e-FISCAL

Financial Study for Sustainable Computing e-Infrastructures

Deliverable Title: D2.1 e-FISCAL questionnaire

Partner Responsible: AUEB-RC

Work Package 2: Computing e-Infrastructure cost calculation

Submission Due Date: 30.11.2011

Actual Submission Date: 14.12.2011

Distribution: Public

Nature: Report

Abstract: This document provides an overview of the whole administration process of the questionnaire developed within the e-FISCAL project to retrieve cost data from HTC/HPC resource centres, as well as the costing methodology under which these data will be analysed.

Document Information Summary

Deliverable number:	*D2.1*
Deliverable title:	*e-FISCAL questionnaire*
Editor	*Sandra Cohen*
Contributing Authors:	*Sandra Cohen, Fotis Karagiannis, Costas Courcoubetis AUEB-RC, Matti Heikkurinen ETL*
Reviewer(s):	*Sergio Andreozzi, EGI, Eoin Brazil, NUIG*
Work package no.:	*WP 2*
Work package title:	*Computing e-Infrastructure cost calculation*
Work package leader:	*Sandra Cohen*
Work package participants:	*Costas Courcoubetis*
	Fotis Karagiannis
	Steven Newhouse
	Sergio Andreozzi
	Matti Heikkurinen
	Owen Appleton
	Eoin Brazil
Distribution:	*Public*
Nature:	*Report*
Version/Revision:	*v.final*
Draft/Final	*Final*
Keywords:	*Total yearly cost of ownership; e-FISCAL; questionnaire*

DISCLAIMER

Log Table

Issue	Date	Description	Author/Partner
v1.0	26-10-2011	Skeleton	Sandra Cohen, AUEB-RC
v1.1	26-10-2011	Updated skeleton based on the partners comments at the All-hands meeting	Sandra Cohen, AUEB-RC
v2.0	21-11-2011	First full draft version submitted for comments	Sandra Cohen, Fotis Karagiannis, AUEB-RC
v2.1	22-11-2011	Initial comments by partners	Sergio Andreozzi, EGI.eu Eoin Brazil, NUIG Matti Heikkurinen, ETL
v3.0	29-11-2011	Pre-final version sent for internal review	Sandra Cohen, Fotis Karagiannis, AUEB-RC
v3.1	30-11-2011	Internal review	Eoin Brazil, NUIG
v3.2	6-12-2011	Internal review	Sergio Andreozzi, EGI.eu
v.4.0	7-12-2011	Integration of comments	Sandra Cohen, AUEB-RC
v4.1	9-12-2011	Final version for PMB approval	Fotis Karagiannis, AUEB-RC
v.final	14-12-2011	Final version	Sandra Cohen, Fotis Karagiannis, AUEB-RC

Document Approval

Approval by	Date
Project Management Board	14-12-2011

EXECUTIVE SUMMARY

The e-FISCAL project is funded by the European Commission to analyse the costs and cost structures of European High Throughput and High Performance Computing (HTC and HPC) research infrastructures, aiming at comparing these costs and cost structures with their closest equivalent commercial leased or on-demand offerings.

In order to achieve this objective, after reviewing the state of the art in e-Infrastructure costing issues, a costing methodology and a corresponding cost model have been developed. A survey (questionnaire) was also created so as to gather the necessary information for the application of the model. This report describes the costing methodology and the planned process of questionnaire administration (sample selection, questionnaire development, questionnaire dissemination and follow up, analysis of data and conclusions). It also presents the detailed structure of the questionnaire and the review process used to generate this survey. The body of the questionnaire is found in the deliverable appendix.

The developed costing methodology is a hybrid approach aimed at calculating the yearly total cost of ownership for years 2010 and 2011. It is a hybrid in the sense that it borrows characteristics from different methodologies. More specifically, it builds on the Total Cost of Ownership (TCO) and on the Full Cost Accounting (FCO) principles. The costing procedure uses a two-step process: a) Simulation of the physical infrastructure and b) Development of the financial model.

The survey instrument is targeted to EGI resource centres via their related NGIs, national HPC coordinators and individual HTC/HPC centres. The survey is divided into two sections: the first section covers the data needed to calculate the total yearly cost of ownership of computing resources; the second section covers the related issues of e-Infrastructure sustainability and 'Green IT' approaches. The survey responses will be followed up and if needed appropriate clarifications questions will be addressed to the respondents or related interviews will be arranged. The preliminary findings of the questionnaire will be reported in deliverable D2.2 at the end of May 2012.

TABLE OF CONTENTS

TABLES

FIGURES

1. INTRODUCTION

1.1   Scope of the document

The goal of the e-FISCAL project is to analyse the costs of the current European dedicated HTC and HPC computing e-Infrastructures for research and compare them with equivalent commercial leased or on-demand offerings. This document has a dual scope: firstly, it aims at providing an overview of the methodology that will be used in order to calculate the total yearly cost of ownership of the dedicated European HTC and HPC infrastructure for years 2010 and 2011; secondly this document describes the characteristics of the questionnaire that will be used in order to extract the necessary cost data that will be used to inform the costing model developed for the purpose of the study.

1.2   Target Audiences

The document is both intended for as an internal and external reference. Internal as a main tool for the convergence towards a questionnaire that on one hand is able to extract the necessary information from its respondents and on the other hand it is not too lengthy. External, as the process and actual questionnaire can be of interest to other projects that engaging in such costing activities.

1.3   Structure of the document

The document has three sections and an Appendix. Section 1 provides a short introduction to the scope of the study. Section 2 outlines an overview of the methodology to be implemented as well as discusses in detail each of the phases of the methodology. Section 3 provides the structure of the survey instrument and outlines the review process that has been used. The survey instrument (questionnaire) is found in the Appendix.

1.4   Terms and definitions

EGI – European Grid Infrastructure	EGI is a federation of national and domain specific resource providers coordinated by EGI.eu that seeks to sustainably operate a secure integrated production infrastructure for a multidisciplinary user community across Europe and their international collaborators.
EGI.eu	EGI.eu is an organisation established on 8 February 2010 to coordinate and manage the infrastructure on behalf of its participants: National Grid Initiatives and European Intergovernmental Research Organisations (EIROs). EGI.eu is a foundation recognised by Dutch law and headquartered in Science Park Amsterdam, the Netherlands.
HPC- High Performance Computing	HPC refers to serving at one single moment in time a coarse number of specialised computing tasks requiring an extremely powerful and tightly integrated computing system. It can be referred to as Capability Computing.
HTC - High Throughput Computing	HTC refers to serving an extremely large number of parallel tasks on a large-scale computing infrastructure. It can be referred to as Capacity Computing (or Grid).
NGI - National Grid Initiatives	NGIs are the entities responsible of procuring and operating the national grid infrastructure (in terms of computers and storage devices) and corresponding services to the research and academic communities.
PRACE (Partnership for Advance Computing in Europe)	PRACE is a unique persistent pan-European Research Infrastructure for HPC implementing 3-5 petaflop supercomputing systems in Europe. PRACE manages extreme computing power and a selected set of highly specialized services.

Table 1 - Terminology

2. OVERVIEW OF THE PROPOSED METHODOLOGY

The methodology defined in this project in order to calculate the cost of the HTC and HPC centres for 2010 and 2011 comprises of six stages:

1. State of the art review in costing issues
2. Development of the generic cost model
3. Sample selection
4. Questionnaire development
5. Questionnaire dissemination and follow up
6. Analysis of data and conclusions

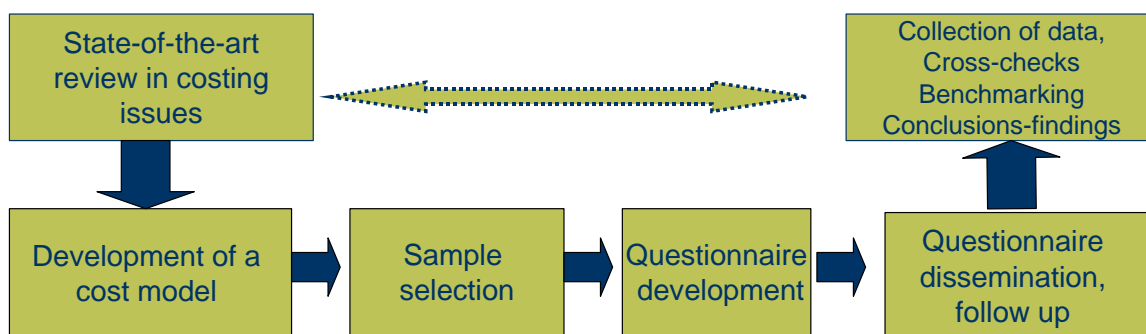A graphical representation of the sequence of these steps is shown in Figure 1.

Figure 1: Overview of the proposed methodology

2.1   State of the art review in costing issues

The first step in our study was to review the relevant literature. We reviewed academic papers, industry project results, EU studies' results, vendor analyses and relevant studies to acquire an overview of the current state of the art relevant to the scope of our study. Therefore, this first step had multiple orientations including the identification of relevant research works that dealt with e-infrastructure costing issues in general (Afran and Bancalore, 2007; Walker, 2009; Nazir and Sorensen, 2010; Opitz et al, 2008), electricity and premises costing (Koomey, 2008; Jie et al., 2011), business models applied by e-infrastructures (EGI-InSPIRE EU deliverable D2.7, 2011), papers that compare cloud and grid options (Foster et al., 2008; Kondo et al., 2009) or discuss cloud computing issues (Klems et al., 2009; Hammond et al., 2010; Microsoft, 2010; Kim et al., 2009), papers that discuss the migration to the Cloud (Misra and Mondal, 2011), industry benchmarks (Crosswell, 2010), case studies (Hyak operating costs[1]) etc. On the basis of the research we have built a repository containing the catalogue of the relevant literature hosted on the e-FISCAL project web site (http://www.efiscal.eu/state-of-the-art).

The review of relevant literature enabled us to take a more informed decision on the best costing methodology that would be most applicable for our requirements. It permitted the identification of the distinctive cost objects for which cost data should be retrieved through questionnaires and provided useful feedback beyond cost issues such as ideas relevant to business models or discussions that would be moved forward from our conclusions. This review allowed for the identification of data and sources of valuable input for cost and pricing analyses and comparisons.

The review of the state-of-art-literature revealed two major findings. Firstly, that there is a rather common break down of HTC/HPC costs into the following categories: 1) computing and storage hardware costs including

---

[1] http://escience.washington.edu/get-help-now/hyak-operating-costs-and-comparison-commercial-alternatives

interconnection costs; 2) auxiliary equipment costs (cooling, UPS, power generator); 3) software costs, 4) personnel costs; 5) site operating costs; 6) connection costs.

Secondly, that despite the rather homogeneous cost structure used in several studies, the results as for the cost per (logical) CPU/hour were very different. In most cases, this is directly attributable to different hypotheses being applied in cost calculations. During the e-IRGPS2 exercise (e-IRGSP2 deliverable D2.4, 2011) a first attempt to approximate the cost per logical CPU/hour for the EGI was performed. This exercise identified several areas that contributed to diverging cost calculations. The experience gained from e-IRGSP2 has been used in order to improve the e-FISCAL survey design.

The state-of-art review process is an on-going procedure that will be applied throughout the project.

2.2   Development of the generic cost model

There are several methods for studying service costs in existence. The most common techniques for e-infrastructures are the Total Cost of Ownership (TCO)[2] and the Full Cost Accounting (FCA)[3]. However, after careful study, e-FISCAL found that none were an ideal fit for the project's requirements. More specifically, Total Cost of Ownership (TCO) tends to be used to look into the future, over the full lifetime of, say, an equipment purchase. This method requires detailed cost data as well as the execution of simulations based on future conditions in order to be correctly applied as a cost model. In comparison, techniques like Full Cost Accounting (FCA) look at the actual costs incurred, through highly detailed line item input data and lengthy calculations. Both can provide valid results, depending on the circumstances, for a single organisation, but when assessing costs across the e-Infrastructure market area for different organizations a different approach is better suited.
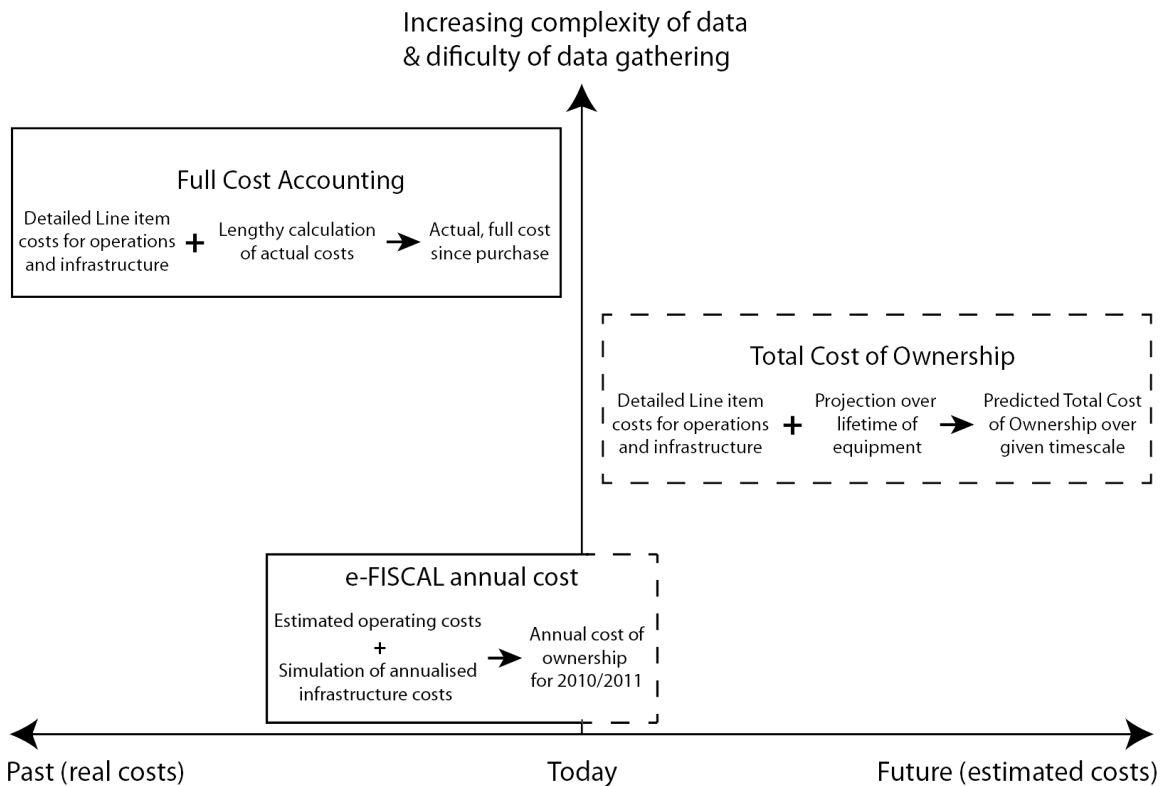

Figure 2: Comparing TCO, FCA and e-FISCAL methodology in cost calculations

---

[2] http://en.wikipedia.org/wiki/Total_cost_of_ownership

[3] http://en.wikipedia.org/wiki/Full_Cost_Accounting

Therefore we have developed a new hybrid methodology building upon the two aforementioned methods. A benefit of our methodology is that it simplifies data collection allowing participants to easily gather the necessary information. Our methodology balances accuracy and easiness of data reporting. A graphical presentation of the proposed methodology compared to full cost accounting and TCO is given in Figure 2.

As it can be inferred by the graph above, Full Cost Accounting may end up using obsolete assumptions, whereas TCO requires making assumptions on the whole lifecycle of the equipment (which in the case of machine rooms can be decades), which bring in their own uncertainties. Our proposed hybrid methodology is suitable for estimating the level and breakdown of current costs as well allowing for the accurate projection into the short-term. The approach balances the level of detail and the accuracy of necessary costs against the effort required to gather and report the cost data.

This hybrid methodology can be used in order to calculate the total yearly cost of ownership. This requires a two-step process: a) Simulation of the physical infrastructure and b) Development of the financial model.

a) Simulation of the physical infrastructure: The investment cost of the infrastructure is approximated by taking into account the capacity in terms of logical CPUs, of storage devices, of interconnection devices and of auxiliary equipment. It further includes the actual purchase values corresponding to each specific site/centre. This information is cross-checked against available accounting data are performed in order to ensure robustness.

Development of the financial model: The financial model is based on two pillars. The annualized cost of the simulated physical infrastructure and the operating cost of the physical infrastructure.
- Annualized cost of the simulated physical infrastructure: depreciation rates are used to annualize the cost of the physical infrastructure simulated in the first step.
- Operating cost of the physical infrastructure: this cost dimension corresponds to the yearly costs for running the site/centre. Information about the operating costs will be gathered per cost category (e.g. personnel costs, electricity, etc.) in order to perform several cost breakdown analyses and economies of scale assessments.
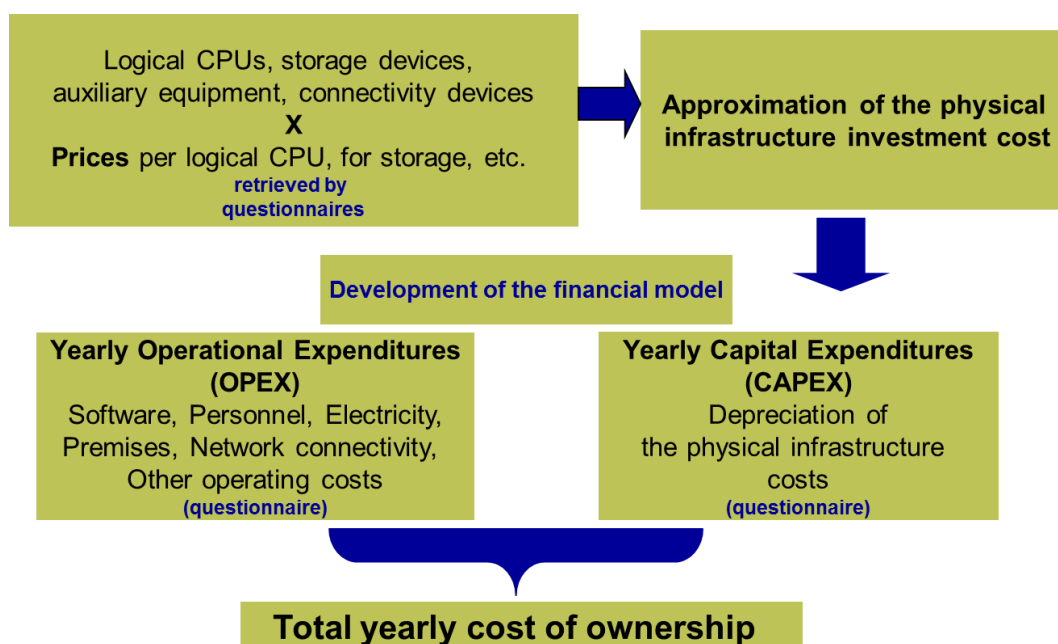

Figure 3: Overview of e-FISCAL cost methodology to calculate total yearly cost of ownership

The yearly cost- of ownership is calculated for years 2010 and 2011 as this is the time frame identified in the e-FISCAL project proposal. External data will be gathered and used to verify and cross-check the (e.g., from EGI, PRACE, market or other literature sources).A graphical overview of the e-FISCAL methodology is present in Figure 3.

2.3   Sample selection

The scope of the study is to calculate the overall cost of the dedicated European HTC and HPC infrastructures. Therefore, ideally, our sample (i.e. respondents to the questionnaire developed to gather data) is the total population of EGI/HTC and PRACE/HPC centres. However, as it is in practical terms very difficult to get data from every single HTC or HPC centre, our analysis is expected to come up with robust and reliable results if the response rate is above 50% of invited NGIs and national HPC centres. Having said that, it is not the absolute percentage of respondents that matter the most; their diversity is what it counts more. In order to be able to extrapolate the findings stemming from analysing the cost information provided by the respondents to the whole population, we require an adequate representation of sites/centres in different counties, of different size and of different nature (HTC/HPC). Getting input from sites/centres of different size would also permit the identification of any economies of scale effects. The approach in this survey uses a convenience method rather than a stratified approach[4] due to the difficult in gaining access to the necessary information and because the total target population is quite small. Our aim would be to provide a census survey, gathering information on all sites providing e-Infrastructure but we acknowledge that this is unlikely to occur due to the complexity of the required information.

2.4   Questionnaire development

The developed questionnaire for the scope of the study was designed to provide the relevant inputs to satisfy requirements of our cost model benefited from the state-of-the-art findings.

The questionnaire design needed to balance between conciseness and the ability to accurately distinguish important differences in cost structures of the centres. To strike an optimal balance, different versions of the questionnaire were tested internally in several iterations, after which the final version was sent to small set of voluntary participants in the survey. Therefore, it has gone through a very intensive review process (see section 3.2). The final form of the questionnaire is shown in the appendix (Appendix A).

We have concluded that a common questionnaire for both HTC and HPC is feasible by reviewing the state-of-the-art literature and by consulting with all the partners within the project. Both pilot testing and feedback from the e-FISCAL workshop in Lyon as discussed in section 3.2 verified that our decision was justified.

A detailed presentation of the questionnaire sub-sections is found is Section 3.

2.5   Questionnaire dissemination and follow up

A graphical representation of the questionnaire dissemination and follow up is present in the following graph (Figure 4):

---

[4] Convenience sampling is a type of nonprobability sampling which involves the sample being drawn from that part of the population which is close to hand) http://en.wikipedia.org/wiki/Sampling_%28statistics%29). Stratification is the process of dividing members of the population into homogeneous subgroups before sampling(http://en.wikipedia.org/wiki/Stratified_sampling).
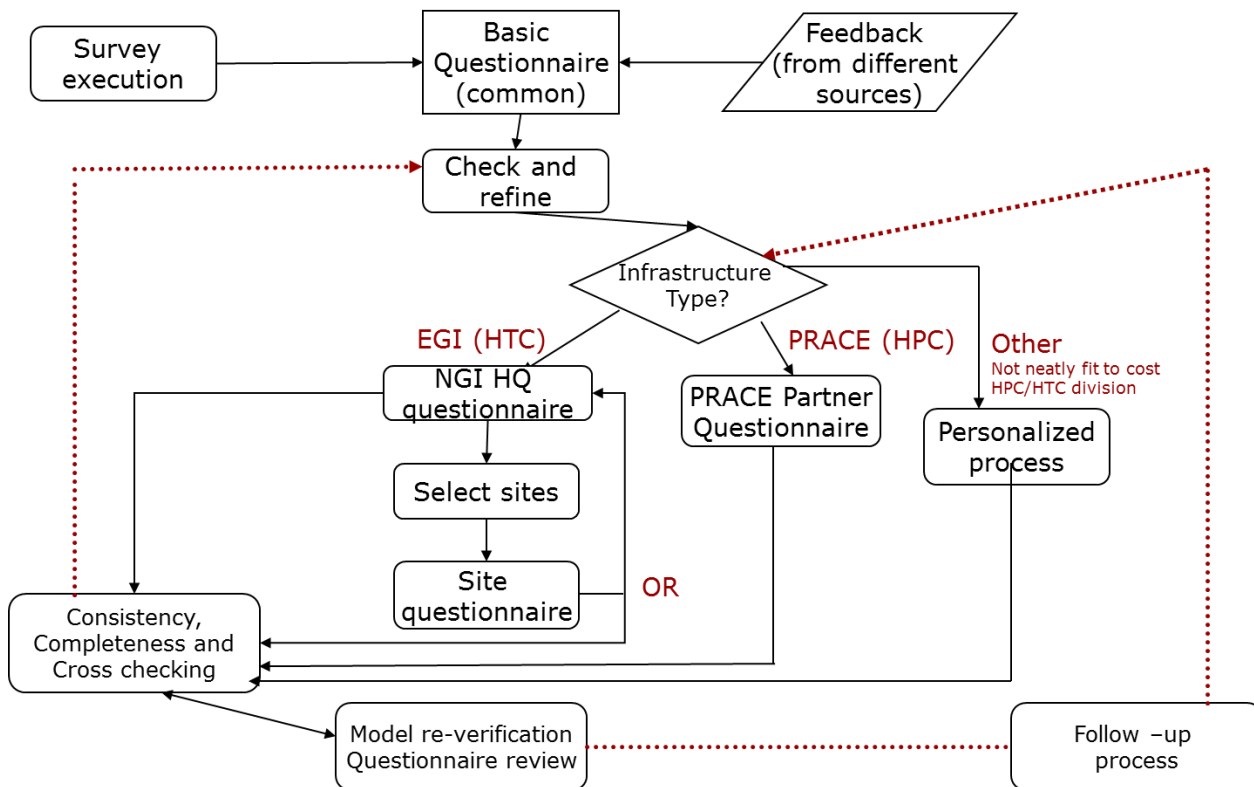
Figure 4: Questionnaire dissemination and follow-up flow

From the graph above it is obvious that dissemination and follow-up of the questionnaire is a complicated and timely procedure. Moreover, we have accounted for alternative approaches for HTC sites and HPC centres, as well as e-infrastructures that do not neatly fit in the dichotomous HTC/HPC categorization. The process is open to feedback gathered from several sources in order to end up with robust and valuable cost calculation outputs.

An inherent characteristic of the process is the continuous validation of the input data. The validation process will be performed through a dual lens. Firstly, we will constantly analyse input data to identify any inconsistencies, outliers or possible misunderstandings that would result in data deviating from what seems to be a common standard from the respondents' point of view. Secondly, we will compare input data with existing benchmarks found in market studies and vendor reports to determine any significant variances.

Finally, we plan to organize interviews with people interested in collaborating with us more closely in our study. Through these interviews we aim to identify useful and detailed information that will assist us in better understanding the cost structures and cost behaviour issues in e-Infrastructures.

A first draft of the questionnaire has been presented in the EGI technical forum 19-21 September 2011 in Lyon (http://go.egi.eu/efiscal-workshop-2011). After incorporating these comments from the presentation phase and the pilot testing phase (see Section 3.2) the survey instrument has taken its final form.

The questionnaire has been presented at the NGI International Liaison kick-off meeting in Amsterdam to inform the official NGI contacts about the existence of this initiative and the near-term announcement of the questionnaire (https://www.egi.eu/indico/event/659). Attendees received an A4 poster including basic information about e-FISCAL and the project factsheet. A letter signed by the EC will also be sent to the EGI, PRACE and e-FISCAL project lists expressing its support to the project. The dissemination of the questionnaire was done on the week of the 5th of December, 2011. Respondents were asked to submit their completed questionnaires by the end of January, 2012.

2.6   Analysis of data and conclusions

The conclusions of the study will be based on the analysis of the input data gathered through questionnaires and the information retrieved from secondary sources (e.g. EGI, PRACE, market and other literature sources). More specifically the conclusions will span the following broad areas:

- Firstly, a comparison between the findings of e-FISCAL and relevant studies will be performed. We believe that our conclusion will enrich literature in several areas, as it will present cost information that reflects current cost structures and corresponding to different sizes of HTC and HPC site/centres.

- Secondly, the analysis of data will permit the calculation of metrics such as Cost per CPU (or CPU core), CAPEX/OPEX ratio, Personnel number (FTEs)/CPU, etc. These metrics can then be used as benchmarks by HTC and HPC site/centres to assess their own position compared to similar organizations.

- Thirdly, as an end product of the study, a generic cost model will be developed. The generic cost model used in the study will be accompanied by benchmarking metrics produced from the analysis of the data supplied by the question. The generic cost model, benchmarking metrics and a subset of the data supplied will be published on the project's website. Business or similarly confidential information supplied by participants will not be made available. The cost calculation spreadsheet will be freely downloadable from the e-FISCAL site for those interested in calculating their yearly total cost of ownership.

Finally, the cost estimations will be used to compare the cost of e-Infrastructures with similar commercial leased or on-demand offerings. The comparisons will go beyond a simple "cost per core hour" difference by identifying and analysing the qualitative differences in service (such as quality of service and availability) between HTC or HPC e-Infrastructures and their closest commercial counterparts. Examples include Infrastructure as a Service (IaaS) offerings such as Amazon EC2, and S3, commercial HPC offerings such as those offered by SGI's Cyclone, Penguin's On Demand computing or Amazon's EC2 Cluster HPC.

As cost information is always a sensitive issue and potential misuse of cost information makes people reluctant to disclose it, extreme caution will be placed on treating input data with confidentiality. More specifically, all answers given will be considered as strictly confidential and only statistically processed results that guarantee anonymity will be publishable. Moreover, only the project partners, who have agreed to keep the information confidential, will have access to the data. The data will not be made public after the project lifetime, but it will be preserved by an organisation (or organisations) who commit to the same level of confidentiality.

As for the project timeline, provided that we have collected an adequate number of answered questionnaires by the end of January 2012, we will be able to present the preliminary findings of our study in key EGI and PRACE events such as the EGI Community Forum[5] and the 4th PRACE Executive Industrial Seminar[6] in March and April 2012 respectively. In those occasions, interviews with respondents of the questionnaire can be scheduled to either clarify certain questions or to receive more inputs that will be deemed necessary.

---

[5] http://cf2012.egi.eu/

[6] http://www.prace-ri.eu/HPC-driving-innovation-in-Europe

3. QUESTIONNAIRE PROPERTIES

The questionnaire developed for the purpose of the study has two main sections. The first covers the necessary input data for the calculation of the total yearly cost of ownership: amortized investment costs and operating expenses. Therefore there are questions referring to the investment in e-infrastructure elements (e.g., hardware such as computing, storage, network and auxiliary equipment) as well as operating expenses related questions (e.g. personnel, electricity, premises costs). The second section is related to the sustainability outlook and Green IT aspects where questions about the current and future use of services by commercial service providers are discussed.

3.1   Description of the questionnaire sections

The questionnaire developed for the purpose of the study is composed of fourteen pages and contains eleven sections and an appendix. In terms of time horizon, the questions cover both the near past (i.e. year 2010) as well as the present (i.e. year 2011). Nevertheless, there are also questions about the near future. The questionnaire follows a thematic development, i.e. each section is devoted to one of the distinct relevant cost categories found in literature (see for example Opitz et al., 2008).

Section	Section name	Section content	Number of questions
Section 1:	Survey overview	Short description of the survey, scope and expected outcome	
Section 2:	General Information	Type of e-infrastructure, country, respondent, etc.	8
Section 3:	Computing and storage hardware costs	Mainly include the cost of CPUs and storage devices	8
Section 4:	Auxiliary equipment costs	Auxiliary elements include UPSs, cooling devices, power related devices, etc.	2
Section 5:	Software costs	Mainly consist of the cost of operating systems, acquired middleware and applications	2
Section 6:	Personnel costs	Salary costs of the FTEs that work on the NGI site/HPC Centre and related projects/organisations	3
Section 7:	Site operating costs	Cost mainly related to electricity and occupancy costs	3
Section 8:	Network connectivity costs	Leases paid for connection to the Internet/NREN	3
Section 9:	Other overhead costs	Other costs not covered by previous questions	1
Section 10:	Sustainability outlook, cloud computing and Green IT questions	The questions refer to funding; cloud computing, Green IT and sustainability. They correspond to both current situation and future prospects	6
Section 11:	Additional comments	Space where respondents could make any comment relevant to our survey and provide input in relation to their own cost studies or achievements	
Section 12:	Appendix A	More details about the scope of the study	

		and an overview of the costing methodology to be applied	

Table 2: Overview of questionnaire sections

The thematic development of the questionnaire (see questionnaire sections 3 to 9) is justified by two reasons: a) as there is an attempt to assess total costs, it would be better for respondents to concentrate on all aspects that are related to each cost category at a time and b) papers discussing e-infrastructure costing issues usually employ these cost categories.

Moreover, within each cost category there are questions related to the collection of both monetary values and metric volumes (e.g. average cost for CPUs acquisition and number of CPUs). The collection of data under this dual format facilitates both the execution of sensitivity analyses as well as the calculation of benchmarks (e.g. cost per CPU). In some cases the structure of the questions allows the respondents to present the value of a cost element as a percentage of another cost element when detailed information is not available (e.g. auxiliary equipment cost as percentage of computing and hardware storage capacity acquisition cost).

The questionnaire is administered using a web interface (Survey monkey)[7]. The on-line version of the questionnaire can be found in http://www.surveymonkey.com/s/e-FISCALquest. An editable portable document format (PDF) version is found in Appendix A.

3.2   Overview of questionnaire review process

The final form of the questionnaire that is found in the appendix (Appendix A) has undergone an intensive review process. The review process has been performed along the lines to conclude on a survey instrument that:

- Balances the effort in gathering and reporting information with the usefulness of the information retrieved
- Ensures that all necessary data for running the costing model is requested
- Ensures that information available by other sources (e.g. EGI portal) is used to avoid asking respondents the same questions and to avoid duplication of work
- Includes questions that are both clear and easily understood in a unilateral way from all respondents
- Is applicable for both HTC and HPC centres

The review process has gone through the following stages:

- 1st Draft questionnaire
- Internal review and feedback from all e-FISCAL partners
- 2nd Draft questionnaire
- Presentation of the questionnaire to the dedicated e-FISCAL workshop in EGI technical Forum in Lyon (21/9/2011) (a copy of this version of the questionnaire is found in https://www.egi.eu/indico/conferenceTimeTable.py?confId=452#20110921)
- Collection of both on-site and off-site comments from participants
- Pre-final questionnaire
- Pilot testing of the questionnaire (1 HTC site (CSIC, Spain), 1 HPC centre (University of Hannover, Germany) and one mixed HTC/HPC centre (PSNC, Poland)
- Final questionnaire integrating the comments from the above centres

---

[7] Access and use of the SurveyMonkey software is courtesy of e-IRGSP3 project.

After reviewing the state of the art literature and by consulting with all the partners within the project, it was concluded that a common questionnaire for both HTC and HPC is feasible. Both pilot testing and feedback from the e-FISCAL workshop in Lyon verified that our decision was justified.

4. REFERENCES & RESOURCES

Afgan, E. and P. Bangalore, (2007) "Computation Cost in Grid Computing Environments", 29th International Conference on Software Engineering Workshops (ICSEW'07).

e- IRGSP2 EU deliverable D4.3 - Final legal issues report public, Members of the e-IRGSP2 Consortium, 28/01/2011, http://www.e-irg.eu/publications/e-irgsp2-public-deliverables.html?task=view

EGEE, (2008), "An EGEE comparative study: Grids and Clouds - Evolution or revolution", Members of the EGEE-II Collaboration, 30/05/2008.

EGI-InSPIRE EU deliverable D2.6 - Integration of clouds and virtualisation into the European production infrastructure, Members of the EGI-InSPIRE Collaboration, 1/3/2011

EGI-InSPIRE EU deliverable D2.7 - EGI sustainability plan, Members of the EGI-InSPIRE Collaboration, 31/03/2011

Foster, I., Y. Zhao, I. Raicu and S. Lu, (2008), "Cloud Computing and Grid Computing 360-Degree Compared", http://citeseer.ist.psu.edu/viewdoc/summary?doi=10.1.1.161.1564 (accessed 30/11/2011).

Grosswell, A. "Green Data Center Program", Presentation, Columbia University Information Technology, June 2010.

Hammond, M., R. Hawtin, L. Gillam and C. Oppenheim (2010), "Cloud Computing for research", Final Report, Curtis + Cartwright Consulting Ltd (7/7/2010).

Kim, W. S. Dong Kim, E. Lee and S. Lee (2009), "Adoption Issues for Cloud Computing", Keynote, Proceedings of the 11th International Conference on Information Integration and Web-based Applications & Services (iiWAS2009).

Klems, M. J. Nimis and S. Tai, (2009), "Do Clouds Compute? A Framework for Estimating the Value of Cloud Computing", *Designing E-Business Systems. Markets, Services, and Networks, Lecture Notes in Business Information Processing*, Volume 22, Part 4, pp. 110-123

Kloomey, J. (2008), "Worldwide electricity used in data centres", Environmental research Letters, September.

Kondo, D., B. Javadi, P. Malecot, F. Cappello and D. P. Anderson, (2009) "Cost-Benefit Analysis of Cloud Computing versus Desktop Grids" 18th International Heterogeneity in Computing Workshop, May, 2009, Rome.

Liu J., M. Goraczko, S. James, C. Belady, J. Lu and K. Whitehouse (2011), "The Data Furnace: Heating Up with Cloud Computing", Microsoft Research paper, 3rd USENIX Workshop on Hot Topics in Cloud Computing

Microsoft, (2010), "The Economics Of The Cloud", Microsoft White paper, November.

Misra, S.C and A. Mondal, (2011), "Identification of a company's suitability for the adoption of cloud computing and modelling its corresponding Return on Investment", *Mathematical and Computer Modelling*, Volume 53, Issues 3-4, pp. 504-521.

Nazir, A, S- A. Sørensen (2010), *"Cost benefit analysis of high performance computing infrastructures"*, Paper presented in Service Oriented Computing and Applications (SOCA) 2010 IEEE International Conference.

Opitz, A., H. König and S. Szamlewska, (2008), "What Does Grid Computing Cost?" *Journal of Grid Computing*, Vol. 6, No. 4, pp. 385-397.

Ratrell, Y. "Why high performance clouds are best kept in-house" March 28.2011 http://gcn.com/articles/2011/03/28/high-performance-clouds-in-house.aspx?admgarea=TC_CLOUD (accessed 30/11/2011).

University of Washington "Hyak Operating Costs and Comparison with Commercial Alternatives", http://escience.washington.edu/get-help-now/hyak-operating-costs-and-comparison-commercial-alternatives (accessed 30/11/2011)

Walker, E. (2009), "The real cost of a CPU hour", *Computing Practices*, Volume 43, Issue 4, pp. 35-41.

5. APPENDIX: QUESTIONNAIRE

In the following pages the body of the survey instrument developed to gather the necessary information for the application of the costing model is presented.

The same questionnaire can be found at http://www.efiscal.eu/survey.