e-FISCAL

e-FISCAL Tutorial: Methodologies and their Uses

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e- FISCAL FINAL WORKSHOP

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Tutorial outline

- Value - Price – Cost: Let's explore the links (if any)
- Cost assessment methodologies for e-infrastructures
  - Full Cost Accounting (FCA)
  - Total Cost of Ownership (TCO)
  - The e- FISCAL way
- Cost considerations on cloud adoption
  - Proposed methodology
  - Avoidable costs

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Value – Price – Cost: Let's explore the links

Value

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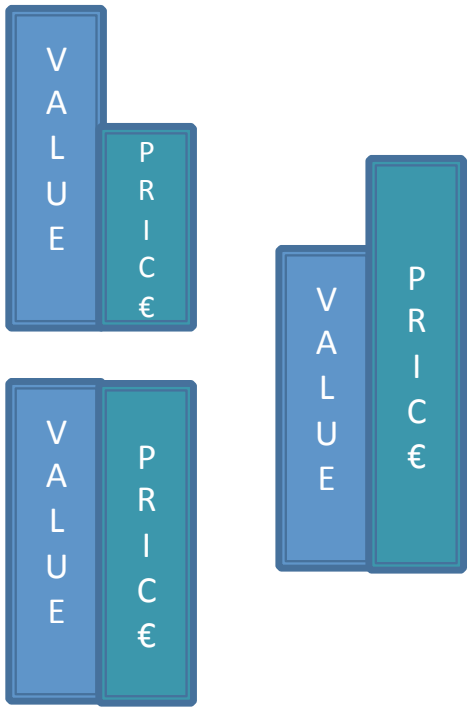
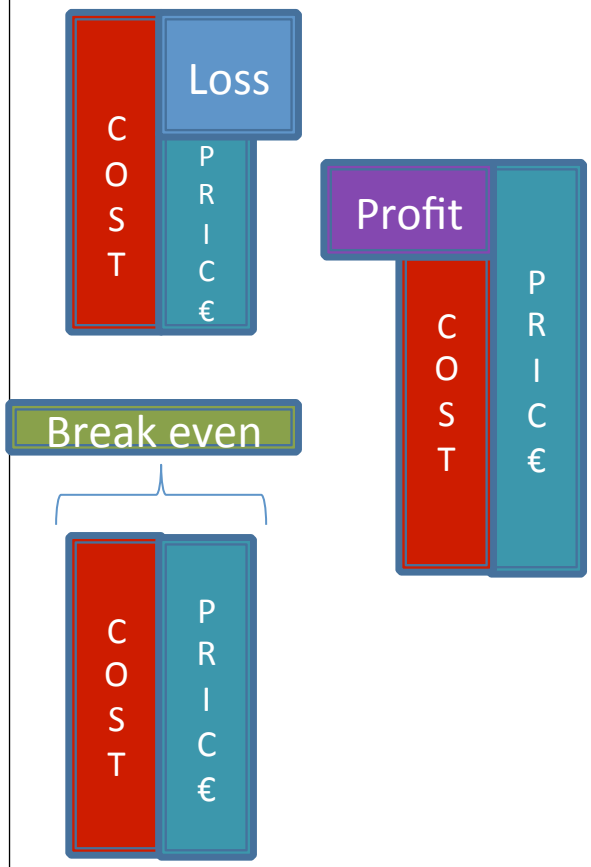


- **Value** is a measure of the benefit that a person can **gain** from either a good or service.
- Therefore value isn't the same for everyone
  - It is based on personal preferences
  - In our case: Scientists get computing services for free in their institutions; this does not mean that they do not attach value on them
- Generally, in business, while value drives demand, price is set by the intersection of demand *and* supply.
- There is a saying
  - **Value for money compared to the price I pay!** ⇒ **The value I get**

Price



- Price is set by the intersection of demand and supply
- This is a general statement that should take into account:
  - Market structure (Monopolistic vs competition)
  - Time horizon (Short –term vs long term horizon)
- In order for a business to be viable its revenues (Price X Quantity) should exceed its costs
  - Meaning: the whole product portfolio and not any given specific product or service!
  - Usually price balances between **cost** and how **market is willing to pay**
  - Products/services may be priced
    - **Below cost**
    - **Above cost**
    - **On cost**

Usually price is visible and cost very carefully hidden !!!

Price

- Why not use just a **simple cost-based pricing policy**?
  - In the long run prices should cover costs
    - Unprofitable businesses cease operations
- The price of a service serves **several marketing purposes**
  - **Penetration price**
    - Setting the price low in order to attract customers and gain market share. The price will be raised later once this market share is gained
  - **Loss leader**
    - A loss leader is a product sold at a low price (i.e. at cost or below cost) to stimulate other profitable sales. This strategy intends to help companies to expand their market share as a whole.
  - **Price discounts based on volume**
    - Encourage heavy use of the service
  - .....

Price

- It is not only **what** you play but **how** you pay for the service?
  - On a Pay-as-you-go basis
  - Upfront payment and on pay-as-you-go basis with a discount
  - Flat rate (monthly basis)
  - …

Cost

- While most believe that cost is unanimously defined, **Cost** is a rather multifaceted concept
  - It takes different numerical forms depending on the purpose
- Therefore the typical **answer** in the question:

"What is the cost of this service"?

Why do you need this information for?

Cost – but cost for what?

- The problem with cost is that there is not only one!

Costing unit	Cost orientation	Cost estimation	Cost control
Average cost	Historic cost	Starting from the books	Controllable costs
Incremental cost	Future(budgeted) cost	Starting from the process	Non-controllable costs

The average cost per unit or the cost of the additional unit(s) ?	The actual (incurred cost) or the expected (forecasted) cost ?	Is it an accounting estimation or an engineering one?	Which costs are controllable by the manager and therefore suitable to be assessed against?

Average vs. incremental costs

Costing unit

Average cost

Incremental cost

The average cost per unit or the cost of the additional unit(s) ?

I have a server that operates at 60 % of its capacity.
The yearly cost of my server is €400.
What is the average cost per core/hour?
€ 400/ (8760 x 60%) = €0.076/core hour

What could be the incremental cost if my server operated at 70% ?
In order to answer this, I have to access the additional cost that could be incurred for the 10% extra utilization provided that the server was already utilized by 60%. If this is assumed to be € 10 then the incremental average cost per core/hour would be
€ 10/ (8760 x 10%) = €0.011 /core hour

Historical vs. Future costs

Costing unit	Cost orientation
Average cost	Historic cost
Incremental cost	Future(budgeted) cost

The average cost per unit or the cost of the additional unit(s) ?

The actual (incurred cost) or the expected (forecasted) cost ?

The cost can be either based on actual – historic information

Or on budget (forecasted information) Usually budget estimations are informed by what has happened in the past and changes planned for the future

Accounting book based vs. engineering assessments

Costing unit	Cost orientation	Cost estimation
Average cost	Historic cost	Starting from the books
Incremental cost	Future(budgeted) cost	Starting from the process

The average cost per unit or the cost of the additional unit(s) ?

The actual (incurred cost) or the expected (forecasted) cost ?

Is it an accounting number or an engineering estimation?

The electricity cost can be assessed by taking into account vendor specifications

Or by consulting the accounting books

Controllable vs. non controllable costs

In order to assess whether a manager is efficient in cost terms only costs that can be influenced by his/her actions should be taken into account

For example, if he/she is not assigned funds to buy new machines that are cost effective he/she should not be blamed for high electricity cost

Cost control

Controllable costs

Non-controllable costs

Which costs are controllable by the manager and therefore suitable to be assessed against?

Cost – but cost for what?

Cost variation	Cost alteration	Cost thoroughness	Cost caclulation sophistication
Variable costs	Sunk costs	All resources consumed	Rough estimations
Fixed costs	Avoidable costs	Only resources paid/accounted for	Complex allocations of cost

Does cost fluctuate with the volume of output ?

Which costs are relevant to a(n) (investment) decision and which will remain unchanged?

Do we account for the total resources consumed irrespectively of the funder?

Do we have a formal cost accounting methodology and costing system or do base our estimations on rough calculations?

Variable vs. fixed costs

Costs can be classified in two broad categories: variable or fixed (semi-variable and step-wise costs being subcategories).
Variable are costs that change (either proportionally or not proportionally) with the level of output. Usually (for simplicity reasons) we consider variable costs to be fixed per unit of output

Cost variation

Variable costs

Fixed costs

Does cost fluctuate with the volume of output ?

Fixed costs remain unchanged for a certain level of activity. Therefore the more the output the less the fixed cost per unit of output.
The existence of fixed costs gives raise to economies of scale .
For costing purposes, fixed costs are considered unchanged in the short-run (i.e. one year)

Sunk costs vs. avoidable costs

Cost variation	Cost alteration
Variable costs	Sunk costs
Fixed costs	Avoidable costs

Does cost fluctuate with the volume of output ?

Which costs are relevant to a(n) (investment) decision and which will remain unchanged?

Sunk costs are costs that have been incurred and cannot be recovered (they cannot be “undone”). Therefore they should not influence future decisions . For example, you have an old data centre that you have spent a lot of money on maintenance and repairs. These cost are not relevant when assessing whether to keep the old data center or invest in a new one .

Avoidable costs are costs that change between alternative options . If for example by either providing in-house computing services or by using cloud, the same number of FTEs is needed, there are no avoidable costs. If one needs 90% of FTEs when moving to cloud compared to in-house provision, the 10% difference in FTEs is avoidable cost

Resources consumed vs. resources accounted for

Cost variation	Cost alteration	Cost thoroughness
Variable costs	Sunk costs	All resources consumed
Fixed costs	Avoidable costs	Only resources paid/accounted for

Does cost fluctuate with the volume of output ?

Which costs are relevant to a(n) (investment) decision and which will remain unchanged?

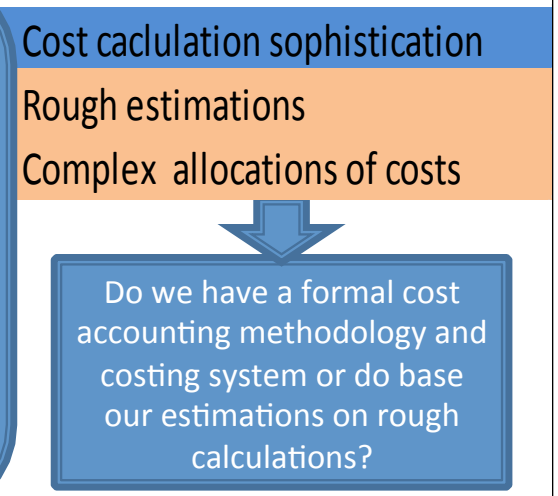
Do we account for the total resources consumed irrespectively of the funder?

All resources consumed regardless of the bearer of the costs are accounted for. In this case, some costs are imputed .

Account only for the costs that are covered by the site. All other costs assumed by others are excluded. For example, a site hosted in a university does not pay for the electivity cost. This cost is nowhere evident even if there were a perfect cost accounting system

Rough estimations vs. complex accounting models

A costing exercise may be a rough estimation (that can be performed at the back of an envelop!) or follow a detailed cost allocation methodology .
New cost accounting system methodologies may become extremely complicated (e.g. activity based costing) and demanding in fine grained data about allocation bases or cost drivers. The balance between precision and complexity is influenced by management needs and supervising authorities requirements .



Don’t forget the cost of the costing tool…

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Existing Costing Methodologies for e-infrastructures and the e-FISCAL way

Costing methodologies

- Therefore in our question **"What is the cost ?"** of the European dedicated High Throughput and High Performance Computing (HTC/HPC) e-Infrastructures for research
  - **The answer to "Why do you want to know?" is multifaceted**

We want to know the annual total cost for planning, scenario development, governance models, assessing economies of scale, compare with cloud prices…

- What costing **methodology** better fits the mission?
  - **Full costing accounting**
  - **Total cost of ownership (TCO)**

Full Cost Accounting

- Relies on actual cost accounting information (historical) available within the cost accounting systems of companies
  - Backward looking stance
    - Cost are always influenced by tax considerations
    - E.g. Obsolete computes not used any more, keep on being depreciated…
  - Information presented in a "Line item format" in accounting books is used
  - Costs are allocated and attributed to products or services on the basis of specific algorithms
  - It is a very useful tool for organizations to **control costs** and **assess performance**
    - Information can also assist pricing decisions

Traditional costing methodology

Full cost accounting – An example

Salaries

Depreciation

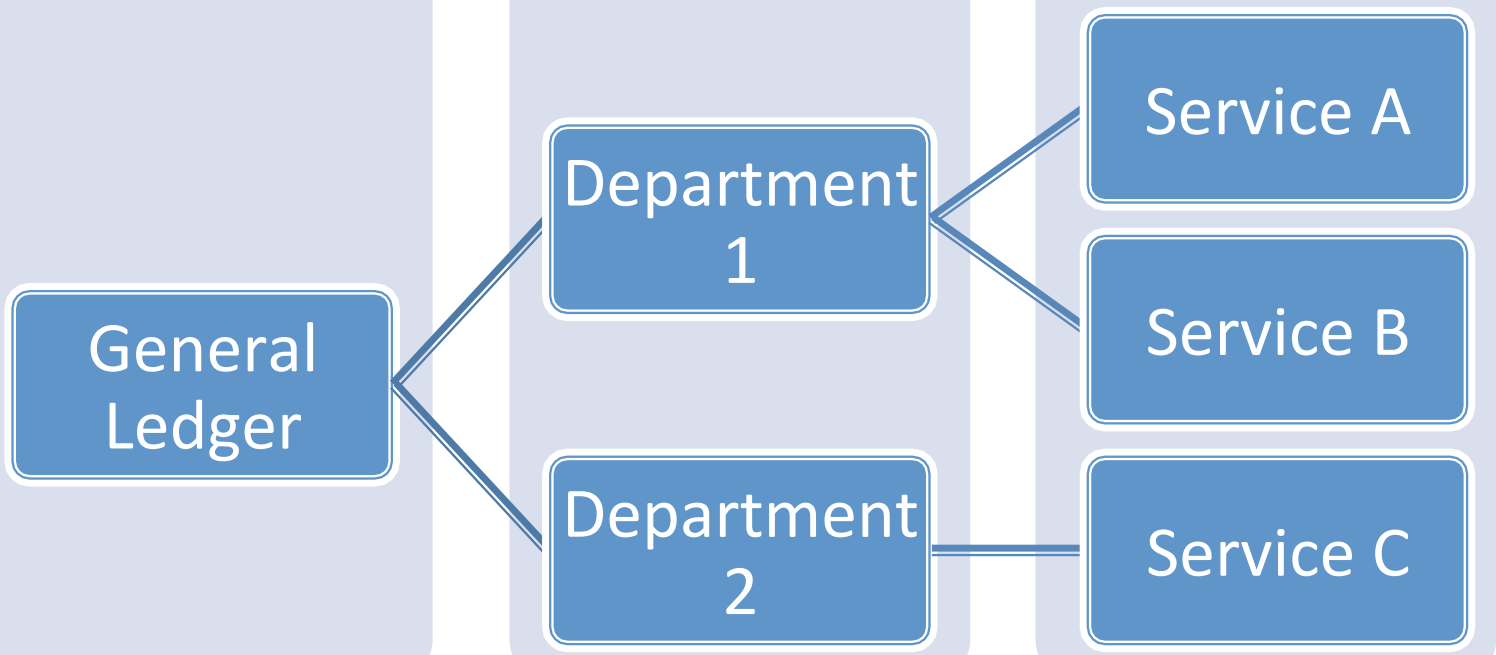
Electricity Cost

……

Attribution

or **allocation** through allocation keys (e.g. m2, FTEs)

Calculation of Services' cost



Full cost accounting – An example

Salaries

Depreciation

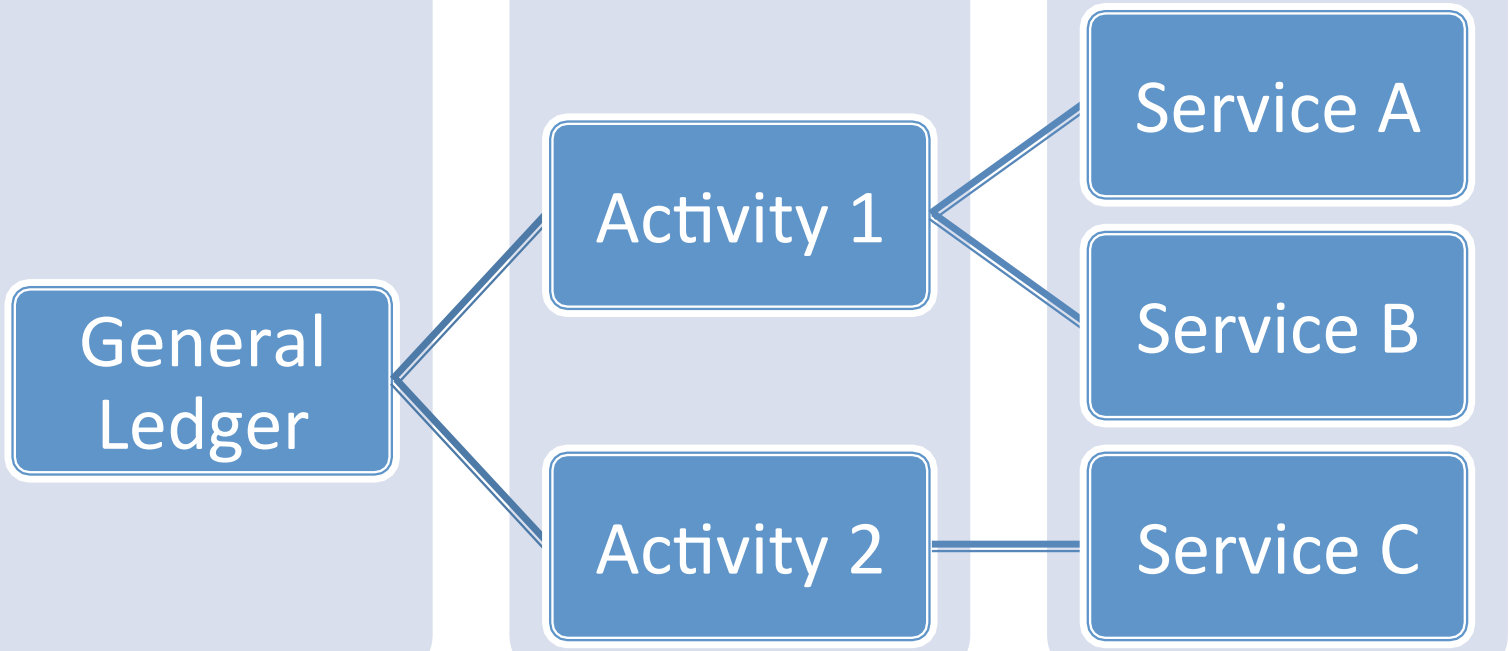
Electricity Cost

……

Allocation of cost to activities through % of time employees devote to these activities

Time information is gathered (basically) through questionnaires, on site observation and timesheets

The cost of activities is the related to services **through cost drivers** (i.e. the reason why the activity was performed)



ABC is better suited in environments with high personnel costs

Total Cost of Ownership

- TCO is a useful tool for assessing the cost of a specific project **over its useful life**
- Most suitable when comparing between alternatives
  - Projects may have different resource requirements through their lifetime
    - Low acquisition cost – high operating cost and vice versa.
- Main characteristics:
  - A forward looking stance is adopted – Cost are forecasted (expected to incur)
  - The total expected costs over the project's lifetime have to assessed
  - The total cost is then divided by the project's lifetime to come up with the yearly cost (or the cost per unit of output)
  - The robustness of the result is highly dependent on the inclusion of information of all costs to be incurred – GIGO principle always stand!
  - Is a very useful tool when planning for the future!

Total Cost of Ownership – An example

Estimate all expected costs

- Expected acquisition hardware cost
- Maintenance and support
- Power and cooling
- Personnel Cost

Assume useful life 4 years

Estimated expected cost/ 4 years = Expected Cost per year

What to choose?

- Unfortunately the above two costing methodologies could not provide a suitable answer to our questions
  - Organizations would not permit access to accounting books
    - Sensitive information – Reluctance to disclose
    - NDA with vendors
    - Lack of detailed cost accounting systems
  - We are interested in the **yearly** cost of the **total existing** e-infrastructures and **not** on cash outlays (budgets)
    - Budgets refer to cash outlays for new investments and operating costs to run both existing and planned infrastructure
    - Therefore budget amounts **do not refer to cost**
  - We would like to take into account all resources consumed irrespectively of whether they are accounted for or not
    - Complex funding structures make our task a difficult one
    - Several sites use infrastructure bought for different purpose

e-FISCAL compared to TCO and FCC

Full Data Analysis
Several sources of funding
Necessary access to accounting books

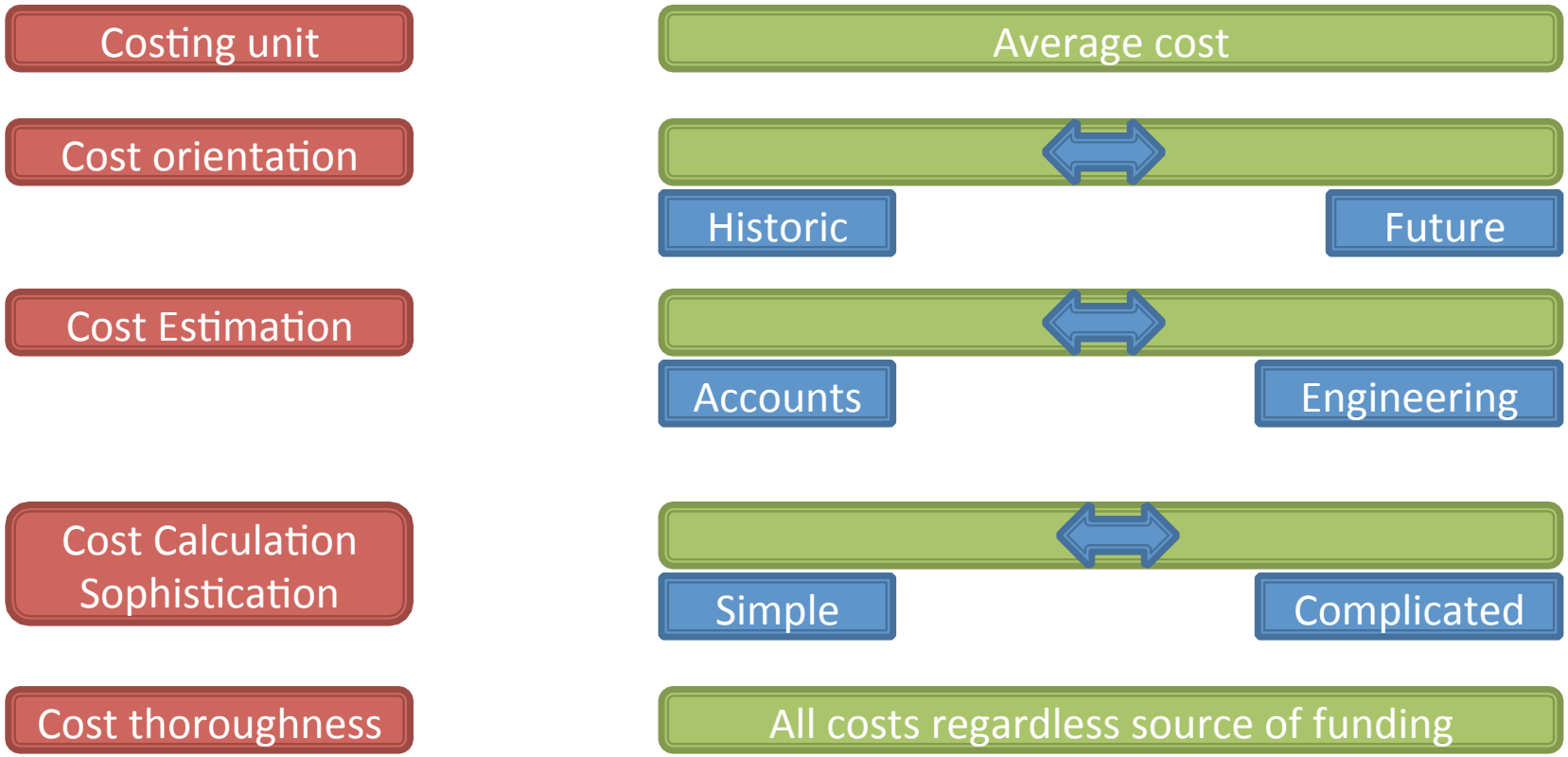
FCA Basis of analysis = Specific Centers

Full Data Analysis
Detailed input
Forward looking considerations

TCO Basis of analysis=
Specific Centers
or Machines

e-FISCAL yearly cost

e-FISCAL methodology



e-FISCAL methodology

- E-FISCAL model is a **hybrid** model that builds on FCA and TCO and adapts to real case constrains
  - It balances easiness of information collection with precision in results
    - Easy to apply
      - Only a few input requirements
      - Excel based
      - Web based application
    - Acceptable cost estimations precision
      - Not aiming at providing detailed costing data but is good enough to approximate cost
      - Suitable for cross site comparisons and cost assessments through time
  - Transparent and auditable
    - Suitable to perform sensitivity analysis
  - Possible to be used by stakeholders outside the organization

Steps in cost calculation

Step 1
- Identification of cost categories to be included in cost calculation
  - CAPEX
  - OPEX

Step 2
- Sum the total cost to be assigned to cost objects
  - Use information available
  - Approximate non available information through a acceptable methodology

Step 3
- Cost objects definition
  - Core per core/year
  - Cost per core/hour

Step 4
- Apply costing methodology
  - Get results and compare with existing evidence

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Step 1

Cost categories identification

Computing and storage hardware costs including interconnection costs, hardware service support, etc.

Auxiliary equipment costs (cooling, UPS, power generator)

CAPEX
Capital
Expenditures

Expenditures incurred to create future benefits e.g. assets acquired have a useful life beyond one year. The cost is accounted for during the periods the assets are economically used through depreciation

Software costs

CAPEX or OPEX (in our case OPEX)

Personnel costs

Site operating costs

OPEX
Operating
expenses

OPEx refers to expenses incurred in the ordinary course of business, such as salaries, administration and selling expenses, energy expenses, overhead, etc.
These expenses are considered costs when they incur.

Connection costs

Other costs

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Step 2

Sum the total cost to be assigned

Use available information

- Sites have detailed information about the technical characteristics of their infrastructure (cores, storage), number of FTEs, cost of FTEs, premises in m2, etc.

More FCA-like procedure

Approximate non available information through an acceptable methodology

- Sites do not have / not want to disclose in detail procurement costs, auxiliary equipment cost, service support cost, energy consumption, etc.
- We approximate these inputs on the basis of ranges of values or ranges of percentages

More TCO-like procedure

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Step 2

Costs to be assigned - CAPEX

- Two step methodology to approximate the total yearly cost
  - **Simulation of the physical infrastructure**

Input data for Investments

- Estimation of the site/centre investment in terms of cores, storage devices, auxiliary equipment, connectivity devices X Prices per core, per TB, percentages, etc.

Simulation

- Approximation of the **current** physical infrastructure investment **cost**

CAPEX calculation

- Annualization of physical infrastructure costs
- Application of **depreciation rates** on the simulated physical infrastructure costs

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Step 2

Costs to be assigned - OPEX

- Two step methodology to approximate the total yearly cost
  - **Operating cost of the physical infrastructure**

OPEX

- Software (value or %)
- Personnel cost (FTEs X average total cost per FTE)
- Premises cost (€/m2 per year x m2)
- Electricity consumption (Kwh x €/kwh)
- Other costs

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Step 3

Cost object definition

Cost per core/year

- Useful metric for comparisons through time in the same site
- Useful for cross-site comparisons
- Is not influenced (much) by utilization rate

Cost per core /hour

- Useful for comparisons with cloud providers
- Takes different values calculated on different utilization rates

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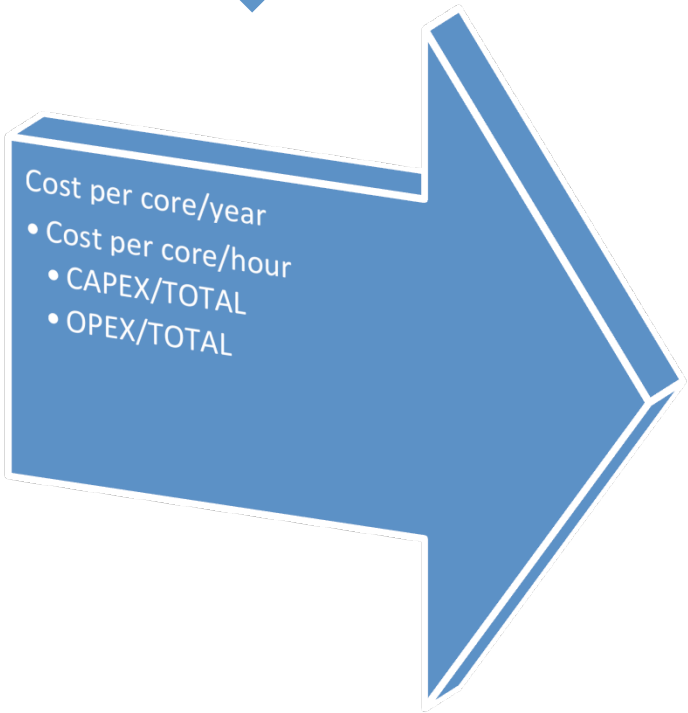
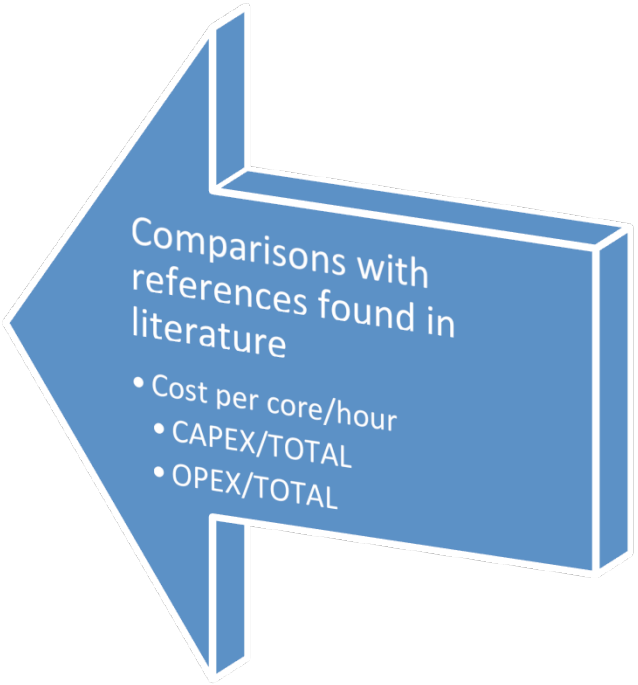
Step 4

Application of the methodology





e-FISCAL methodology - Limitations

- We cannot be as precise as in Full Cost Accounting
- The simulation of e-infrastructure is mainly based on current procurement costs
  - As prices go down (our evidence confirms that), we may have underestimated CAPEX (if infrastructure in place has been procured in higher prices)
  - Nevertheless, old machines consume more energy (OPEX correctly estimated)
- We do not differentiate the cost per core between machines
  - We treat core/hour as a homogenous service regardless of the machine
- The accuracy of findings is reliant on the completeness and reliability of inputs
  - Nevertheless, outliers have been isolated
- The model concentrates on computing cost not on storage
  - However, part of the storage cost is included (as with other similar studies)

e-FISCAL methodology – Critical factors

Depreciation rates

- Literature usually refers to 3 year useful life for computing
- Our results show that the average useful life is 5 years
  - This drives CAPEX down
  - Old machines consume more energy, this may drive OPEX up

Utilization rates

- The cost of unused capacity burdens actual use
- The higher the utilization the lower the cost per core/hour
- Sites should strive for utilization maximization
  - This doesn't mean 100% utilization

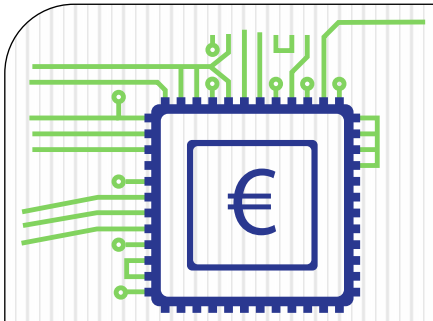
e-FISCAL methodology – Critic factors

Economies of scale

- Smaller sites usually have a higher FTEs/ 1,000 core rate compared to bigger ones
  - Personnel costs dominate OPEX

Economies of scale

- Evidence from questionnaires shows that increase in CPU cores is followed by a (significantly less) than proportional increase in FTEs
  - Increased number of CPU cores with fixed number of FTEs would decrease cost per core/hour, provided utilization is not affected



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e-infrastructure

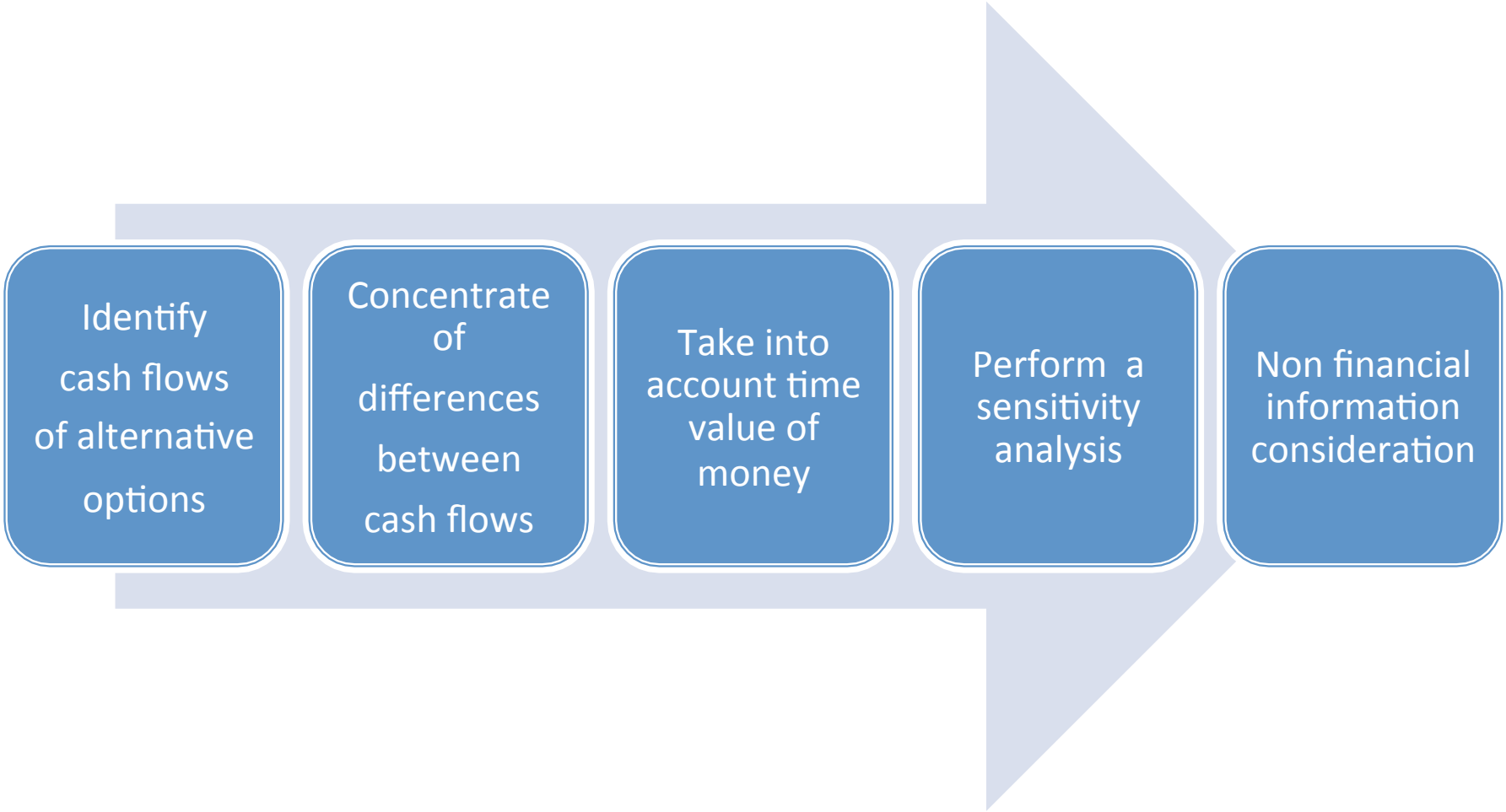
CAPACITIES

Cost considerations on cloud adoption

Does e-FISCAL answer what would be the cost of using the cloud?

- e-FISCAL model cost estimates are **suitable for comparing the cost of in-house computing with cloud prices**
- However we do not answer the question about what would be the cost if cloud computing is to replace either fully or partially the in-house computing provision.
- A **different type of analysis** is needed in order to come up with approximations that properly address this issue.
  - The analysis should concentrate on:
    - Avoidable and non-avoidable costs (i.e. costs that the institutions could save provided they would replace in-house computing with cloud and costs that could be unaffected by this change such as salary costs, internet connection costs, etc.)
    - Full costs related to cloud provision (storage costs, costs for uploading and downloading data)
    - Hidden costs that relate to contracting, quality of service, etc.

A glimpse in a methodology that could be used in making such an assessment



Identify cash flows of options

- The cash flows refer to the outflows for investments (CAPEX) and the outflows for operating expenses.
- The analysis should be based on a given cost category break down for a period of time (e.g. 3 to 5 years) in order to include all types of costs.
- A general cost categorization would be computing and storage hardware costs (including interconnection costs), auxiliary equipment costs (i.e. cooling, UPSs, power generators), software costs, personnel costs, site operating costs and connectivity costs
  - **Cost categories like e-FISCAL**
- Be careful to identify hidden costs (e.g. contracting, training, etc)

Does it look like a TCO analysis?

Concentrate of differences between cash flows

- Concentrate the analysis **only on costs that change between the 2 options** (i.e. exclude all costs that are expected to be the same between two alternatives)

Ignore non-avoidable costs
Avoidable costs are that matter!

- For example, if there is a room used for hosting space, Cloud outsourcing might save OPEX costs (cooling and power). However, it might be that costs remain (building including the hosting room needs to be maintained) and can be difficult to offset by converting the space into other use.
- Anecdotal studies claim that there will be not much savings in man power compared to in-house computing
  - What is for sure is that FTEs will still be needed to run several tasks
    - Application developers and administrators could be needed for configuring and operating cloud services as well as for adapting to application codes

Time value of money

- Money has not the same value over time
  - It is different to spend € 1 today compared to spend € 1 after 3 years
  - Therefore in comparing € that are spent with a different pattern, time value of money is important

Cost of money	1 € in Year 1	equals € in Year 3
3%	1	0,915
5%	1	0,864
7%	1	0,816
10%	1	0,751
12%	1	0,712

  - Investing in in-house e-infrastructures or using reserved instances (e.g. upfront payments in Amazon EC2) requires cash outflows in year 1.
    - Paying on a pay –as-you-go basis even the same amount of money in total have a different value
  - In case the cost of money is low, time value of money can be overlooked without considerably hampering precision

Performing a sensitivity analysis

- It is important to know which parameters exhibit the most influential effect on cost
  - Cost break down analysis
- Also to take into account expected changes in input prices through time
  - E.g. inflation rates, salary increases, energy cost trends…
- Identify the level of uncertainty over parameters
  - Some information may be completely exogenously determined (e.g. Cloud service prices) while others are more controlled by decisions made by the organization (e.g. built a new data center)

Include non financial consideration

- Business decisions are not only based on financial considerations
  - Research and policy decisions likewise
- Non financial parameters play their (important) role in the final call
  - Control over resources
  - Security of data
  - Speed of transferring huge volume of data to and from the Cloud
  - Quality of service - Performance (are all core hours the same?)
  - Promoting innovation within research community
  - Political priorities and agendas

Maybe is not either black or white…

- In – house e-infrastructure and cloud computing should not be considered as mutually exclusive options
- Cloud could be used to accommodate extra capacity needs while in – house e-infrastructure for standard needs
- Different user needs fit better under different regimes
- Cloud is not always cheaper than in – house provisioning
  - Should be careful with “one-size fits all” declarations
  - Understanding the cost structure of HPC and HTC in Europe would help better informed policy making and would assist sustainability

State of the art

For more information about relevant works

46 entries

- Multi scope orientation:
  - Costing issues in general
  - Business Models
  - Cloud vs. Grid papers
  - Migration to the Cloud papers
  - Industry benchmarks

Home

State of the Art

This table provides a list of papers relevant to the e-FISCAL work, which have been reviewed as part of the project state-of-the-art analysis. The papers mainly deal with financial aspects of High Throughput, High Performance, or Cloud Computing or other aspects related to the project such as Energy and Green IT.

If you are aware of a paper that is relevant and not listed below, please send us a note using the contact f

The e-FISCAL summer workshop (July 3rd - 4th 2012) will also offer a chance to discuss state of the art.

:: e-FISCAL at the e-IRG workshop (Copenhagen, June 11-12)

- Academic papers,
- Industry project results,
- EU studies' results,
- Engagement with experts
- **No** promotional material

Methodologies and Their Uses

Paper	Summary

:: e-FISCAL computing cost survey - deadline extended to 29th February

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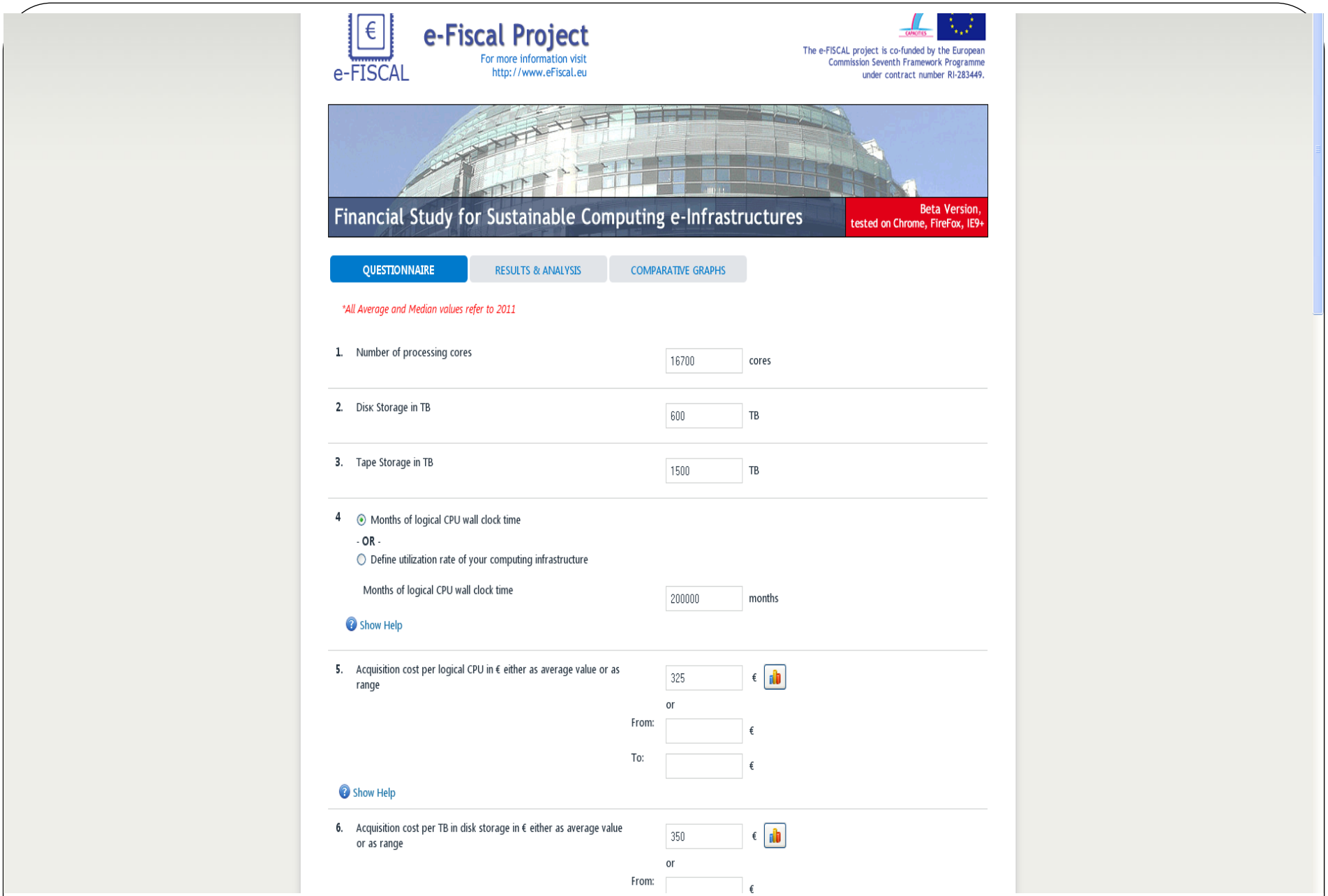
Let's see how e-FISCAL model works in practice

http://195.251.253.11:8080/cloud/index.php


e-FISCAL
e-Fiscal Project
For more information visit
http://www.eFiscal.eu
The e-FISCAL project is co-funded by the European Commission Seventh Framework Programme under contract number RI-283449.
Financial Study for Sustainable Computing e-Infrastructures
Beta Version, tested on Chrome, FireFox, IE9+
QUESTIONNAIRE
RESULTS & ANALYSIS
COMPARATIVE GRAPHS
*All Average and Median values refer to 2011
1. Number of processing cores
16700
cores
2. Disk Storage in TB
600
TB
3. Tape Storage in TB
1500
TB
4
Months of logical CPU wall clock time
- OR -
Define utilization rate of your computing infrastructure
Months of logical CPU wall clock time
200000
months
Show Help
5. Acquisition cost per logical CPU in € either as average value or as range
325
€
or
From:
€
To:
€
Show Help
6. Acquisition cost per TB in disk storage in € either as average value or as range
350
€
or
From:
€

e-FISCAL

e-Fiscal Project

For more information visit
http://www.eFiscal.eu

The e-FISCAL project is co-funded by the European Commission Seventh Framework Programme under contract number RI-283449.

QUESTIONNAIRE | RESULTS & ANALYSIS | COMPARATIVE GRAPHS

*All Average and Median values refer to 2011

Totals

Show Calculations

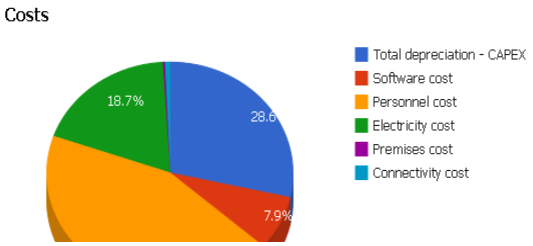
CAPEX	2,011,593.75 €
OPEX	5,027,375.00 €
CAPEX + OPEX	7,038,968.75 €
Utilization rate	98.43 %
Cost per Core/Hour	0.0489 €
Cost per Core/Year	421.50 €

Ratios

FTEs/1000s cores	1.80
m2/1000s cores	11.98
kwh/core per year	786.83
Power Usage Effectiveness	1.59
OPEX/Total	71.42 %
CAPEX/Total	28.58 %

Final Costs

Total depreciation - CAPEX	28.58 %
Software cost	7.86 %
Personnel cost	43.90 %
Electricity cost	18.67 %
Premises	0.28 %
Connectivity cost	0.71 %
Other cost	0.00 %



e-FISCAL

e-Fiscal Project

For more information visit
http://www.eFiscal.eu

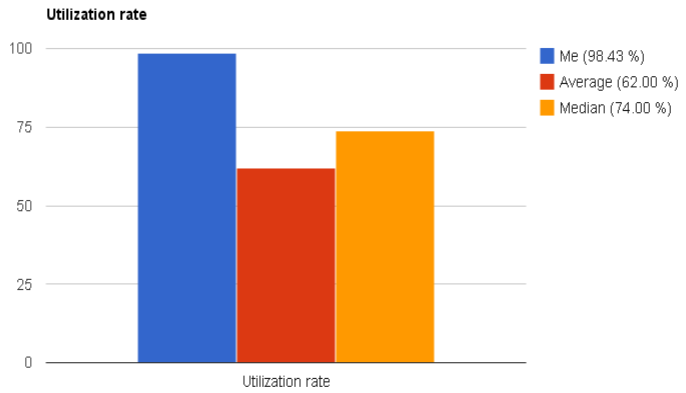
The e-FISCAL project is co-funded by the European Commission Seventh Framework Programme under contract number RI-283449.

QUESTIONNAIRE | RESULTS & ANALYSIS | COMPARATIVE GRAPHS

*All Average and Median values refer to 2011

Expand All

Utilization rate



Cost per Core/Hour

Cost per Core/Year

kwh/core per year

Power Usage Effectiveness

OPEX/Total

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Thank you for your attention!
Time for questions!

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Couple of highlights

- Hawtin et al. (2012) – Study for JISC
  - The more powerful cloud computing instances, rented on an hourly basis, appear to be **one-and-a-half to two times** more expensive per core-hour than well-managed, locally-provided clusters in modern data centres operating at high utilisation levels.
  - However, other purchasing models (such as 'Reserved Instances') can reduce the costs **to parity or better**
- Magellan final report (2011) – US DoE Hopper System
  - "the cost analysis shows that DOE centers are cost competitive, typically **3-7x less expensive** when compared to commercial cloud providers"

Summary numbers

Reference	Cost per core hour	Comments
Hawtin et al. (2012)	€ 0.075	Study for JISC UK - Differences between institutions reviewed
US DoE - Magellan report (2011)	€ 0.015	Hopper system – National Energy Research Scientific Computing Centre- including storage sub- system
Smith (2011)	€ 0.031	Purdue campus, USA
University of Washington	€ 0.020	Hyak cluster, USA
Cohen and Karagiannis (2011)	€ 0.09 – € 0.14	Stratified sample of EGI centres - Assuming 60% utilization ratio – storage cost included ((numbers refer to 2009)
Cohen and Karagiannis (2011)	€ 0.08 – € 0.10	Stratified sample of EGI centres - Assuming 60% utilization ratio – storage cost excluded (numbers refer to 2009)

TCO PRACE methodology

- Investment costs taking into account the expected lifespan of
  - –supercomputers, including installation costs;
  - –related Information Technology (“**IT”) equipment required for the operation (storage system, back-up and internal computer centre networks);**
  - –buildings;
  - –technical facilities, including cooling, power supply
- Maintenance of the supercomputers and related IT equipment and software licenses, including vendor support for hardware and software;
- Maintenance of the buildings and technical facilities;
- Electricity charge, including the depreciation cost of the power line and main substation if needed;
- The staff, including management, computer centre operation, building and technical infrastructure support;
- Changes and upgrades that might be required during the **first five years**

Slide No 10, Annaig Leguen, e-FISCAL Summer Workshop

Cloud computing

- **Lower costs for the provider**
- Large customer base
  - Economies of scale
  - Lower number of FTEs/ core
  - Negotiating power when negotiating with vendors
  - Power efficiency
    - Large system justify investments in cooling

- **Convenient for the user**
- Low up-front costs
- Pay as you go models
- No need for procurement activities
  - Update infrastructure, rather than performance depreciation

Perfect FCA case

- Single entity
- Strictly – managed organization
- Well organized accounting books
- Established practices
- Formal Infrastructure planning sufficient enough to be able to forecast procurement
- Utilization patterns able to be forecasted rather accurately

Perfect TCO case

- New organization
- Nothing in place – everything will start from scratch
- People know exactly what they want to do in the near future
- A lot of detailed information about cost and cost trends, inflation trends, etc. is necessary
  - TCO is a very good tool for infrastructure comparative cost assessments

Perfect e-FISCAL case

- Numerous loosely coupled organizations
- Evolving practices
- Not detailed accounting books
- Several funding sources
- Generally, an easy tool to apply.