gridpp.ac.uk/>.
38. Wallis, P., *A Brief History of Cloud Computing: Is the Cloud There Yet?* 2008, Cloud Computing Journal.
39. Salesforce.com. *Application Development with Force.com's Cloud Computing Platform - salesforce.com*. 2010 28th April 2010]; Available from: <http://www.salesforce.com/platform/>.
40. AWS. *Amazon Web Services*. 2010 4th May 2010]; Available from: <http://aws.amazon.com>.
41. AWS. *Amazon Elastic Compute Cloud Amazon (EC2)*. 2010; Available from: <http://aws.amazon.com/ec2/>.
42. Hein, T., *BEING GREEN Comes Naturally*. Baseline, 2008. 91: p. 40-42.
43. Anderson, P., et al., *Low Carbon Computing: a view to 2050 and beyond*. 2009, JISC Techwatch. p. 1-89.
44. Google. *Google Apps for Business*. 2010 28th April 2010]; Available from: <http://www.google.com/apps/intl/en/business/index.html>.
45. Google. *Gmail: Email from Google*. 2010 4th May 2010]; Available from: mail.google.com
46. Microsoft. *Microsoft Dynamics*. 2010 4th May 2010]; Available from: <http://www.microsoft.com/dynamics/en/gb/default.aspx>.
47. Geelan, J., *Twenty-One Experts Define Cloud Computing*. Cloud Computing Journal, 2009.

48. Ellison, L., *What the Hell is Cloud Computing?* 2008, YouTube.
49. Mell, P. and T. Grance (2009) *The NIST Definition of Cloud Computing (Version 15, 10-7-09)*. 1-2.
50. Gartner Group. *Gartner Highlights Five Attributes of Cloud Computing (Press release 23/06/09)*. 2009; Available from: <http://www.gartner.com/it/page.jsp?id=1035013>.
51. Laird, P. *Laird OnDemand: Cloud Computing Taxonomy*, at Interop Las Vegas, May 2009. 2009; Available from: <http://peterlaird.blogspot.com/2009/05/cloud-computing-taxonomy-at-interop-las.html>.
52. NetSuite Inc. *Business Software, ERP Software, Business Accounting Software, CRM and ERP Business Software: NetSuite*. 2010 28th April 2010]; Available from: <http://www.netsuite.com/portal/home.shtml>.
53. Concur Technologies Inc. *Concur, click. done. Corporate Travel and Expense Management*. 2010 28th April 2010]; Available from: <http://concur.com/>.
54. Caspio Inc. *Platform-as-a-Service for Creating Web Database Applications and Forms: Caspio Web Database Platform*. 2010 28th April 2010]; Available from: <http://www.caspio.com/>.
55. Intuit Inc. *Online Database - Web Based Database Software: Intuit QuickBase*. 2010 28th April 2010]; Available from: <http://quickbase.intuit.com/>.
56. WorkXpress. *WorkXpress*. 2010 28th April 2010]; Available from: <http://www.workxpress.com/>.
57. Google. *Google App Engine*. 2010 28th April 2010]; Available from: https://www.google.com/accounts/ServiceLogin?service=ah&continue=http://appengine.google.com/_ah/login%3Fcontinue%3Dhttp://appengine.google.com/start<mpl=ae&sig=ec11c91820d7b1b72bdfad022767a603.
58. Apprenda Inc. *Apprenda - Enabling Software as a Service*. 2010 28th April 2010]; Available from: <http://apprenda.com/>.
59. Microsoft. *Microsoft Azure Platform*. 2010 28th April 2010]; Available from: <http://www.microsoft.com/windowsazure/>.
60. Rackspace. *Rackspace Cloud*. 2010 28th April 2010]; Available from: <http://www.rackspacecloud.com/>.
61. Eucalyptus Systems. *Eucalyptus: Your Environment*. 2010 28th April 2010]; Available from: <http://www.eucalyptus.com/>.
62. University of Chicago. *Nimbus*. 2010 28th April 2010]; Available from: <http://www.nimbusproject.org/>.
63. Enomaly Inc. *Enomaly: Elastic Cloud Computing Platform*. 2009 28th April 2010]; Available from: <http://www.enomalism.com/>.
64. AWS. *Amazon Simple Storage Service (Amazon S3)*. 2010 28th April 2010]; Available from: <http://aws.amazon.com/s3/>.
65. Google. *Google Research Publication: BigTable*. 2010 28th April 2010]; Available from: <http://labs.google.com/papers/bigtable.html>.
66. Microsoft, *SQL Server Data Services Solution Overview*, Microsoft, Editor. 2009. p. 1-2.
67. AWS. *Amazon Simple Queue Service (Amazon SQS)*. 2010 28th April 2010]; Available from: <http://aws.amazon.com/sqs/>.
68. Boomi. *Boomi - The Integration Cloud Company*. 2009 28th April 2010]; Available from: <http://www.boomi.com/>.
69. Microsoft. *.NET Services*. 2009 28th April 2010]; Available from: <http://www.microsoft.com/biztalk/en/us/netservices.aspx>.
70. Aria Systems Inc. *Aria Systems: Billing & Subscription Management, SaaS Billing, On-Demand Billing, Recurring Billing, Subscription Billing, CRM*. 2010 28th April 2010]; Available from: <http://www.ariasystems.com/>.

71. Evapt Inc. *Subscription Management, Usage Metering & Recurring Billing Platform for cloud Computing, Web 2.0 and On-demand Service Provider*. 2009 28th April 2010]; Available from: <http://www.evapt.com/>.
72. Vindica Inc. *Vindicia: On demand strategic billing solutions for online merchants*. 2010 28th April 2010]; Available from: <http://www.vindicia.com/>.
73. eNstratus Networks. *Governance For The Cloud*. 2010 28th April 2010]; Available from: <http://enstratus.com/>.
74. Ping Identity Corporation. *The PingFederate Internet Identity Security Platform* 2010 28th April 2010]; Available from: <http://www.pingidentity.com/our-solutions/pingfederate.cfm?>
75. Symplified Inc. *Cloud Security Company: Symplified*. 2010 28th April 2010]; Available from: <http://www.symplified.com/>.
76. 3tera Inc. *Cloud Computing without Compromise: 3tera*. 2010 28th April 2010]; Available from: <http://3tera.com/>.
77. Cloudkick. *cloudkick: the best way to manage the cloud*. 2010 28th April 2010]; Available from: <https://www.cloudkick.com/>.
78. RightScale Inc. *Cloud Computing Management Platform by RightScale*. 2010 28th April 2010]; Available from: <http://www.rightscale.com/>.
79. Hosts Unlimited. *Hosts Unlimited UK Cloud Computing*. 2010 5th May 2010]; Available from: <http://www.hosts-unlimited.com/>.
80. NASA. *NASA Nebula - Cloud Computing*. 2009 5th May 2010]; Available from: <http://nebula.nasa.gov/>.
81. Chatfield, C. *Rice's Private Cloud*. 2009 12th May 2010]; Available from: <https://docs.rice.edu/confluence/display/ITTUT/Rice%27s+Private+Cloud>.
82. Towns, S. *Google Launch Government Cloud*. 2009 4th May 2010]; Available from: <http://www.govtech.com/gt/724044>.
83. O'Reilly, T. (2005) *What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*.
84. Anderson, P., *What is Web 2.0: ideas, technologies and implications for education*. 2007, JISC Technology & Standards Watch. p. 1-64.
85. Mowbray, M., *The Fog over the Grimpen Mire: Cloud Computing and the Law*. SCRIPTed, 2009. 6(1): p. 133-146.
86. JISC infoNet. *PESTLE and SWOT Analyses. Tools & Techniques* 2009 07/01/10]; Available from: <http://www.jiscinfonet.ac.uk/tools/pestle-swot>.
87. Cabinet Office. *Government Cloud (G-Cloud)*. 2010 28/04/2010]; Available from: http://www.cabinetoffice.gov.uk/cio/ict/ict_strands/g_cloud.aspx.
88. Bellamy, M. *Bellamy gives Cloud crowd a G-Cloud update*. 2009; eGov Strategy]. Available from: <http://www.publictechnology.net/print.php?sid=22046>.
89. Gibbs, L., *Activity Review Interview, Laura Gibbs, IT Director, Royal Holloway University of London*, C. Breslin, Editor. 2010.
90. McDonald, D., D. Cullen, and A. Comrie, *Final Report on the JISC Study into Evolution of Working Practices*. 2009, JISC.
91. JISC. *JISC: Flexible Service Delivery Programme*. 2010 10th May 2010]; Available from: <http://www.jisc.ac.uk/whatwedo/programmes/flexibleservicedelivery.aspx>.
92. McDonald, D., D. Cullen, and A. Comrie, *Final report of Work-with-IT: A JISC Study into Evolution of Working Practices*. 2009.
93. Womack, J.P. and D.T. Jones, *Lean thinking: banish waste and create wealth in your corporation*. 2003, London: Simon & Schuster UK Ltd.
94. Microsoft. *Free hosted email accounts for all students : Live@edu : Microsoft Corporation*. 2009 5th May 2010]; Available from: <http://www.microsoft.com/liveedu/free-hosted-student-email.aspx>.

95. Jaeger, P.T., et al., *Where is the cloud? Geography, economics, environment, and jurisdiction in cloud computing*. First Monday, 2009. **14**(5).
96. Sultan, N., *Cloud computing for education: A new dawn?*. International Journal of Information Management, 2009. **In Press**.
97. Scarrott, M., *Activity Review Interview, Martin Scarrott, Acting Director of Information Services & Systems, St Mary's University College Twickenham*, A. MacDonald, Editor. 2010.
98. McDonald, D., C. Breslin, and A. MacDonald, *Environmental and Organisational Impact of Cloud Computing: PESTLE Workshop*. 2010.
99. Bryenton, P., *Activity Review Interview, Peter Bryenton, IT Teacher, New College Worcester* A. MacDonald, Editor. 2010.
100. Parrett, J., *Activity Review Interview, Julian Parrett, IT Support Manager, Cheadle and Marple Sixth Form College*, C. Breslin, Editor. 2010.
101. Kambil, A., *Ahead in the Clouds*. Journal of Business Strategy, 2009. **30**(4): p. 58-59.
102. JISC. *Study of Ownership and Responsibility for Energy Costs*. 2010 10th May 2010]; Available from: <http://www.jisc.ac.uk/whatwedo/programmes/greeningict/recso.aspx>.
103. JISC. *Business & Community Engagement Programme*. 2009 12/12/09]; Available from: <http://www.jisc.ac.uk/whatwedo/programmes/bce.aspx>.
104. University of Strathclyde. *Impact of HEIs on Regional Economies Initiative* 2007 10th May 2010]; Available from: <http://ewds.strath.ac.uk/Default.aspx?alias=ewds.strath.ac.uk/impact>.
105. Microsoft. *SkyDrive - Windows Live*. 2010 5th May 2010]; Available from: <http://skydrive.live.com/>.
106. HEFCE. *The National Student Survey*. 2010 18/01/10]; Available from: <http://www.thestudentsurvey.com/>.
107. McDonald, D., C. Breslin, and A. MacDonald, *Environmental and Organisational Impact of Cloud Computing: Scenario Development Workshop*. 2010.
108. Breslin, C., McDonald, Diane., Perry, Dan., Bristow, Rob., Hawker, Alex., Wallace, John., *Cloud Computing: Telephone Conference Call*. 2010.
109. McIntosh, E., *Activity Review Interview, Eric McIntosh, Technology Architect, City University London*, A. MacDonald, Editor. 2010.
110. OCC. *Open Cloud Consortium*. 2010; Available from: <http://opencloudconsortium.org/>.
111. CCIF. *Cloud Computing Interoperability Forum (CCIF)*. 2009; Available from: <http://www.cloudforum.org/>.
112. Schubert, L., *The Future of Cloud Computing: Opportunities for European Cloud Computing Beyond 2010*. 2010, European Commission. p. 1-71.
113. JISC. *Introduction to the Federated Access Management in the UK*. 2010 10th May 2010]; Available from: <http://www.jisc.ac.uk/whatwedo/themes/accessmanagement/federation/about.aspx>.
114. Reichman, A., *Business Users Are Not Ready For Cloud Storage* 2010, Forrester Research.
115. Pariseau, B., *TheInfoPro and Forrester say cloud storage is way overrated*, in *Storage Soup*. 2010.
116. US Government. *USA Patriot Act*. 2001; Available from: <http://epic.org/privacy/terrorism/hr3162.html>.
117. US Government, *Homeland Security Act*, D.o.H. Security, Editor. 2002: USA. p. 1-187.
118. Sommerville, I., *Socio-technical issues around Cloud Computing. (Short thought paper)*. 2009.
119. Watt, S., *Activity Review Interview, Steven Watt, Chief Information Officer, University of St Andrews*, C. Breslin, Editor. 2010.
120. Anderson, P., et al., *Low Carbon Computing: a view to 2050 and beyond (Executive Summary)*. 2009, JISC Techwatch. p. 1-4.
121. HEFCE, *Carbon reduction target and strategy for higher education in England*. 2010.

122. Google. *Going Green at Google: Clean Energy Initiatives*. 2010 [cited 2010 March 30, 2010]; Available from: <http://www.google.com/corporate/green/datacenters/measuring.html>.
123. Singh, T. and P.K. Vara, *Smart Metering the Clouds*, in *Enabling Technologies: Infrastructures for Collaborative Enterprises*, 2009. WETICE '09. 18th IEEE International Workshops on. 2009. p. 66-71.
124. Lucas, T., *What is so green about cloud computing?* 2009. p. 1-9.
125. JISC infoNet. *What is Scenario Planning*. 2009 5th May 2010]; Available from: <http://www.jiscinfonet.ac.uk/tools/scenario-planning>.
126. JISC. *Scenario Planning*. 2010 13th May 2010]; Available from: <http://www.jisc.ac.uk/whatwedo/programmes/staffroles/scenarioplanning.aspx>.
127. Google. *Google Apps for Education - Free hosted email (Gmail) for EDU*. 2009 10th May 2010]; Available from: <http://www.google.com/a/help/intl/en/edu/index.html>.
128. The Open University. *Google Apps for Education adopted by the OU: Platform-Open University Community*. 2010 10th May 2010]; Available from: <http://www.open.ac.uk/platform/news/ou-news/google-apps-education-adopted-ou>.
129. Educause, *7 things you should know about Google Apps*, educause, Editor. 2008, Educause Learning Initiative. p. 1-2.
130. IBM. *IBM collaboration software - Lotus software*. 2010 10th May 2010]; Available from: <http://www-01.ibm.com/software/lotus/>.
131. Fronter AS. *Fronter - Learning Together*. 2010 10th May 2010]; Available from: <http://com.fronter.info/>.
132. OpenOffice.org. *OpenOffice.org - The Free and Open Productivity Suite*. 2010 10th May 2010]; Available from: <http://www.openoffice.org/>.
133. Schadler, T. *Should Your Email Live In The Cloud? A Comparative Cost Analysis - Forrester Research*. 2009 10th May 2010]; Available from: http://www.forrester.com/rb/Research/should_email_live_in_cloud_comparative_cost/q/id/46302/t/2.
134. Sclater, N., *OU adopts Google Apps for Education*, in *virtual learning*. 2010.
135. Miles-Board, T. *EPrints Services*. 2010 12th May 2010]; Available from: <http://www.eprints.org/services/>.
136. AWS. *Amazon Elastic Block Storage*. 2010 12th May 2010]; Available from: <http://aws.amazon.com/ebs/>.
137. Boles, J. *The benefits of cloud-based storage, part 2*. 2010 12th May 2010]; Available from: http://www.infostor.com/index/articles/display/0567106142/articles/infostor/backup-and-recovery/cloud-storage/the-benefits_of_cloud-based.html.
138. King, J., *5 key questions about cloud storage*, in *Computerworld*. 2009, Computerworld. p. 1-3.
139. DuraSpace. *DuraCloud*. 2010 13/05/10]; Available from: <http://www.duraspace.org/duracloud.php>.
140. Blackboard Inc. *Blackboard Learn Managed Hosting*. 2010 10th May 2010]; Available from: <http://www.blackboard.com/Teaching-Learning/Services/Managed-Hosting.aspx>.
141. Jasig. *Unicon Announces New Hosting Services for Sakai and Moodle Open Source Learning Management Systems*. 2009 10th May 2010]; Available from: <http://www.jasig.org/unicon-announces-new-hosting-services-sa>.
142. Sakai Foundation. *Sakai Project - an Open Source suite of learning, portfolio, library and project tools: Sakai Project*. 2010 10th May 2010]; Available from: <http://sakaiproject.org/>.
143. Moodle. *Moodle.org: open-source community-based tools for learning*. 2010 10th May 2010]; Available from: <http://moodle.org/>.
144. Liber, O. *PLE Project Summary*. 2005 10th May 2010]; Available from: http://zope.cetis.ac.uk/members/ple/resources/ple_summary.
145. Malik, M., *Cloud Learning Environment - What is it?*, in *EduBlend*. 2010.

146. Chatfield, C. *Cloud Computing - ITTutorials - Confluence*. 2009 12th May 2010]; Available from: <https://docs.rice.edu/confluence/display/ITTUT/Cloud+Computing>.
147. Thomas, B., *How Cloud, Private Cloud & Utility Infrastructure Are Different*, in *private cloud*. 2010.
148. Wheeler, B., and Waggener, Shelton., , *Above-campus services: Shaping the promise of cloud computing for higher education*. EDUCAUSE Review, 2009. **44**(6): p. 52-66.
149. Katz, R.N., *The Tower and The Cloud: Higher Education in the age of Cloud Computing*, R.N. Katz, Editor. 2008, EDUCAUSE.
150. HEFCE, *Feasibility Study Shared Services Data Centre*. 2009.
151. Young, J.R., *3 Ways That Web-Based Computing Will Change Colleges--And Challenge Them*. The Chronicle of Higher Education, 2008. **55**(10).
152. JISC, *Blue sky thinking or head in the clouds*, in *JISC Inform*. 2009. p. 14-15.
153. Berl, A., et al., *Energy-Efficient Cloud Computing*. The Computer Journal, 2009. **Accepted for publication** p. 1-15.
154. Doyle, E., *The Green Jungle*, in *Computer Weekly*. 2008.
155. Yates, C., *Activity Review Interview, Chris Yates, Head of ILT Services, Shipley College*, A. MacDonald, Editor. 2010.
156. Coventry University. *Location Independent Working*. Work-with-IT: JISC Study into the Evolution of Working Practices 2008 07/01/10]; Available from: <http://www.work-with-it.org.uk/CaseStudies/LocationIndependentWorking.aspx>.
157. James, P. and L. Hopkinson, *Sustainable ICT in Further and Higher Education*. 2009.
158. The Data Management Institute. *The Green Data Project*. 2007 01/09/09]; Available from: <http://www.greendataproject.org/>.
159. McDonald, D., E. McCulloch, and A. MacDonald, *Greening Information Management: Final report*. 2009, University of Strathclyde. p. 1-42.
160. JISC. *Glossary*. 2010 12th May 2010]; Available from: <http://www.jisc.ac.uk/aboutus/glossary.aspx>.
161. Hogan, N., *Activity Review Interview, Nicola Hogan, Sustainable ICT project manager, EAUC*, A. MacDonald, Editor. 2010.
162. Cobb, N., *Activity Review Interview, Nathan Cobb, e-Learning Manager, Uxbridge College*, A. MacDonald, Editor. 2010.
163. Hidlebaugh, D., *Activity Review Interview, Dr Daniel Hidlebaugh, Director of Network Services, Hertford Regional College*, A. MacDonald, Editor. 2010.
164. Aldridge, S., *Activity Review Interview, Steve, Aldridge, Head of PC Team/ Network & Infrastructure Team, University of Liverpool*, A. MacDonald, Editor. 2010.
165. Hayes, A., *Activity Review Interview, Aline Hayes, Director of Information Systems and Technology, Sheffield Hallam University*, D. McDonald, Editor. 2010.
166. Wilcox, M., *Activity Review Interview, Mick Wilcox, Head of IT, Oaklands College*, A. MacDonald, Editor. 2010.
167. Gallacher, J., *Activity Review Interview, Dr John Gallacher, Director of Finance, York St John University*, C. Breslin, Editor. 2010.

Appendix B: Technical Glossary

See also JISC's Glossary [160].

Application Programming Interface (API) – The interface (calling conventions) by which an application program accesses operating system and other services.

Application Service Provision (ASP) – Application service provision is a deployment option that delivers software as a service.

Graphical User Interface (GUI) – The use of pictures rather than just words to represent the input and output of a program. A program with a GUI runs under a windows-based system. The program displays certain icons, buttons, dialogue boxes, etc. in its windows on the screen and the user controls it mainly by moving a pointer on the screen and selecting certain objects by pressing buttons on the mouse while the pointer is pointing at them.

Grid Computing – Allows computing and data resources to be shared by scientists and engineers to tackle problems which are too large for their local resources. A Grid is a loose collection of processors, storage, specialised hardware and network infrastructure.

Load-balanced – Balancing a workload amongst multiple computer devices, for example, virtual servers or servers.

Power Usage Effectiveness (PUE) –A metric used to determine the energy efficiency of a data centre. PUE is determined by dividing the amount of power entering a data centre by the power used to run the computer infrastructure within it. PUE is therefore expressed as a ratio, with overall efficiency improving as the quotient decreases toward 1.

Software as a Service (SaaS) – A software distribution model in which applications are hosted by a vendor or service provider and are made available to customers, on demand, over a network, typically the Internet. The supplier manages the process in a secure central location. No software is installed on the premises of the purchaser.

Thin Client – A simple client program or hardware device which relies on most of the function of the system being in the server.

Virtualisation –Can refer to a variety of computing concepts, but it usually refers to running multiple operating systems on a single machine. While most computers only have one operating system installed, virtualisation software allows a computer to run several operating systems at the same time. One physical server may have a number of virtual servers hosted on it.

Virtual Server – A server, usually a Web server, that shares computer resources with other virtual servers. In this context, the *virtual* part simply means that it is not a dedicated server -- that is, the entire computer is not dedicated to running the server software.

Appendix C: Survey Findings

About survey respondents

Of the respondents to the cloud computing survey over half were in ICT roles with a third being institutional ICT Directors (see Figure 1). The remaining respondents included an e-learning manager, an estates director, academics, a finance director, a technology architect and a sustainable ICT project manager. The respondents were overwhelmingly from England (15 out of 16) with one from Scotland and none from Wales or Northern Ireland.

Over half the respondents were from higher education with over a third from further education (FE). Survey respondents also included one person from an association – the Environmental Association of Universities and Colleges (EAUC)[161] (see Figure 2).

Figure 1 – Organisational role of survey respondents

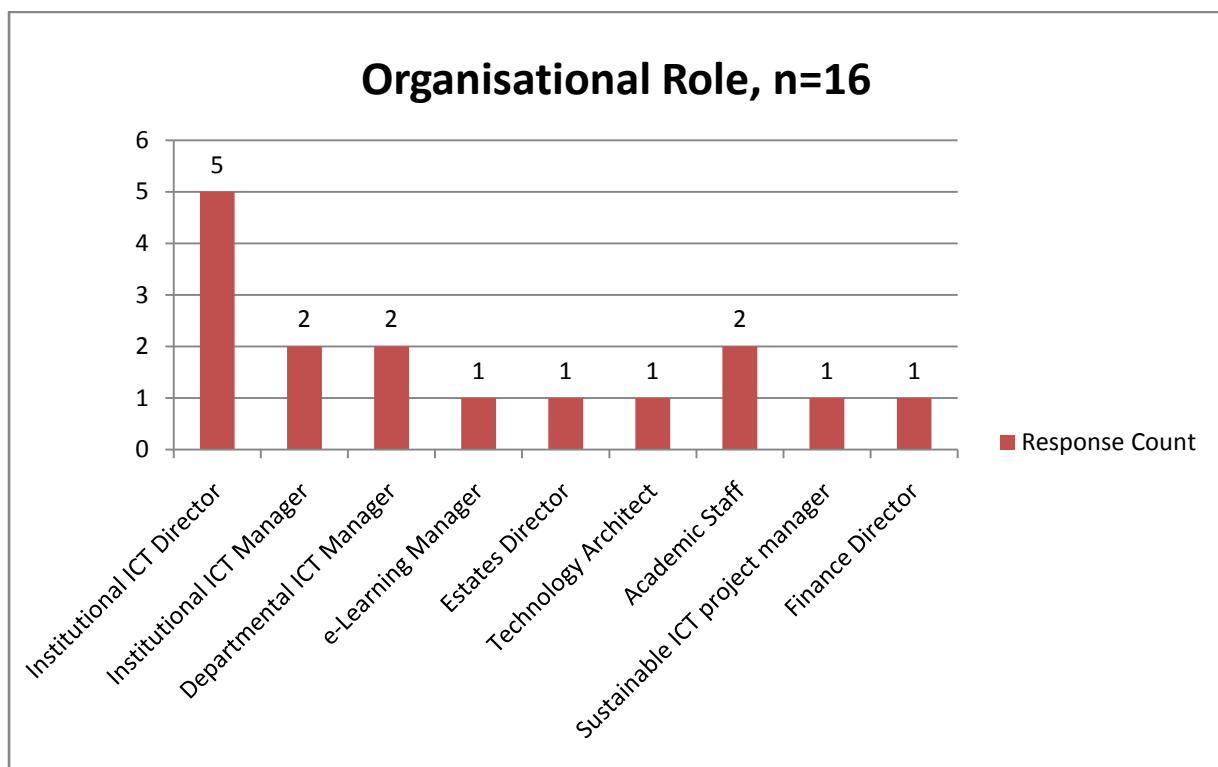
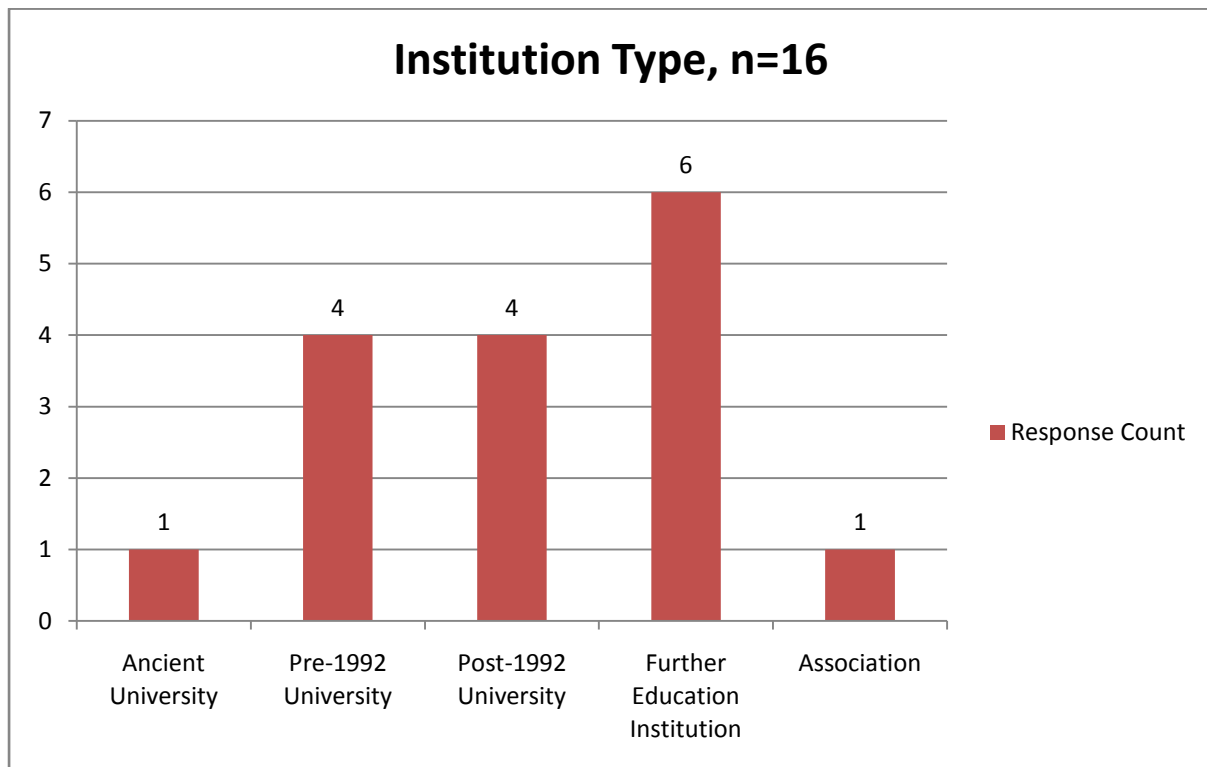


Figure 2 – Survey respondents' institution type

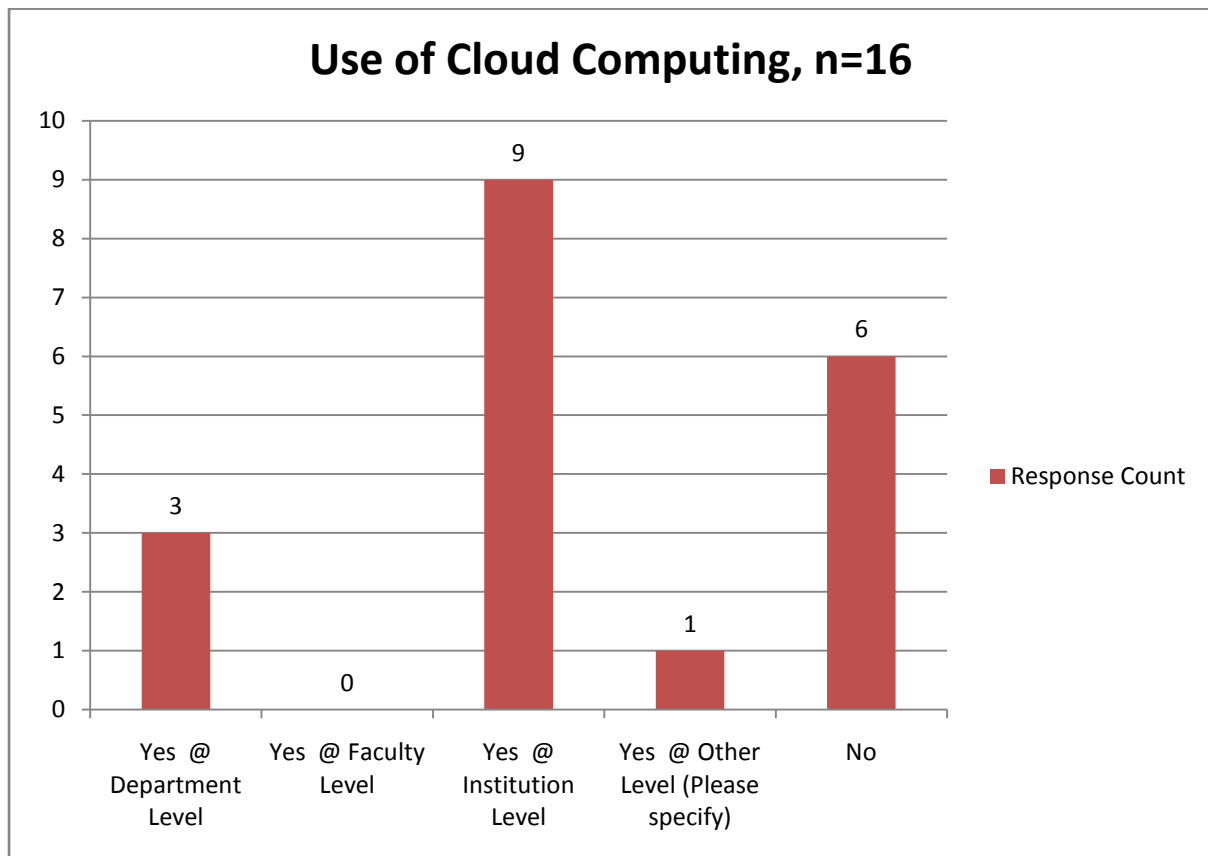


Use of Cloud Computing

Of the institutions in which the interviewees worked, over half (10) are using cloud computing at some level with 6 currently not using cloud computing services. From all the survey respondents 3 used cloud computing at the department level, none at faculty level and 9 at institutional level, with a number using services at both departmental and institutional level (see figure 3).

Of those institutions currently not using cloud computing only two are not currently considering cloud services (University of Surrey, Uxbridge College [162]). Of the remainder, one is planning a private cloud (Hertford Regional College [163]), another is due to migrate student email this year (St Mary's University College [97]) and another is considering cloud services for storage (University of Liverpool [164]).

Figure 3 – Use of cloud computing

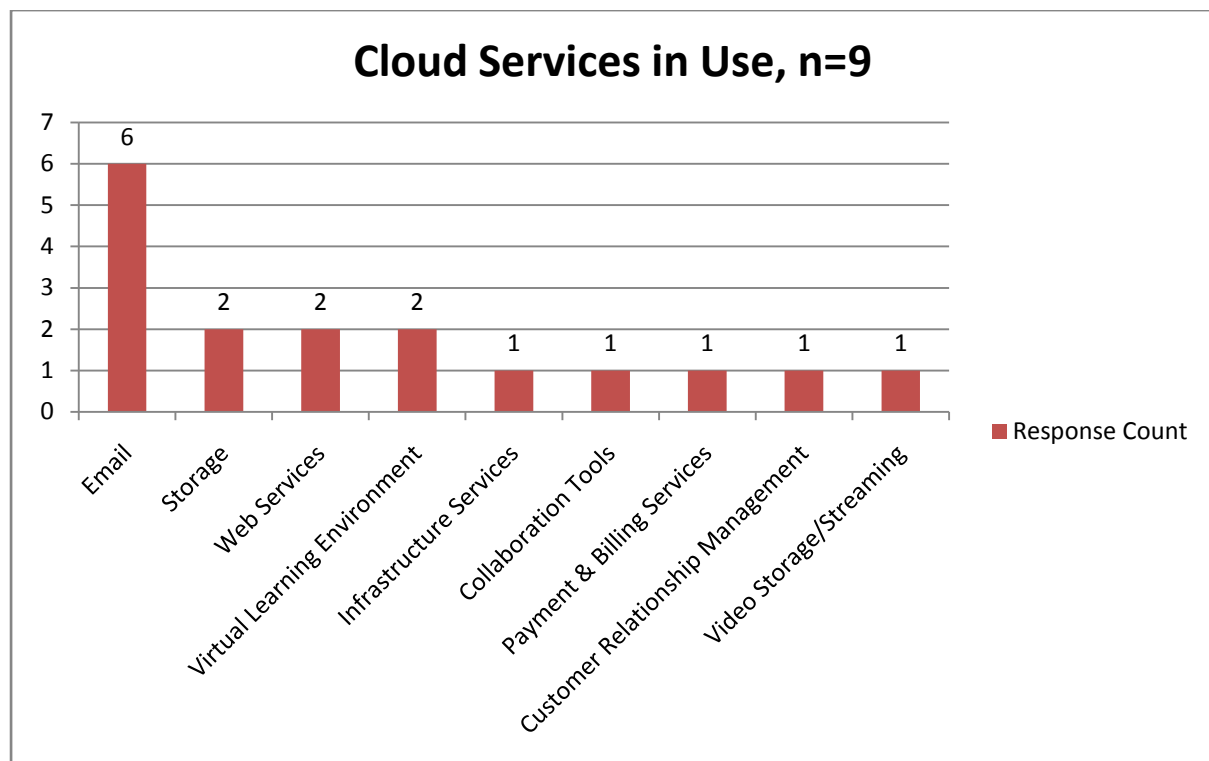


The most common reasons given for not using cloud computing were security concerns and the requirement that cloud-based services fit with institutional IT strategies. Other reasons given included the cost, lack of expertise, legal concerns, stakeholder perceptions, the need to build up a case for use, continuity of service, political considerations and recent restructuring making further changes unlikely anytime soon.

Of those respondents already using cloud computing services, the areas of concern were security, and legal and stakeholder perceptions, with half of those using cloud computing services concerned with security and also legal issues. Stakeholder perceptions were a concern for 3 (out of 10) of those using cloud computing. Of those that commented, two indicated that all areas should be considered for cloud services as all areas should be secure. Others indicated that payroll, finance, registry and critical systems, or anything with confidential materials, should not be considered for outsourcing to cloud services. Other concerns were protection of data from data mining and the perceptions of senior management that cloud-based services are more dangerous than in-house.

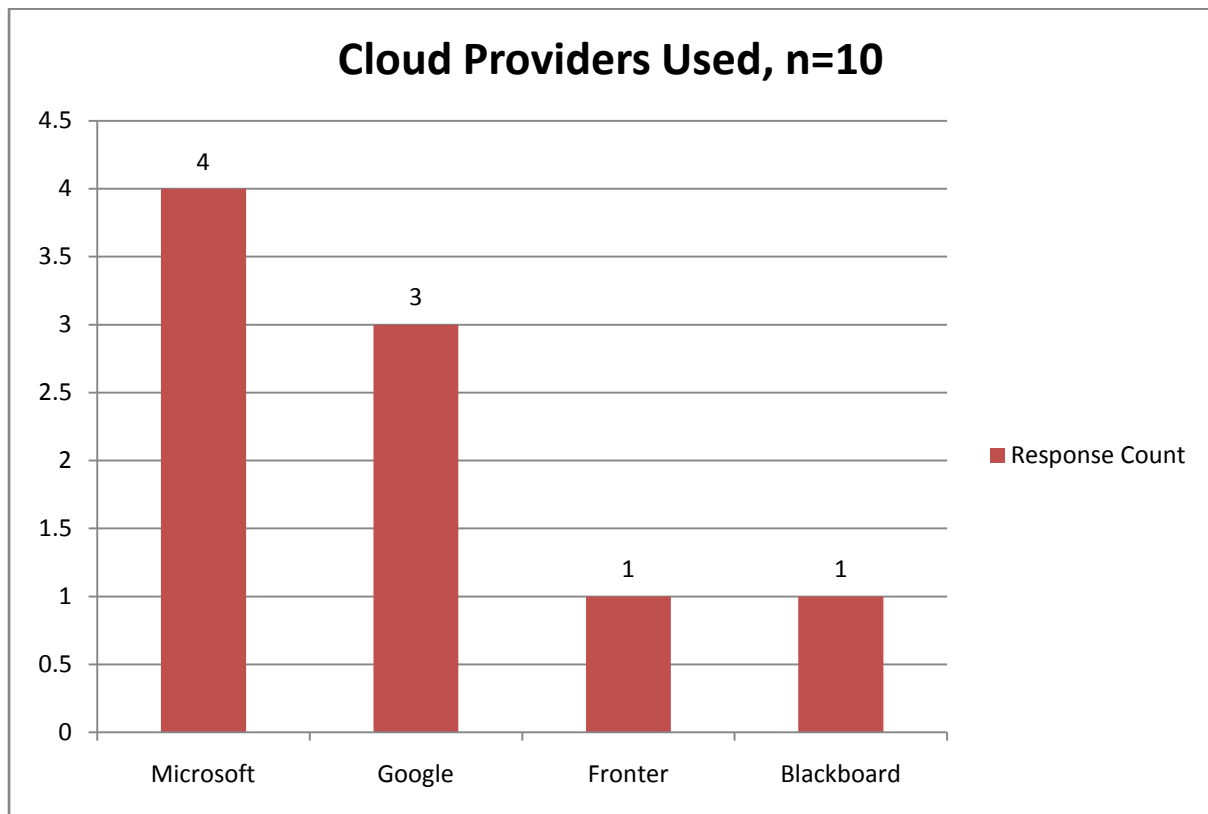
Of the cloud computing services that are currently used, two thirds of those that responded indicated that they were using cloud email services for student email (see Figure 4). The next most used services are storage (2), web services (2), and virtual learning environments (VLEs) (2). Other cloud services in use are: infrastructure services, collaboration tools, a customer relationship management system (CRM), payment and billing services and a video storage and streaming service. Three of the 6 institutions using cloud services for student email are from higher education (HE), 3 are from further education (FE).

Figure 4 – Cloud services in use



Institutions using cloud services for student email are split between Google [45] and Microsoft [94] with 3 using Google (Sheffield Hallam University [165], University of St Andrews [119], New College Worcester [99]) and 3 using Microsoft (Royal Holloway University of London [89], Oaklands College [166], Cheadle and Marple College [100]). Other cloud service providers are Fronter [131] for a virtual learning environment (VLE) (Shipleigh College [155]) and Microsoft again, for a Customer Relationship Management solution - Microsoft Dynamics [46] (City University London [109]). Another institution uses Blackboard [140] for a hosted VLE (York St John University [167]) (see Figure 5).

Figure 5 – Cloud providers used by HE/FE institutions



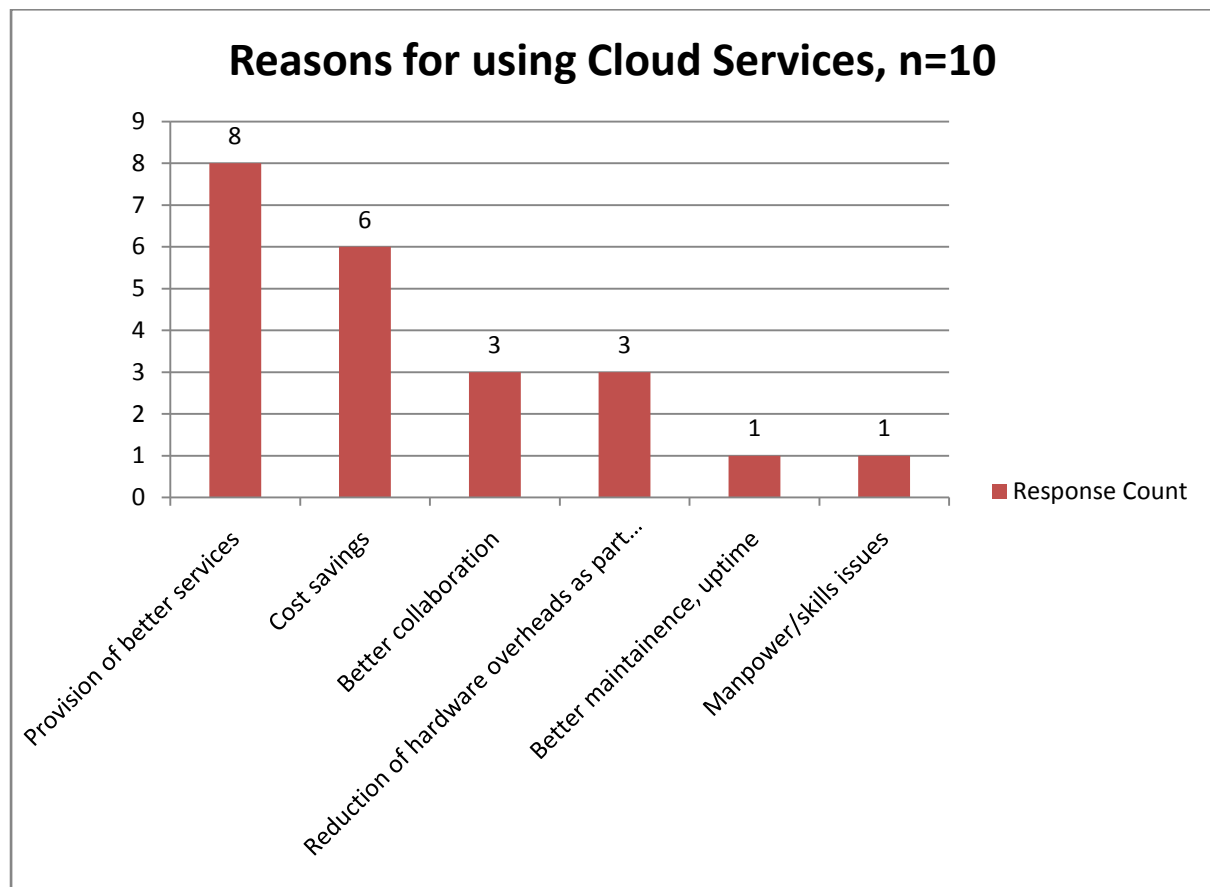
Contracts with Providers

Seven out of the 10 institutions in the survey that are currently using cloud computing services indicated they have contracts with the service providers and of those that have contracts 3 involved other departments within the institution for approval of the contract.

Reasons for using Cloud Services

The most common reason given for using a cloud computing service/vendor is the provision of a better service, with 8 out of 10 of those using cloud services citing this as the motivator. Cost is the next most common reason given (6) followed by better collaboration (3) and a reduction of hardware overheads as part of a green IT strategy (3). Other reasons given include manpower/skills issues and guaranteed uptime/availability (See Figure 6).

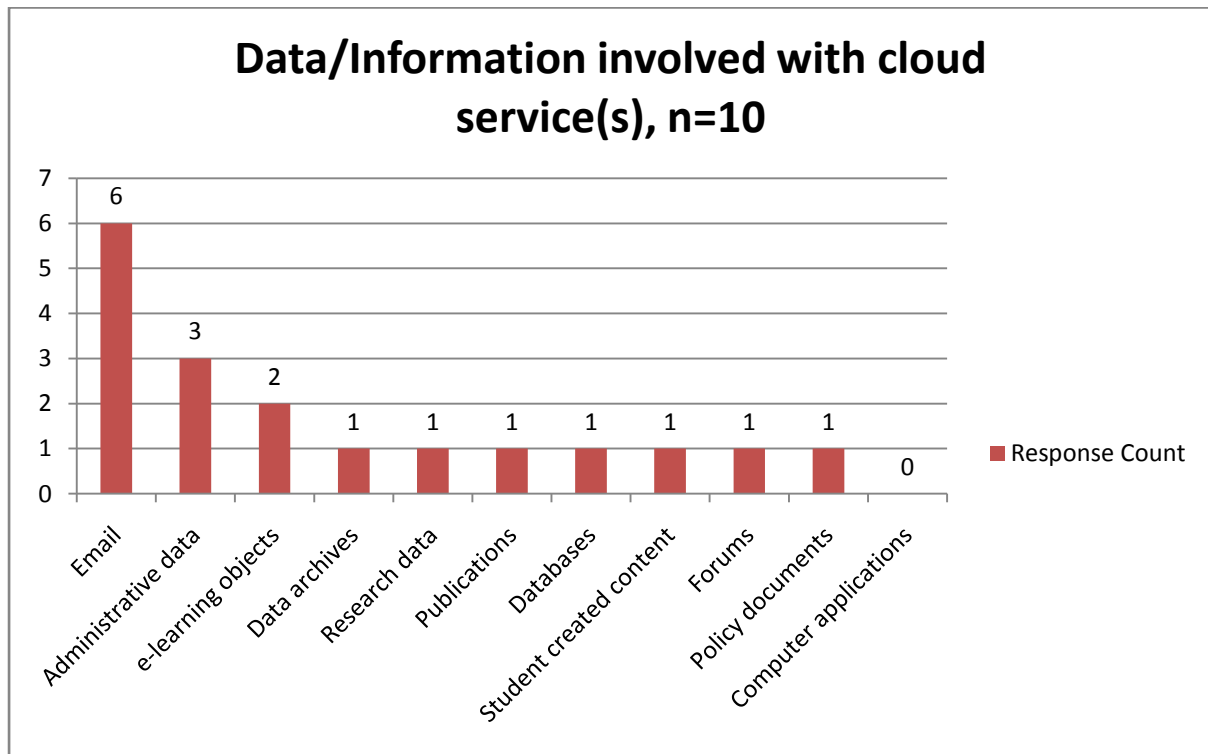
Figure 6 – Reasons for using cloud computing services



Use of Cloud Computing Services – Data/Information

The most common type of information/data used in cloud computing services in the survey is email, with 6 out of 10 of those using cloud services indicating they use cloud-based email. The next most common types of data are administrative data (3) and e-learning objects (2). Other types of information used in cloud computing services at the institutions that responded include data archives, publications, research data, databases, policy documents, forums and student-created content (see figure 7). Of those that used cloud computing services to store and manage administrative data, the types of data included: financial records, policy documents, student assessments, staff development materials and surveys. From respondents that gave indications about the volumes of data involved in cloud computing this varied from a few tens of gigabytes up to potentially 200 Terabytes (an example for 8000 students with combined email and data storage quotas of 25 Gb).

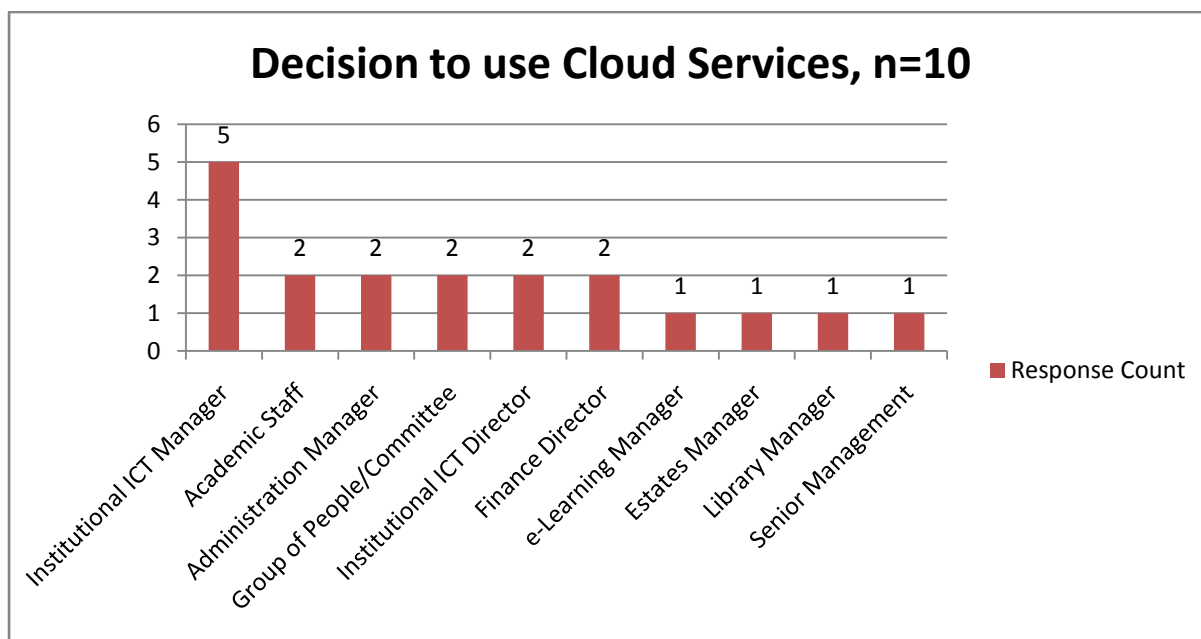
Figure 7 – Data/Information involved with cloud services



Decision to use cloud computing

When universities and colleges made the decision to use cloud computing services, the most common person involved in making the decision was the institutional ICT manager, mentioned in half of all cases (see figure 8). The next most common people mentioned were (mentioned by 2): groups/committees, institutional ICT directors, finance directors, academic staff and administrative managers. Others mentioned were e-learning managers, estates managers, library managers and senior management.

Figure 8 – Decision to use cloud computing services



Experience of Cloud Computing

Of those replying to the statement *“My experience of cloud computing has been a positive one”*, 7 out of 9 either agreed (3) or strongly agreed (4) with this statement, with the remaining 2 neither agreeing nor disagreeing. This indicates that those responding to the survey/activity review and currently using cloud computing have an overwhelmingly positive view of cloud computing on a personal level.

Problems implementing or using Cloud Computing

In reply to the question *“Have there been any significant problems with using cloud computing services?”* 7 out of 10 said no with the other 3 indicating yes. These significant problems were: i) cost issues (rise in costs) due to US dollar exchange rate changes (York St John University) and ii) maintenance problems, where the functionality of the service was affected due to poor maintenance by cloud vendor (Shipley College). Other problems encountered were: minor security problems (New College Worcester), legal problems – students concerned about data protection when using Gmail (Sheffield Hallam University) and information supply problems with student email (Oaklands College).