Energy efficiency measures in Lisbon, a case study analysis of a Thin Client system in an office environment

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The present paper focus on measures that can contribute to improve energy efficiency in urban areas, because these areas are responsible for an increasing share of energy consumption.

The case study selected is under the scope of Information and Communication Technology, due to its current weight in energy consumption in urban areas and its growth potential. The technologies analyzed were a terminal system with thin clients compared with a system of desktop PC. The values of energy consumption of both systems were estimated as well as their cost in the energy bill, so it would be possible to perform an economic analysis to the two systems. With the data collected 3 scenarios were created: a scenario where the technology used is only desktop PC (scenario A); a scenario where the technology used is thin client with a server (scenario B) and a mixed scenario, identical to the Lisbon Energy Agency comprising a mixed system where a thin clients are used together with PC converted in client (scenario C). These scenarios were used to analyze the factors that should be taken into account by a company that acquires a new office and has to decide whether to implement a terminal system or a conventional desktop PC system.

With this analysis it was possible to conclude that this kind of action brings benefits to a company both at an energetic and economic level. However, there are some key factors that have to be taken into account when choosing these kind of ICT systems, such as the number of operators. When this number is ideal, this system can bring, financial payback, lower costs with maintenance and lower levels of energy consumptions. Although, if the desktop PC system is really efficient, with very low values of energy consumption, these kinds of measures might not bring any return in energetic terms but only in economic terms.

\textbf{Key words:} Energy Efficiency, Lisbon, Urban Areas, Thin Client, Energetic analysis

\section{Introduction}

One of the greatest issues concerning the world nowadays in the field of energy is its consumption, as well as to comprehend how to provide the same quantity and quality of services with the reduction of energy consumption. Today almost half of the global population lives in urban areas and it is projected that three quarters of the entire population in 2050 will live in urban agglomerations [1]. Energy efficiency (EE) could be the key for this present and future demand of energy, it might further contribute to economic growth than any other energy source, while simultaneously reducing energy demand can also reduce emissions of greenhouse gases (GHG) in a much cheaper way than any other policy measures. EE means using less energy while keeping an equal level of economic activity and services, i.e., optimizing energy consumption. With EE other benefits, besides its positive impacts to the climate, can be obtained, for instance improvement in the air quality and in energy security, since it is cheaper and cleaner than investments in pipelines and shale gas [2]. One of the most energy demanding sector in cities is the services sector, for example in
Lisbon this sector accounts for more than 60% of the total electric energy consumption in 2011 [3]. Information and Technology Communication (ICT) takes part in the services sector, and Gartner, Inc. reports that the ICT sector is responsible for approximately 2% of the global greenhouse gas (GHG) emissions [4]. Also, the residues left by this sector are increasing three times faster than any other type of residues, partly due to the very fast cycles of innovation that this sector has [5], [6].

The case study selected for this article was in the ICT sector, the thin client, which can be used with a terminal system and a server, which offers a great potential in a more efficient use of energy when compared to a traditional desktop PC system. Since this technology can be used as a solution to a better use of energy and subsequently reduction of GHG emissions, this type of action meets the objectives of the Green Digital Charter (GDC). An initiative created by the Eurocities that aims, through innovation, to find solutions that can reduce energy consumption, improve EE and reduce GHG emissions [7].

This case study was selected in partnership with Lisbon’s Energy-Environment Municipal Agency (Lisboa E-Nova), which is the agency responsible for most of the measures implemented in Lisbon regarding EE. A terminal system with thin clients is already used in this agency, and was this system that gave support to the creation of the scenarios analyzed in this article. The energy consumption values of the thin clients and server were taken from the equipment of the agency and the values of investment in this kind of equipment were facilitated by the agency as well so it could be possible to do an economic and energetic analysis of this system when compared with a traditional desktop PC system.

Thin Client (TC) is a technology that has a great potential in reducing energy consumption and improving EE, as well as the reduction of material consumption in the ICT sector [8]. Software and hardware from desktop PC (DPC) have been evolving at an incredible fast pace in recent years, with very short innovation cycles. This results in a faster demand for the next generation computer, however, removing the old ones to deposition remains one of the biggest concerns without a solution [9].

TC technology is equivalent with the traditional DPC system, where the biggest difference is that in TC systems the applications runs in an external server [10]. Thus the TC can reduce costs with hardware and software in a company and it can last twice as much the DPC, taking this into account, TC systems can be a viable solution in ICT sector to substitute the traditional DPC system [11].

These systems which include a server that runs all the applications, have a lot of benefits, regarding the prevention of data loss, sharing of hardware with all operators, easier data sharing between users, easier access to applications, simpler software updates and easier data management [12].

2. Methodology

As mentioned before the case study of this work was a thin client system. This technology was compared to a desktop PC system in an office environment. The TC system analyzed was in the Agency Lisboa E-Nova. This system is composed by thin clients, a server and PC that were converted to clients. This system served as the basis to compare the following cases:

- A scenario where the technology used is only DPC (scenario A)
- One scenario where the technology used is TC with a server (scenario B)
- And finally a mixed scenario, identical to what the agency has, a mixed system where TC is used with PC converted in client (scenario C)

This case study made it possible to obtain sufficient information to verify if this kind of systems really pays off both energetically and economically when compared to a DPC system. A comparison with a laptop system; was not made because even though they have the same output they are not directly comparable. Some laptops have already great autonomy, the screen is embodied in them (in this study the screens of both TC and DPC systems were not taken into account), having very low consumption. However this device has a considerably higher cost than a DPC or a TC. Plus the operating system may not be same among them, which jeopardizes the objective of a centralized IT system and the security of data; for this reason this system was not included in the present case study.

In this article a TC system will be compared with a DPC system in order to comprehend if a TC system has effectively lower
consumption as well as a lower investment in the long term.

2.1 Lisboa E-Nova Agency Scenario (Scenario C)

The system used as basis for this article was, as mentioned before, the thin client system implemented in the Lisboa E-Nova Agency. This agency installed this system in order to fulfill the following objectives:

- Reduce expenses (with machinery and licenses);
- Increase information security;
- Increase work potential.

In this agency the terminal server was acquired with the objective of also being the host of the agency website. The server acquired is an IP BRICK SCHOOL that can run up to 32 terminals, and the operating system is Linux. Along with the terminal server, the agency purchased and installed a network server and virtualization, UPS (uninterruptible power supply), a gateway Alix Ethernet and several network cables. The thin clients acquired are from the Wyse brand. As mentioned before, some of the existing PCs were converted into terminals. The conversion of some of the PCs into terminals aimed to take advantage of the already existing equipment at the agency. The substitution of the remaining PCs into TC could be a possibility for a near future, in order to ensure the reliability and stability of the system in the long term.

The Agency has its working period from 9 a.m. to 6 p.m., for 250 working days and the following electricity contract:

- Retailer: EDP Universal Service;
- Contracted Rate: Medium Uses BTN >= 27.6 kVA;
- Cycle time: Daily;
- Contracted Power (kVA): 27.6

For the analyses of the energy consumption it is necessary to take into account the different energy prices. According to the national energy services regulator (ERSE), Directive No.25/2013, the rate applicable to the agency is tri-hourly, peak hours with a price of 0.2938 €/kWh, full hours at 0.1477 €/kWh and off-peak hours at a price of 0.0845 €/kWh.

The measurements were performed during a full month, between April and May. The data collected was performed for 31 days, taking 4 measures per day in situ, according to the different hour price. The measurements were done at 9 a.m., 10:30 a.m., 1 p.m. and 6 p.m. for all the outlets. During weekends and holidays the energy consumption was regarded as constant.

In order to get the energy cost of each device, the data gathered was multiplied by the cost of the energy, given by the national energy services regulator (ERSE). The only device not measured in the agency was the desktop PC, both the values of cost and power consumption were taken from the bibliography.

Figure 1 has the values of power consumption throughout a typical day of each device.

3 Results and Discussion

The values given by the avidsen outlet were in kWh, Volts, maximum power (W) and amperes. All these values were compiled for the 31 days, to the four outlets and the four daily measurements. The values computed for the energy analysis were the ones taken in kWh. For the economic analysis it was, as mentioned in the previous chapter, multiplied by the price of each hour period (full, peak and off-peak hours). The first measurement was done at 9 a.m. and the last at 6 p.m., from 6 p.m. until the next day at 9 a.m., the power consumption was considered constant over time.

With these results it was possible to obtain the total value and cost of power consumption. The monthly cost of the server was 22,896€, for the thin client 0,53€ and the CPC 2,12€.

Figure 1, shows how the server, TC and CPC behave over the 30 days of measurements. It is possible to conclude that the consumption of both the TC and CPC have very low energy consumptions. As for the server, the consumptions increases after the 17 day, probably because two other interns entered the agency and both used a thin client. Even
though the CPC has very low consumptions, the thin client has even lower power consumptions, that do not surpass the 0.2 kWh/day.

![Power consumption of each device throughout 30 days](image)

**Figure 1 – Power consumption of each device**

### 3.1 Energetic analysis

In this analysis it was possible to conclude that a thin client consumes less than a desktop PC and even a CPC. From the data collected it was possible to obtain the consumption for the Agency, which has 4 thin clients, 6 CPC and 1 terminal server. The values for the total power consumption during one month were 155 kWh for the server, 3, 24 kWh for one thin client and 15, 7 kWh for one CPC. With these results was then determined the total annual power consumption of every device. For all the devices, the value of 31 days of measurements was divided, in order to obtain an average of daily consumption; it was then multiplied by the number of days in one year. For the TC a value of 38, 1 kWh/year was obtained, for the CPC a value of 184, 9 kWh/year and for the terminal server a value of 1827, 8 kWh/year.

![Power consumption distribution of a thin client environment](image)

**Figure 2 – Power consumption distribution of a thin client environment**

From the analysis of Figure 2 it is easy to conclude that it is in the server where the most of the consumption is allocated. The server is consuming power constantly (it is never turned off), being both the host for the terminals and for the Lisboa E-Nova Agency website. From this analysis is obvious that the thin client is in fact the device that consumes the less energy.

The value of the desktop PC power consumption was obtained from bibliography [13]–[16]. For the comparison of a scenario A with the scenario C, the value of the desktop PC power consumption was of 344 kWh/year [16].

![Annual Consumption](image)

**Figure 3 – Annual Consumption of 4 TC, 6 CPC, 1 server and 10 desktop PC**

In a desktop PC system with an average consumption per computer of 344 kWh/year, the power consumption is higher than a thin client system even with CPC (Figure 3).

Regarding the energy bill of the devices only, in the next table (Table 1), it is possible to conclude that it is in fact the desktop PC that has the higher cost in the energy bill over one year.
Table 1 – Annual Consumption and energy cost for 10 desktop PC, 4 TC, 6 CPC and 1 server

<table>
<thead>
<tr>
<th></th>
<th>Annual Consumption (kWh)</th>
<th>Annual energy bill (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server</td>
<td>1827.8</td>
<td>269.6</td>
</tr>
<tr>
<td>Thin Client CPC</td>
<td>152.6</td>
<td>25.0</td>
</tr>
<tr>
<td>CPC</td>
<td>1109.1</td>
<td>190.1</td>
</tr>
<tr>
<td>DPC</td>
<td>3440.0</td>
<td>584.8</td>
</tr>
</tbody>
</table>

3.2 Economic analysis

For the economic analysis, the values of the energy bill were used, obtained in the previous chapter. The investment necessary to obtain each device and maintenance costs. All these values were measured or obtained based on the Lisboa E-Nova Agency system.

Two cases were analyzed, one where a scenario A (with 10 desktop PC) was compared with scenario C (the Agency scenario).

The Agency acquired an Air Conditioner for the same room as the terminal server. For the power consumption of the AC it was used a coefficient of performance (COP) of 3, assuming that for each kWh consumed by the server and that it will be dissipated in the form of heat, it has to be removed from the environment by the AC. It was considered only the cooling months in Lisbon that according to the national legislation it is of 6, 7 months.

The other case analyzed (case 2), is a company, without equipment, that can buy in year 0 either a TC system or a desktop PC system, scenarios A and B.

3.3 Comparison of scenario A and C

For this comparison the scenario A was composed by; 10 desktop PC, and the scenario C by; 4 TC, 6 CPC, 1 server and 1 AC. The values were provided by Lisboa E-Nova, and the server has an investment cost of 4.000€, 200€ per TC and 25€ per CPC plus a cost of 100 € for the conversion of all of the CPC. For the AC a cost of 1.500€ was considered. A cost of 500€ per desktop PC was admitted.

In this analysis the savings in the energy bill were regarded as revenues and the maintenance cost, between a TC system and desktop PC system, were regarded as expenses. The value of maintenance was provided by Lisboa E-Nova, with the TC system having a cost of 1.667 € per year and system of 10 desktop PC, 667 €. The maintenance cost of the TC system is higher probably because in Lisboa E-Nova Agency the server is hosting the agency’s website. This server has a capacity of 32 operators and here it is compared only a system of 10.

If the number of operators increases so the maintenance cost of a desktop PC, but not a TC system, at least until the 32 operators are fulfilled.

The following table has the investment analysis of this first case (Table 2). Here, the company opted for the TC system instead of the desktop PC system and so the avoided investment represents the money of the 10 desktop PC that were not bought. This avoided investment appears on the year 0 because it is the year of the acquisition of new equipment, and in year 5, since this was the renovation cycle admitted for equipment like desktop PC.

Table 2 – Investment Analysis of the comparison between scenario A and C

<table>
<thead>
<tr>
<th></th>
<th>Investment (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 0</td>
<td>6550</td>
</tr>
<tr>
<td>Avoided Income</td>
<td>5000</td>
</tr>
<tr>
<td>Revenues</td>
<td>0</td>
</tr>
<tr>
<td>Expenses</td>
<td>0</td>
</tr>
<tr>
<td>EBITDA</td>
<td>0</td>
</tr>
<tr>
<td>Depreciation</td>
<td>0</td>
</tr>
<tr>
<td>Results</td>
<td>0</td>
</tr>
</tbody>
</table>
In an economic point of view, the first case (comparison between scenario A and C) is not a good investment, in which the Net Present Value (NPV) and Internal Rate of Return (IRR) are negative. However this system was installed with the main objective of changing the operating system to Linux. It is worth mentioning that in Lisboa E-Nova, before installing this system, they did not have an air conditioner and when they replace all CPC for thin client the power consumption of this AC will be significantly lower.

The NPV (3) and IRR (4) were computed in excel with the following equations:

\[ NPV = \sum_{i=0}^{n} \frac{CF_i}{(1 + t)^i} \] (3),

\[ CFi = \text{Cash-flow in the year } i, \text{ and } t = \text{ tax}. \]

The IRR is the tax in which NPV is equal to 0 [18] and it can be interpolated:

\[ IRR = i_1 + (i_2 - i_1) \times \frac{NPV_1}{NPV_1 + [NPV_2]} \] (4),

\[ i_1 - \text{ tax which generates a NPV }> 0; i_2 - \text{ tax that generates a NPV } < 0; \text{ NPV}_1 - \text{ positive NPV} \text{ e NPV}_2 - \text{ negative NPV}. \]

### 3.4 Comparison of scenarios A and B

In this case, scenario A, with 20 desktop PC each with an investment value of 400€ and with an annual power consumption of 250 kWh, was compared with scenario B with 20 thin clients, 1 server and 1 AC, all with the same investment values of the scenario C. The power consumption value of the desktops was taken from the bibliography [13], [14], [15] e [16]. The total investment for scenario A is 8.000€ and for scenario B is 9.500€.

Opting once again with the TC system the difference between investments has a value of 1.500€. Concerning the revenues, the desktop PC system has an expense in the energy bill of 850 €/year and the TC system is 780 €/year, resulting in 70€ of revenues. Here the revenues are higher because in this TC system all the terminals are composed by thin clients. The maintenance cost was considered proportional in the desktop PC system, having a cost of 1.334€ and equal for the TC system, resulting in 333 € of expenses.
The same methodology was used in order to do the investment plan of this comparison (Table 4). To compute the cash flow the following equation was used:

\[
CF = -Investment + Avoided\ Investment + Depreciation + Results, (5)
\]

The updated and cumulative cash flow was computed the same way as the previous investment plan, as well as the IRR, NPV and payback. The tax was once again of 5%. Table 5 has the results obtained through the investment analysis of the comparison between scenario A and B. Between these two analysis is clear that case 2 is the most attractive one in financial terms, having a positive NPV and IRR. The IRR has a large value because main objective of this type of solution is to save money.

3.5 Sensitivity Analysis

In this chapter, sensitivity analysis were performed in order to pinpoint variables that have more influence in the analysis between scenarios A and B. Table 6 has the NPV, total investment and the energy bill savings of both cases analyzed.

Sensitivity analysis were only performed to the second case (comparison between scenarios A and B), since it was the only case where the NPV and IRR were positive, and the difference in investment was smaller. The first sensitivity analysis performed was to the IRR (Figure 4), here it is confirmed (as it was computed in the previous chapter), that the IRR is indeed 30%. This is the tax for which the NPV is equal to 0; it means that only a tax of 30% or higher would imply that this project has no (or a negative) financial return.

<table>
<thead>
<tr>
<th>Table 4 – Investment analysis of the comparison between scenario A and B</th>
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<tbody>
<tr>
<td><strong>Investment analysis (€)</strong></td>
</tr>
<tr>
<td><strong>Year</strong></td>
</tr>
<tr>
<td>Investment</td>
</tr>
<tr>
<td>Avoided Investment</td>
</tr>
<tr>
<td>Revenues</td>
</tr>
<tr>
<td>Expenses</td>
</tr>
<tr>
<td>EBITDA</td>
</tr>
<tr>
<td>Depreciation</td>
</tr>
<tr>
<td>Results</td>
</tr>
<tr>
<td>Cash Flow</td>
</tr>
<tr>
<td>Cash Flow Updated</td>
</tr>
<tr>
<td>Updated Cumulative Cash Flow</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5 – Results from the investment analysis of case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results and variables</strong></td>
</tr>
<tr>
<td>NPV</td>
</tr>
<tr>
<td>TAX</td>
</tr>
<tr>
<td>IRR</td>
</tr>
<tr>
<td>Payback (year)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6 – Comparison between the two cases analyzes</th>
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</thead>
<tbody>
<tr>
<td><strong>Scenarios A and C</strong></td>
</tr>
<tr>
<td>NPV (€)</td>
</tr>
<tr>
<td>TC Investment (€)</td>
</tr>
<tr>
<td>Desktop PC Investment (€)</td>
</tr>
<tr>
<td>Energy bill savings (€/ano)</td>
</tr>
</tbody>
</table>
Another analysis done was to the quantity of users. To avoid the error of not considering that the power consumption of the server increases with the number of users, it was admitted that this consumption increases in a proportional way with the number of users. There were 4 other cases studied, one with 10 operators, and others with 15, 25 and 30.

For the scenario where the system had 10 users the server power consumption was admitted to be equal to the first case. The scenario where there were 15 users, 1,5 times greater; for 25 users the server power consumption was 2,5 times higher and for 30 users, 3 times higher.

In Table 7, the changes in the NPV regarding the number of operators in the company are presented. If the company has 25 users and opts for a TC system even the maintenance costs are lower than that of a desktop PC system.

### Table 7 - NPV regarding the number of users

<table>
<thead>
<tr>
<th>Number of operators</th>
<th>Savings in the Energy Bill (€)</th>
<th>Difference in maintenance costs (€)</th>
<th>NPV (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>35,2</td>
<td>1000</td>
<td>-4543,1</td>
</tr>
<tr>
<td>15</td>
<td>52,8</td>
<td>666,5</td>
<td>-456,0</td>
</tr>
<tr>
<td>20</td>
<td>70,3</td>
<td>333</td>
<td>3631,0</td>
</tr>
<tr>
<td>25</td>
<td>87,9</td>
<td>-0,5</td>
<td>7718,1</td>
</tr>
<tr>
<td>30</td>
<td>105,5</td>
<td>-334</td>
<td>11805,2</td>
</tr>
</tbody>
</table>
4 Conclusions

The sector of ICT evolves at an astonishing speed, partly due to the widespread use and the positive evolution of indicators of social and economic development and, secondly, to the very short innovation cycles that ICT has. Therefore, it is essential to take measures that might improve energy efficiency in this booming sector, and also to raise awareness of its users, since different types of behavior of the same equipment can lead to disparate results in the power consumption [15], [16], [19]. As for the case study of this article, an action under the scope of the ICT sector proves to be a measure with great potential for reducing both energy consumptions and costs.

There are several benefits when opting for a TC system assigned to a server comparing with a desktop PC system in an office environment, some of them being:

- The prevention of data loss and facilitated sharing, as well as sharing of software and hardware between all users;
- Data management of the entire system simplified;
- The individual energy consumption of each terminal in the TC system is quite lower than in desktops as well as the space they occupy.

With the analysis performed it was possible to conclude that these TC systems are effectively more efficient than desktop PC systems. However, in some situations opting for a TC system might not bring any benefits. The main conclusions; from an economic point of view were that, it is an attractive solution as long as the numbers of users are sufficiently high and all terminals are thin clients, ensuring that:

- The feasibility of the system and the investment required to obtain the complete system of terminals is less than the actual purchase of desktop PC and its renewal;
- The maintenance of a centralized system like the TC system is less than the effort of maintaining a desktop PC system;
- The energy consumption is lower and may lead to a high financial return, due to the savings in the energy bill and avoided investment in the renovation of older by newer desktops.

Another conclusion was that if the desktop PC system is very efficient in terms of energy, it might not compensate at all to acquire a TC system, if the goal of the company is only savings in energy consumption. These types of measures should be present when studying the possibility of installing new desktop PC in a company. The potential of a centralized system in use with thin clients is high in terms of energy savings, but associated with the use of cloud computing services it might be even higher because, in cloud computing the server is provided as service and so its consumption and maintenance is no longer the responsibility of the company. It should be considered whether the acquisition of this service compensates, instead of having a physical data center in the office.

Cloud computing may also be a solution for a company that needs more capacity, from time to time, since here the company can acquire an infrastructure as a service, without having to buy new equipment. Additionally, it is suggested that future revisions of the national action plan for the energy efficiency (such as PNAEE in Portugal) and other plans at a local and national level, include this ICT measure for hospitals, schools, universities and large office or call centers where its benefits are higher.
## References


