Environmental and economic benefits of green public procurement through the Bilan Carbone and Life Cycle Costing methodologies: a case study for Arpa Piemonte

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Abstract

The main objective of this article is to analyse the economic and environmental benefits associated with the implementation of Green Public Procurement and Minimum Environmental Criteria in a specific tender published by Arpa Piemonte for its headquarters in the city of Turin. The focus lies on the modernization of the internal lighting system shifting from CFL to LED technology: the analysis of environmental aspects measures the reduction of GHG emissions through Bilan Carbone; the economic benefits are analysed with the Life Cycle Costing tool of the European Commission.

Keywords

Benefits, Environment, GHG, Italy, LCC, Lighting, Procurement.

1. Introduction

In recent decades, the close interdependencies between the economic and the earth system have been at the centre of the discourse narrated by policy makers, scientists and citizens. The sustainability challenge has been advocated to face the current society's mechanism of consumption and production across the market economies (European Commission, 2008; Röckstrom et al., 2009; IPCC, 2022) and studies recalled the limited capacity of the earth system to sustain the current dimension and behaviour of business activities (Bonedahl & Eriksson, 2011).

Within academic literature, however, the potential of Green Public Procurement (GPP) is rarely understood (Nikolaou & Loizou, 2015), despite an increasing number of international organizations recognized its role to encourage firms towards less-polluting activities (OECD, 2003; UNEP, 2012). As indicated by the European Commission, GPP is "[…] a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured" (European Commission b, 2008, p.5).

In the European Union (EU), public procurement makes up 14% of the Gross Domestic Product (GDP): the percentage is variable, as attested by countries like Portugal where it accounts for 4%, to others, such as Finland, which is around 18%. These differences reflect the different portfolio of public services offered by the countries, whether, for example, education or healthcare system are provided by the government (Sapir et al., 2022).

Indeed, only the emissions stemming from the public purchase amount to 15% of global Greenhouse Gases (GHG) emissions. Acting on the lever of public purchases could align to the scope of the Paris Agreement and to tackle climate change below the 2° threshold (World Economic Forum, 2022). For instance, the United Nations (UNEP, 2013) and the Organization for Economic

Cooperation and Development (OECD, 2007) have taken significative steps to decrease the Carbon Footprint (CF) associated with the public purchase (Darnall et al., 2015).

Public purchase can influence both private and public behaviour in the market by affecting consumption and production patterns (Sapir et al., 2022). A change in the public consumption pattern can be obtained directly whether the PA replaces its current acquisition of products with less-polluting options (Sapir et al., 2022); indirectly, when public authorities are adopting GPP as well. With the latter dynamic, firms can develop clean technologies (Jiménez & Joint Research Centre, 2019) potentially generating a spill over, a dynamic that may change the composition of the market demand towards less polluting goods (Mazzucato, 2014).

In Italy, the Public Procurement Code in 2006 included environmental considerations in public contracts. For instance, intervention on different types of pollution, e.g. waste, water discharges, atmospheric emissions, etc., were gathered in one document. The Code had also the role to fully implement the 2004 Directives. The Legislative Decree April 18th, 2016, n. 50 "Code of public contracts" has replaced the previous 2006 Code and implemented the 2014 Directives. Among the novelties introduced within the 2016 Code, Article 34 made Italy the first European country to impose Minimum Environmental Criteria (CAM) in public procurement (Botta, 2022).

2. The context of the case study: the modernization of the indoor lighting system in Arpa Piemonte's headquarters

The scope and application of this research must be read within in the Arpa Piemonte's commitment to study the impacts caused by its activities. The object of this research is the central office (HQ) in the city of Turin and composed of 13 buildings, with 6 or 7 floors, and a single-floor structure that functions as a reception. Each building owns a specific denomination, such as: A1, A3, A4, B0, B2, B4, C1, C4, D0, D2, D3, E1, E4 and Reception (Figure 1). Building B2 is intended for other public organizations, while building D2 is undergoing renovation as of September 2022. In detail, in each building the number of the lightings is variable, depending by the number of floors and by the plan of the building itself.

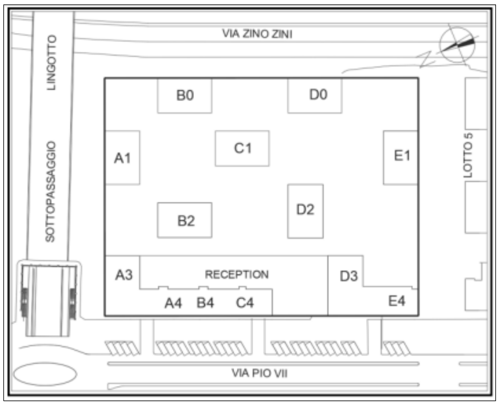

Figure 1 - Headquarters of Arpa Piemonte, plan of the former MOI complex placed in the city of Turin. [1]

Among the commitments of Arpa Piemonte there is the drafting of a social report aimed to analyse and reduce its energy-intensive activities. In September 2021 Arpa Piemonte announced a call for tenders to substitute the lighting system of the HQ buildings, specifically the lightings located in the hallways, corridors, stairwells of the fourteen buildings. The intervention includes the

[1] Source: Arpa Piemonte a, 2021.

replacement of the previous compact fluorescent lamp (CFL) lighting system, with Light Emitting Diode (LED) lamps. The intervention, as justified in art. 2 of the Tender Regulation, would guarantee "[...] lower electricity consumption and longer life than other types of lamps" (Arpa Piemonte a, 2021, p.2). The features of the CFL lamps can be found within the General Technical Report of the public tender, according to three parameters (Arpa Piemonte a, 2021): (1) Installation method: recessed (I) or ceiling (P); (2) Functions performed: ordinary lighting (O) or emergency lighting indicated as multifunction (S), since it works also as ordinary lighting; (3) Protection level: glass screen (V) or without glass screen (N).

There are four types of lamps, which can be grouped according to the previous classification. The I-O-V and the I-S-V type have a power of 2x26 W and are placed in stairwells, hallways and corridors; the P-O and P-S type have a power of 2x18 W and are only placed in stairwells. All the substituted lamps are CFL, the technical characteristic that will be crucial for this research. CFLs are made of fluorescent lamp tubes in which the ballast is incorporated in the lamp; they consume between 65% and 80% less energy compared to the conventional incandescent lamps that were common before 2009 (Incandescent conventional lamps were substituted with CFLs with the Regulation 244/2009); usually have a lifetime between 6000 and 15000 hours.

The technical references relating to the new plant required in the public tender are mainly present in the Special Tender Specifications and in the Technical Report. The latter states that the new lamps must incorporate characteristics, such as: high lighting performance, ease of assembly / disassembly and aesthetic. The document shows some possible examples of lamps that should replace recessed lamps, i.e. classified as I-O-V or I-S-V, or ceiling lamps, i.e. classified as P-O or P-S.

LED technology is referred to in the exemplification of the requested lamps. 5 types of lamps must have a lifetime longer than 50.000 hours, such as (1) Type 1, n.554 of LED panel with ordinary function, nominal power ≤ 36W; (2) Type 2 n. 330 multifunction LED panel recessed lamps, nominal power between 18-24 W; (3) Type 3 n. 180 wall lamps with emergency exit signalling function and a nominal power between 18-24 W; (4) Type 4 n. 27 LED ceiling lamps with ordinary lighting function only and a nominal power ≤ 36W; (5) Type 5 lamp n. 105 multi-function LED ceiling lamps, with the same technical characteristic of Type 4.

The technical specifications reflect the criteria envisaged in the CAM of 2017 relating to the "Minimum environmental criteria for the award of design services and works for the new construction, renovation and maintenance of public buildings" (Ministerial Decree 11/10/2017). Additionally, regarding the luminous efficiency and colour grading features, the lamps requested in the technical report have even more stringent specifics than those in the CAM.

After the launch of the tender in September 2021, new CAM (Ministerial Decree 08/07/2022) were published in June 2022, affecting the requirements for indoor and outdoor lighting systems. While the new CAM does not impact the tender in question as it precedes the new rules, it may still be relevant as Arpa Piemonte has deliberately tried to present more stringent requests than the 2017 CAM. In the new CAM, at point 2.4.3, greater emphasis is given to three main issues that constitute a novelty for the indoor lighting system: the provision of systems that regulate the operation of lighting devices, a minimum life of the LED lamps and the structure of the CAM reporting document presented by the designer of the contracting company.

The first novelty privileges those devices that can regulate the switching of the lighting, for example by incorporating twilight sensors. None of the LED lamps required in the tender include this type of sensor, requesting only an ON/OFF type light control; this will affect the calculation of the overall energy consumption of the buildings that will follow in the LCC and CF analysis. On the other hand, a lamp lifetime longer than or equal to 50,000 hours for all five types aligns itself with the new CAM. The third novelty concerns the means of proof that must be provided by the successful bidder, in addition to safety standard certifications, such as environmental product declarations of Type III or the ReMade in Italy certification. The tender document in question did not require these declarations.

The award criterion for the tender chosen is the lowest price. The choice is motivated by the fact that the "[...] characteristics of the service to be acquired are standardized [...]", therefore "[...] it is decided to use the criterion of the lowest price, in accordance with the provisions of art. 95 of the Code of public contracts" (Arpa Piemonte a, 2021, p.3). In fact, within the Procurement Code, this is one of the exceptional cases in which it is still possible to use the criterion of the lowest price. This choice prevents tenderers from being rewarded for environmental certifications or other innovative features. However, before drafting the tender notice, Arpa had launched an internal analysis of its needs. It verified whether twilight sensors could have reduced the lighting operating hours. However, since the lightings are placed in stairwells and corridors, where there is no exposition to the natural light, the twilight sensor would have been unnecessary. Therefore, in the call for tenders, the bidder is awarded only according to the aggregate lowest cost attributed to the following macro activities: (1) Definitive elimination of existing recessed CFL lamps; (2) Installation of new LED lamps (recessed ceiling panels); (3) Installation of LED emergency lamps (in false ceiling); (4) Installation of LED emergency exit lamps with pictogram (on the wall).

The total amount for the procurement was 207.055,37 euros. The winner was chosen among the 224 offers received and considered valid. It was awarded with a total cost commitment of 163.735,37 euros, proposing an auction discount of 38.021,85 euros.

2.1 Evaluations on the economic benefits of the public tender with the LCC tool of the European Commission

The LCC tool can be instrumental in quantifying cost benefits stemming from the application of the GPP. In this case study, the evaluations are placed in the ex-post scenario, in which the call for tenders was closed and the works to install LED lamps were entrusted to the successful tenderer. The goal is to identify whether the purchase of LED lamps has actually brought benefits to the Agency, in terms of the total costs of the tender, compared to the purchase of new CFL lamps with the same features of the one that were previously installed.

The boundary of the calculation is delimited by the LED lighting systems subject of the tender called "modernization of the internal lighting system of the Arpa Piemonte headquarters". The total number of lamps required is greater than the previous number of CFL lamps present in the buildings, i.e. 1526 compared to 1209. The greater number is due to the fact that the existing CFL recessed lamps, in some cases, had the normal and the emergency function, while the LED panels only perform the former function. Therefore, the analysis is restricted to LED of Type 1, 4 and 5 only, since they are comparable with the previous state, owning the ordinary function.

The tender includes LED lamps intended for stairwells and corridors, excluding all other types of lighting, such as those provided inside the offices or common areas, such as the canteen or bar area. While there are currently 13 buildings plus the reception structure, however, as already indicated, building B2 is intended for other public organizations and building D2 is undergoing renovation. Moreover, the Reception is a single storey structure with structural differences compared to the other buildings. For these reasons, the above three buildings were excluded from the reporting perimeter, including only buildings A1, A3, A4, B0, B4, C1, C4, D0, D3, E1 and E4 (Figure 1). Furthermore, since the LCC analysis and the estimates produced are closely intertwined with the respective analysis of GHG emissions that will follow and a previous study of CF of the site will be used as a basis for the comparison of LED and CFL benefits for the Agency, the same reporting perimeter is beneficial for the comparison.

There is no actual data available concerning the annual operating hours of the interior lighting. The switching on is regulated by a centralized time system divided by building and the on/off times change by the various periods of the year. For instance, the data made available by the project office for September 2022, are the following: for buildings A1 - A3 - A4 - B0 - B4 - C1 - C4 - D3 - E1 - E4, the switching on takes place from Monday to Friday in the time slot 6:30 - 7:30 and 18 - 19:30; Building D0 from Monday to Friday from 6:30 to 19:30; for building D3, it is switched on from Monday to Sunday in the 6:30 - 7:30 and the 17:45 - 20:00 slots. From these data, excluding the two buildings B2, D2 and the Reception, it is possible to deduce that the weighted arithmetic mean of the weekly hours per floor, amounts to 16 hours approximated by excess; while 828 are the annual operating hours approximated by excess.

The "LCC_Inputs_Results" in the LCC tool contains the information that should be entered by the PA, concerning the main characteristics of the space in which the system should be installed. For instance, it is requested the identification of an installation area that should function as base unit for the calculation; in this case, a single building floor has been identified as the base unit.

Other basic parameters are requested for the calculation in this sheet, such as the country of reference, the currency, the LCC evaluation period and the discount rate, which is indicated as optional. The selection of the time reference is a relevant decision for the public purchaser: a shorter lifetime weights more the purchase price, but a longer lifetime doesn't act the same way, giving major weight to operational and maintenance costs (European Commission, 2019). Therefore, for the selection of a suitable time range for the lighting sector, several sources were analysed. For instance, the calculator suggests a 20-year period, adopting as a reference the recommendations of the previous LCC calculator for lighting sector published in 2007. However, 15 years is the time range selected since one of the few best practices reported and suggested to follow by the European Commission concerning the LCC estimation for the LED lighting is a case study for a municipality in Denmark (the Municipality of Syddjurs adopted the total cost of ownership approach to save on lighting costs in a public tender), which indicated a reference of 15 years (European Commission, 2017).

The discount rate is indicated as an optional parameter to consider; however, it is a relevant information to assess since it enables to transform future cost into present value, i.e. the discounting mechanism. As for the length of the evaluation period, a lower or a higher value implies a different consideration of the costs; for instance, a higher discount rate gives less weight to annual costs, e.g. operational, service and externalities (European Commission, 2019).

The tool proposes a discount rate of 1,8% based - again - on the previous EU LCC tool, or alternatively, references the orientation of the Directorate-General for Regional and Urban Policy of the EC. The latter recommends using, as a general rule, a social discount rate of 5% as a benchmark in Cohesion Member States, e.g. also in line with the social discount rate used for addressing costs in a Cost-Benefit Analysis (European Commission, 2014) or alternatively 3% for those countries not included. Italy is not comprehended in the category of the Cohesion Member States; additionally, it is considered that in the best practice of Denmark suggested by the EC it is proposed a 4% discount rate. Since these points and the context in which the analysis is embedded, it is set a social discount rate of 4%. For the evaluation of the operation costs, it is requested the value of the electricity price for the year 2021, which is reported as 0,143 Eur/kWh; since the aim and scope of this research, the electricity annual price increase has not been included.

To evaluate the energy consumption is made the following assumption: since the illuminated area, in terms of m2, is not similar in the different buildings, it is considered the annual operating hours of the system referred to the base unit selected previously, i.e. a building floor of the Arpa Piemonte's HQ. Considering the different operating hours of the buildings reported in the boundaries of this research, 828 resulted the weighted arithmetic mean of the operating hours in each floor for the year 2021. The maintenance costs to be indicated in the section attributed to the PA are not referenced. In fact, Article 21 of the tender specifications does not deal with maintenance costs, since they are effectively zeroed: only if a LED breaks it is replaced, while CFL bulbs are periodically replaced. The tender includes guarantees that the installation company shall provide: up to the 5th year after the installation; in case of breakages or malfunctions, the company must intervene and replace, with the exception of breakages considered physiological, such as an additional guarantee that relieves the Agency of replacement costs. Since the impact of additional guarantees does not find space in the calculator, it has been decided to not evaluate this aspect for the LED system.

The calculator also treats CO2 eq emissions as cost incurred during the use of the lightings. For the year 2021, the electricity provided is 100% from RES, as witnessed with the certificate released according to the European Energy Certificate System (EECS). Therefore, the CO2 eq emissions correspond to the value of 0,024 kgCO2/kWh, the same taken as reference in the GHG report of Arpa Piemonte for the year 2019 within the CreiAMO PA project (Arpa Piemonte b, 2021). Finally, the cost of CO2 eq, in terms of EUR/ton CO2 eq, is set to 90, adopting the proposal of the tool, which is based on the report "Update of the Handbook on External Costs of Transport" where is suggested a central value of 90 EUR/ton.

The bidder response sheet treats the data that enables to evaluate the economic offer with the specific costs of the lightings. The luminaires and its components are considered within the boundary of this research, and are considered respect to the unit base, i.e. the building floor. The number of the lamps installed in each floor is not fixed because it depends on the planimetry of the building: it is implemented an estimation in average of their number for the Type 1, Type 4 and 5.

Additional data concerns the lifetime and power resulted from the technical sheet provided by the winning bidder. Since the area in terms of m2 is not available, it is not possible to calculate the LENI of the room, therefore, it won't be indicated in the calculator. The purchase price of the LED lamps is identified in the tender document called as the Estimated Metric Calculation. The luminaire installation cost is represented by the difference of the total amount required for the work, i.e. 115.310,53 euros, which is the amount resulting from the auction discount offered by the bidder, deducting the total price of the lamps, i.e. 88.883 euros; then, the result is divided by the 556 lamps installed in the buildings considered, which amounted 17,32 euro, excluding VAT and security charges. Furthermore, since the purpose of this research, e.g. the costs of removing the previous lamps, the new installation and the labour, are combined and represented by the unique import of 17,3 euros, the other costs by the authority per room or building zone are left blank.

Crucial to this analysis is to provide a valid comparison with the Business as Usual (BAU) scenario, under which Arpa Piemonte would continue to purchase CFL lamps. The specific objective, hence, is to verify whether the longer lifetime of LED lamps and lower energy consumption, in a range of 15 years, would justify the higher purchase price in comparison with new CFL lamps.

The benchmark CFL lamps meet the requirements of the CAM in force at the time of the call for tenders and match the power and number of previously installed. As in the Danish best practice, the prices of CFL lamps can vary considerably depending on the supplier despite having the same technical characteristics. For this study, CFL lamps were searched with all the aforementioned features and to deal with the price variability, two lamps were considered and indicated as CFL low price (CFL LP) or high price (CFL HP).In the previous installation there were two types of lamp, with 26x2 W and 18x2 W power, therefore the CFL LP lamps, obtained on the Philips manufacturer's portal are a pair of "Philips 230425" CFL lamps with a total power of 26 W, a purchase price of 14,08 euros and with 12.000 hours of lifetime as an alternative to Type 1 LED lamps; a pair of "Philips 383331" CFL lamps with 18 W, a purchase price of 15,46 euros and 10.000 hours of lifetime as alternative to Type 4 and Type 5 LED lamps. For the more expensive scenario, a pair of "Sylvania Cf26dd/841" with 26 W, a purchase price of 39,98 euros and 10.000 hours of lifetime; the pair of Philips 34500-9 CFL lamps with 18x2 W, a purchase price of 22,66 euros and 12.000 hours of lifetime. Following the same assumptions on the annual operating hours, the electricity prices, the discount rate and the system boundaries, the data are entered in the calculator with the technical specifications, however with evident differences as regards the estimate of maintenance costs attributable to each lamp. Each lamp is not made up of a single block, as for LED panels, but is made up of several parts, such as two light sources and the ballast, which increase maintenance costs, while for LED lamps they are zeroed and for this reason they were not included in the tender as costs.

Based on these assumptions, the output of the LCC calculator is analysed. At the bottom of the sheet named as "Inputs_and_Results", is reported a list of total amounts, e.g. investment costs, operation costs, maintenance and service costs, other costs and externalities costs, life cycle cost, energy use and CO2 eq emissions associated with the LED, CFL LP and HP scenario (Table 1). From these results, a series of considerations can be made on each aggregate cost item deriving from the three scenarios.

Table1 - LCC results associated to the CFL and LED scenarios contained in the LCC calculator for the lighting sector published by the European Commission [2]

		LED	CFL LP	CFL HP
Investment costs	EUR	50502,92	26134,44	45747,04
Operation costs	EUR	20581,56	54617,36	54617,36
Maintenance and service costs	EUR	39179,18	65879,78	123675,96
Other costs	EUR	0,00	0,00	0,00
Cost of externalities	EUR	310,88	824,99	824,99
Life cycle cost	EUR	110574,55	147456,57	224865,34
Energy use	kWh	194174,28	515280,96	515280,96
CO2-eq emissions	kg CO_2eq	4660,18	12366,74	12366,74

The total investment costs regard the acquisition and installation activities assumed to occur at the beginning of the contract and are indicated as higher with the adoption of LED lighting,

[2] Source: Calculation of the author; European Commission, 2019.

aligning with market prices and purchase prices of the Danish case study as well. In this case, despite the considerable variability of the purchase price of CFL lighting, its price is doubling the CFL LP solution, while CFL HP is almost equivalent, saving only 4.755,88 euros compared to the LED. However, it is in the other aggregate costs that there is a substantial gap among the three solutions, i.e. within the operation and in the maintenance costs.

The operation costs represent the cumulative annual cost due to the energy use of installations during the evaluation period and expressed in net present value; they result as considerably higher for the solution with the CFL. This seems justifiable for two reasons: for the higher wattage of both CFL scenario; for the fact that the number of LED is lower since they own more brightness respect to CFL, as reported by the project office and witnessed in the technical scheme. In this way, over a time range of 15 years, the LED solution is preferable, since it results less expensive of 62.32% respect to CFL LP and CFL HP. The maintenance costs represent the cumulative annual maintenance and service costs for the duration of the evaluation period expressed in net present value; in this cost category there is again a saving attributable to the LED solution for 40,53% compared to CFL LP and 68,32% to CFL HP. This gap seems attributable to the lower lifetime of the CFL solutions of 10,000 or 12,000 hours, i.e. approximately 5 times lower than the LED solution, which lead to a cost increase associated with maintenance, the decommissioning of old appliances and labour. The cost of externalities, i.e. concerning GHG emissions in the calculator, and the amount of CO2 eq emissions are quite low compared to the total amount of the costs. Since the energy comes from RES, the emission factor is only 0.024 kgCO2/kWh, but the LED scenario allows a 62,32% saving, in terms of CO2 eq emissions, compared to the other solutions. However, it is in the energy use, in terms of kWh, that there is an evident saving equivalent to the 62,32% in the total electricity demand when the LED system is adopted. Furthermore, the LCC of the three solutions indicates that the LED lighting scenario is less expensive than the CFL LP for 25,01% and to CFL HP for 50,83%. With the availability of the output data from the calculator, it is possible to consider financial metrics as well, which may be instrumental for the PA to verify and test the financial performance of the proposals within the call for tenders. For instance, with the payback period metric can be found the amount of time needed to recuperate the original investment for the project. The payback period of LED compared to the savings associated to the less expensive scenario amounts to 45 years, a value higher than the average time for the lighting sector witnessed in the literature, where there is a maximum payback of 33 years for LED (EIB, 2019). Compared to CFL HP solution, instead, the LED investment is repaid faster, i.e. 19 years however it is reported as a higher value than the average lifetime of a LED lighting.

The high amount of time to repay the investment is addressed to the savings per year, i.e. 2458,80 and 7619,39 euros, which don't compensate enough to have a lower payback period than the lifetime. The additional consideration of this metric within the LCC calculator could be substantial for the PA in the awarding stage: for instance, a proposal with a higher LCC compared to others could be still awarded considering a lower payback period. As reported, within the LCC calculator it was set a 4% discount rate considering a 15-year range; however, a last consideration is implemented to verify the effect of applying a discount rate on the total cost of the LED lightings. To test this effect, a sensitivity analysis is realized, where are considered four types of discount rates: (1) $\rho1$: 1,80%, proposed by the EU LCC tool (European Commission, 2019); (2) $\rho2$: 3%, for those countries not included in the Cohesion Member States category (European Commission, 2014); (3) $\rho3$: 4%, the discount rate applied within the Danish best practice regarding the installation of LED lightings for a municipality (European Commission, 2017); (4) $\rho4$: 5%, the social discount rate suggested to conduct Cost Benefit Analysis for countries categorized as Cohesion Member States (European Commission, 2014).

Therefore, to calculate the Net Present Value (NPV) of the LCC, it is not set any discount rate in the LCC calculator, resulting a total LCC for the LED lightings of 129.192,18 euros. The result of the analysis shows that applying ρ1 the NPV at year 15 is reduced by 23,42%, with ρ2 is 35,81%, with ρ3 is 44,47% and with ρ4 a 51,9%.

2.2 The measurement of GHG emissions of the LED and CFL system through Bilan Carbone calculator

To quantify the CO2 eq emissions, this analysis starts from the theoretical framework given by the previous report produced by Arpa Piemonte, which accounted the emissions of the Agency's HQ with the Bilan Carbone tool, with reference to the years 2017, 2018 and 2019 (Arpa Piemonte b, 2021).

The objective of this analysis is to verify any benefits brought about, ceteris paribus, by the new approach compared to the previous one, i.e. to identify the CO2 eq emissions associated with the LED technology, and verify any differences compared to the BAU scenario with CFL. Therefore, the scope of the project, the boundaries of the investigation, the emission factors and the same calculation methodologies are maintained (for hydroelectric power is 0,024 kg CO2 eq/kWh from the 7.4 Version of Bilan Carbone; for solar energy is 0,055 kg CO2 eq/kWh from the Italian National Inventory Report, 2016).

The scope of the previous report included the main flows of several materials (Arpa Piemonte b, 2021); energy consumption for lighting was presented in an aggregate form in the macro-category "Electricity". The perimeter is represented by 11 buildings A1, A3, A4, B0, B4, C1, C4, D0, D3, E1 and E4, which coincides with the boundary of the LCC analysis previously carried out. The organization has identified the operational boundaries on the basis of the incoming and outgoing flows to identify the emissions associated with its activity, according to the ISO14064: 2018 Standard and has divided them into direct emissions (Scope 1) and indirect emissions (Scope 2 and 3). This research is intended to analyse those emissions that accounts specifically under the category of Scope 2, i.e. those deriving from purchased or consumed electricity. The Emission Factors are specific to the individual systems of electricity production, which for the lighting are referred to the hydroelectric and oceanic energy power. As mentioned, the report referred to three years, 2017, 2018 and 2019, however, for this research it was decided to refer only to the year 2019 to compare the benefits between technologies.

The total luminaire power for all the buildings is 15.634 W, while for the CFL is 41.470 W. The resulting value for each building is then weighted for the operating hours, which were previously reported to be significantly different among the structures. The total annual consumption with the LED system amounts to 13.734,24 kWh, while for the CFL is 35.854,28 kWh.

The resulting value of the luminaire consumption is embedded in the specific frame named as "Energy Purchase and Production from RES" and weighted according to the origin of the energy source. The LED system of the winning proposal for the tender would have produced 340 kg CO2 eq emissions adopting the data available for the year 2019, while the previous system with CFL produced, according to the estimation, 886 kg CO2 eq emissions.

From the Bilan Carbone results a consideration emerges in line with what has already been described during the analysis of the LCC calculator. Since the supply of electricity for the Agency originates for 100% from RES, the emissions are lower, compared to other consumption activities of the agency, which, instead, originates from other non-renewable sources, i.e. as for the heat that comes from natural gas district heating (Arpa Piemonte b, 2021). However, it is found that with the new LED system there is a reduction in CO2 emissions of 61.63% compared to the previous CFL system. However, these emissions are referring to Scope 2 only, i.e. to those emissions that occurred due to the purchase or consumption of electricity during the ownership. This data, therefore, should be offset by the respective emissions released during the production and decommissioning phase of the luminaires. The main limit to estimate the overall CO2 eq emissions for Scope 3 is due to the lack of emission factors provided by the tool. In fact, the emission factor is envisaged for other types of inputs, therefore is possible the accounting of Scope 3 emissions, while for the lighting sector is not provided in the database. To act against this lack, it would have been necessary to rely on an LCA analysis made available by the manufacturers of light bulb; however, for a PA that has to draw up numerous tenders and that has other duties, this implies and means a considerable consumption of resources and time. Furthermore, the bidders are the companies that deal with the installation and not the production companies of lighting, and the inclusion of more actors would add more complexity to the drafting of the tenders and to ex-post considerations. Additionally, comparing the benefits between the LED versus the CFL scenario emerged that with the adoption of LED there is a saving in electricity consumption of 61,69%, i.e. 22120,04 kWh amounting to 3163 euros per year (assuming an energy price of 0,143 EUR/kWh).

Alternatively, there was an option to compensate for missing factors for Scope 3, which was the one attempted for this research. This would have been to consult ENEA and ask whether a national emission factor for the sector in question had been determined. In this way, the simplest solution for a PA, and for this research, would be to use the emission factors for the lighting sector by the tool; however, the data is not available. Finally, the last point to stress is the gap between the CO2 savings resulting from the Bilan Carbone and the LCC calculation. The difference is due to the fact that the total consumption, from which the emissions derive, have different values: for Bilan Carbone it was possible to insert the weighted consumption for the operating hours of each building reported from the project office and for this reason is a more accurate data, i.e. with LED are emitted 340 kg of CO2 eq emissions, while with CFL 886 kg in the reference year, therefore there is a saving of 546 kg. In LCC it is not possible to multiply the consumption by the annual operating hours of each building, but it is the calculator that automatically estimates the consumption from the number of lamps inserted and then multiplies it by the total weighted average of hours, i.e. 828 hours. The total resulting value accounts for 15 years, while for one year amounts to 310 (LED) and 824 kg (CFL) of CO2 eq emissions, i.e. a saving of 514 kg with LED. Despite 514 kg has the same order of magnitude of the emissions measured with the Bilan Carbone, there is a gap of 480 kg in a range of 15 years between the two calculations.

3. Conclusions

This research aimed to verify whether the new Arpa Piemonte's internal lighting system carried out environmental and economic benefits. It resulted that the LED solution, object of the tender, led to savings, respectively, to the alternatives CFL LP and CFL HP, of 25.01% and by 50.83% in terms of total cost. Also, in terms of environmental benefits, LED technology has led to a saving of 61.63% in CO2 eq emissions compared to the previous system. However, as demonstrated in the quantification of the payback period of the 3 cost scenarios, it is found that the times to recover the investment by the Agency are greater than the useful lifetime of the lamps considered. With the adoption of a joint analysis through LCC, Bilan Carbone and financial metrics, the shortcomings were confirmed, but also the peculiarities of each calculation tool. With Bilan Carbone it came out that the possibility of inserting the values of the total consumption calculated from the operating hours weighted for each building. This brought a more specific estimation of the emissions rather than the one contained in the LCC calculator, where it is not allowed the insertion of the electricity consumption. Similarly, Bilan Carbone omits the economic aspects, strictly focusing on measuring environmental factors. However, the major limit leading the CF comparison between the LED and CFL scenario was the absence of the Scope 3 emissions due to the raw material processing and to the disposal of the lamp. The motivation behind this lack may lie in the fact that the energy-intensive and more emitting phase occurs during the consumption stage as reported in the literature by LCA for the LED (Ferreira et al., 2021). In this way, this LCC calculator should be read together with a product LCA that can cover the other missing stages.

A substantial limitation of the research derives from the moment in which this analysis was implemented, i.e. in the post-tender phase, meaning that the award of the contract cannot be actively affected. However, the exemplification process showed how the use of these calculators, when the MEAT is adopted, can bring both environmental and economic benefits. In fact, it has been shown how the environmental and economic benefits could be considered within a tender with LCC award criteria and, additionally, how the financial metrics could avoid short-sightedness regarding the investment payback times and the actual overall savings.

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