NOVA SCHOOL OF BUSINESS AND ECONOMICS LISBON

Work Project

Energy Efficiency in Public Lighting and Stadium Lighting

Friedrich Felix Tacke

Masters in Finance / CEMS Masters in International Management

Student number: 16000561

CEMS MiM Business Project: "Energy Efficiency in Public Lighting" (EDP)

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I. Brief Context of the Business Project

1. EDP and EDP Distribuição

The business project "Energy Efficiency in Public Lighting" has been conducted for EDP Distribuição, an entity of the Energias de Portugal (EDP) group that is working in the field of electricity and natural gas distribution (EDP, 2012).

EDP is Portugal's largest distributor, generator and supplier of electricity and is employer to over 12.000 people. The company's biggest shareholder is the China Three Gorges company representing a share of 21,35%. EDP encourages and emphasizes energy efficiency and sustainability. While EDP is a worldwide operating company present in 13 countries, EDP Distribuição is operating in Portugal only (EDP, 2014).

EDP Distribuição owns roughly 99% of the electricity distribution network in continental Portugal. In 2012, it has distributed nearly 45.000GWh within the country. In the same year, more than 3.500 people were employed by EDP Distribuição. Its EBITDA was at 661 M€, 3,2% higher than in 2011 (EDP, 2013; EDP, 2014).

2. Market Overview and Client Situation

The energy distribution market is part of the broader energy market. One can divide energy services along the value chain (example electricity) from power generation to power transmission and power distribution. EDP Distribuição covers the last step of this value chain (see appendix 1). As EDP owns 99% of the network, it operates almost without competition.

The distribution occurs through a high- and medium-voltage grid and through a low voltage grid. For the distribution of high- and medium-voltage electricity, EDP Distribuição has an open-ended license. Regarding energy distribution through the low voltage network, EDP Distribuição has concession contracts with municipalities and is providing maintenance and investment services. Currently it has concession contracts with all 278 municipalities. As part of these contracts, EDP Distribuição is also responsible for public lighting (EDP, 2014).

EDP Distribuição distributes electricity to both public and private end-users. It has a stable client base of more than 6 million clients (EDP Distribuição, 2013).

EDP Distribuição collects revenues from energy providers, most importantly its mother company EDP. From a non-technical perspective, EDP Distribuição's fees are part of the consumers' energy bill paid to their providers, which in turn pass it on to EDP Distribuição (EDP, 2013). For using low voltage networks, EDP Distribuição pays a rent to municipalities (see appendix 2) (EDP Distribuição, 2014; EDP Distribuição & Municipalities, 2001).

3. Project “Energy Efficiency in Public Lighting”

The public lighting market is going through a phase of structural change. From 2015 on, mercury vapor lamps will not be produced anymore due to an EU Directive on eco-design requirements for energy-using products (European Commision, 2009). Mercury lamps will have to be replaced by more efficient technologies. With 20% of public lighting lamps in Portugal being mercury vapor lamps (the remaining 80% are sodium lamps), the technology switch is a large scale project. EDP Distribuição, as the operator of public lights, is responsible for developing and executing a phase out and replacement plan for Portugal.

A CEMS business project was set up in 2013 to assist EDP Distribuição develop their replacement strategy. The project includes the evaluation of economic benefits considering investment, operation and maintenance. Further, an impact analysis on tariffs due to the reduced energy consumption was conducted and several sensitivity analyses on key variables were carried out. Lastly, financing options were evaluated (EDP Distribuição, 2014).

The profitability of the options was evaluated using a net present value (NPV) calculation. Total financing need was another evaluation criterion. Lastly, the project developed corresponding financing options and an implementation schedule.

4. Conclusions of the Project

Based on an NPV calculation, three scenarios were compared with a setting in which no substitution takes place. For substituting mercury lamps, two technologies were considered: Sodium vapor lamps and LED lamps. Three scenarios of technological change were analyzed:

1) Mercury lamps are substituted by sodium lamps
2) Mercury lamps are substituted by LED lamps
3) Both mercury and sodium lamps are substituted by LED (see appendix 3).

The outcome is that EDP Distribuição should substitute both mercury and sodium by LED. Even though the scenario has the highest investment with 100 M€, it also has with 114 M€ a very high NPV. In scenario 1, investment costs were only at 18 M€, but NPV dropped to 15 M€. In scenario 2, the NPV was 65 M€ and financing need 27 M€ (see appendix 4).

The recommended financing option is to set up an Energy Performance Contract (EPC) specifying that EDP is acting as an Energy Service Company (ESCO) that is sharing the savings from the reduced energy consumption with municipalities. The sharing of savings may be transformed in a renegotiated concession agreement where EDP pays a lower concession rent to municipalities instead of paying back part of the savings. EDP has control over the project but also bears all financial risk as it has to carry the initial investment.

II. Energy Efficiency in Stadium Lighting

The more energy efficient LED technology can lead to significant savings in maintenance and energy consumption. This is not only the case for the previously analyzed public lighting but also common sense with regard to household lighting. In other facilities as football stadiums however, LED technology has not yet been introduced. This raises two questions: First, is it technologically feasible to introduce LED floodlight to football stadiums? Second, is it favorable in financial terms to introduce the new technology?

This section analyzes the technological and financial feasibility of LED floodlights in football stadiums and discusses whether stadium operators are considering investments in LED floodlight. Then, potential options to increase the attractiveness of LED are presented. Finally, a conclusion is provided.

1. Technological Appropriateness

Currently, most football stadiums are using metal halide lamps for their floodlights. A replacement of these lamps by LED floodlights could offer various advantages:

In comparison to commonly used metal halide floodlights, LEDs provide lower energy consumption for three reasons: First, they consume less energy when they are illuminated. Second, LEDs don't need an energy consuming warm-up period. Third, in contrast to metal halide lamps, LEDs provide the possibility of dimming. Moreover, the lifespan of LED lamps is significantly higher decreasing maintenance costs. Another advantage of LED floodlights is that they provide a more stable light. This leads to an advantage for television broadcasting: Besides the possibility of high definition broadcasting, LED floodlighting provides the opportunity of high-speed recording and super slow motions without flickering of pictures (Lighting research center, 1995-2014; Siteco, 2000-2014).

However, currently LED floodlighting is not yet used in football stadiums. There is also no data about the specifics of an installation in stadiums. For instance the angle of the lamps has a big impact as it greatly influences the illuminance on the pitch and therefore the required power per lamp. The flatter the angle, the more power a floodlight must have or the more floodlights are needed, which increases initial investment and energy consumption.

As indicated above, technologically the introduction of LED floodlights makes sense. Nevertheless, the absent experience with LED floodlight systems leaves some uncertainty about the technical adaptation that may significantly influence investment costs.

2. Financial Feasibility

This paragraph evaluates the financial feasibility of an installation of LED floodlight in stadiums. In order to assess the feasibility an excel model has been created. In the following, first the main assumptions of the model are presented. Second, the way the model works is shown. Third, the model's main result, the NPV of an introduction, is discussed. And fourth, the results of three sensitivity analyses are evaluated.

i) Assumptions

The project takes a time horizon of 16 years until 2030 with a fictive investment in floodlight made in 2015. A stadium that is in need for new floodlights is assumed to consider two technologies: the commonly used metal halide technology or the new LED technology.

Regarding those two technologies, it is assumed that LED lamps are 1/3 more energy efficient than metal halide (Krüger, 2013). In order to reach the same level of illuminance as 224 metal halide lamps with a power of 2000W, 300 LED lamps with a power of 1000W are needed. The price of a 1000W LED floodlight is considered to be at 1.200€, whereas a 2000W metal halide floodlight costs 800€.[1] Costs of installation are assumed to be equal. The lifespan of LED is with 50.000h significantly higher than for metal halide with 5.000h.[2] An annual lighting time of 125h (referring to 25 matches with an illumination of 5h per match) is seen as realistic. Despite the long lifetime, it is assumed that part of the lamps will have to be substituted before 2030 due to failure. For taking into account the longer lifespan of LED lamps, average maintenance costs are calculated as *(1/lifespan in years) x price of a lamp x number of lamps* (Allianz Arena München Stadion GmbH; Osram, 2014).

The floodlight system is needed to illuminate a pitch with the size of 7.000m² and the illuminace has to be at 2.000 lux for fulfilling the requirements of the 2014 football World Cup in Brazil (FIFA, 2013). For doing that, lamps with a total of more than 12,4 million lumens are needed. However, as the example of the Allianz Arena in Munich shows, there are 4 times more lights needed in order to illuminate the entire stadium including tribunes (Allianz Arena München Stadion GmbH). Therefore, the total need for lumen is approximately 50 million (for detailed calculations see appendix 5).

Inflation is assumed to only impact the price of energy. The intuition behind that is that an increase in the prices of floodlights is very unlikely as prices for technological products are rather decreasing than increasing. The discount rate is assumed to be at 10%. This is the same

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[1] The price of 1 LED floodlight is about 1.900$ (Dias, 2014). However, the price significantly depends on the amount ordered (LEDdevil, 2014). Due to the big amount and bulk discount a price of 1.200€ seems reasonable.

[2] 50.000h lifespan for LED is a conservative assumption (LEDsmaster, 2013).

as EDP assumes for a similar project, the previously mentioned change in public lighting (Fonseca, 2014) (for a table of assumptions see appendix 6).

ii) The model's approach

The approach is to compare two scenarios: a scenario in which the stadium is equipped with the commonly used metal halide floodlight with a scenario of investing in the new LED technology. The cash flows of the LED Scenario are then subtracted from the metal halide scenario.[3] Therefore, in case of a positive NPV, the stadium should be equipped with LED floodlights and in case of a negative NPV metal halide floodlights should be installed.

Due to the assumptions of equal installation costs, these costs are kept out of the model as they cancel each other out.

iii) NPV of an LED introduction

The introduction of LED has an overall negative NPV of around 120.000€ and is thus under current conditions financially not favorable (for a table of assumptions see appendix 6). The lower NPV is caused by a higher initial investment for LED of around 165.000€ as compared to metal halide lamps. The energy consumption of LED is at 600MWh and thus significantly lower than 896MWh for metal halide. However, the reduction in energy consumption translates into savings of 17.500€ (NPV) only. Together with ~28,000€ lower maintenance costs of LED these savings are not sufficient to outweigh the higher investment costs. For absolute costs see appendix 7.

Category	Comparison in NPV(rounded)
Investment	- 165.000€
Energy consumption	17.500€
Maintenance	28.000€
NPV	**- 119.500€**

Table 1: NPV calculation with base assumptions

Thus, under the current technology costs, the introduction of LED is financially not attractive.

iv) Sensitivity analysis

The sensitivity analysis in this section is made on 3 inputs: The change in energy consumption, the annual lighting hours of floodlight and the price of a single LED floodlight.

[3] The cash flows refer to expenses (investment, cost of energy and maintenance). If the subtraction of the LED scenario cash flow from the metal halide scenario cash flow yields a positive number, an investment in LED is saving money compared to an investment in metal halide.

A. Change in energy consumption: In the Ratiopharm Basketball Arena in Ulm, Germany, the used LED floodlights are 1/3 more energy efficient than metal halide floodlights (Krüger, 2013). However, for lower power lamps, LEDs need only about 50% of the energy a metal halide lamp needs (Eclipse Lighting, 2014). As the LED technology is still developing, this reduction of energy consumption may become reality for high power LEDs, too.

Assumption	Comparison in NPV (rounded)
LED requiring 67% of metal halide energy	- 119.500€
LED requiring 50% of metal halide energy	- 25.000€

Table 2: Change in energy consumption sensitivity analysis

As indicated by the table above, the energy efficiency of LED significantly influences the NPV of the project. The impact on NPV is more than proportionate as a decrease in LED energy consumption not only impacts the money spent on energy but also the amount of lamps needed and therefore investment and maintenance. Nevertheless, an increase in efficiency cannot turn a negative NPV project into a positive NPV project under the base assumptions.

Appendix 8 shows that the cash flows of the more energy efficient scenario are always higher than for the base scenario. Especially the lower initial investment has a large impact on project cash flows and thus on its NPV.

B. Annual lighting hours of floodlight: A football team has about 25 home matches per season, depending on the league, how far it advances in the national cup and if it is playing in international competitions. Due to broadcasting, the floodlights are switched on for most of the games, even in the case of afternoon games (Röderer, 2013). But there are teams with more games and there is the possibility of using the stadium for other purposes as concerts. Therefore, a sensitivity analysis on annual lighting hours is conducted.

Annual lighting hours	NPV with 67% of metal halide energy consumption	NPV with 50% of metal halide energy consumption
125	- 119.000€	- 25.000€
175	- 100.000€	- 2.600€
300	- 55.000€	54.000€

Table 3: Annual lighting hours of floodlight sensitivity analysis

The analysis unfolds that NPVs are negative for all analyzed lighting hours if LED is consuming 67% of metal halide lamps. In case of more energy efficient lamps, the NPV is positive if the lights are switched on 300 hours a year (NPV of 54.000€).

A change in annual lighting hours has impact on both energy consumption and maintenance.

C. Price of LED floodlights: Due to the lack of implemented LED floodlights in stadiums, there is little data about the prices of LED floodlight. Furthermore, the LED technology is a recent one and decreases in prices are likely to occur. Therefore, a sensitivity analysis on LED prices is conducted. The table below shows the prices of an LED floodlight that will make the project a zero NPV project.

Annual lighting hours	NPV with 67% of metal halide energy consumption	NPV with 50% of metal halide energy consumption
125	730€/LED floodlight	1.080€/LED floodlight
175	840€/LED floodlight	1.190€/LED floodlight
300	1.000€/LED floodlight	1.450€/LED floodlight

Table 4: Price of LED floodlight sensitivity analysis

In the case of an LED lamp that is consuming 67% of the energy than the metal halide lamp is consuming, a price below 730€ would generate a positive NPV when illuminated 125 hours a year. For annual lighting hours of 175 and 300 the price has to be below 840€ and 1.000€, respectively.

Regarding a more energy efficient LED floodlight that is only consuming 50% of the halide lamp, the prices have to be below 1.080€ for 125 annual lighting hours, 1.190€ for 175 hours and 1.450€ for 300 hours of annual illumination.

To sum up, under current circumstances an introduction of LED would yield a negative NPV and is therefore not advisable. However, future developments in the technology leading to lower costs and/or higher energy efficiency could make it financially feasible to invest in LED floodlight, especially if the floodlight is used frequently.

3. Are Stadium Operators Considering an Investment in LED?

To test the results in practice, two football stadium operators were asked whether they are considering the investment in LED floodlight technology: The operators of the Esprit Arena in Düsseldorf, Germany, where Fortuna Düsseldorf holds its home games (2nd German Division) and stadium operators of the Mage Solar Stadium in Freiburg, Germany, in which Sport-Club Freiburg plays its home matches (1st German Division).

Esprit Arena operators are currently considering investments in new floodlight, including LED floodlight. However, they are still at the beginning of the decision-making process (Baumann, 2014).

Sport-Club Freiburg, operator of Mage Solar Stadium and known for its commitment to environmental protection, is currently not considering an investment in new floodlight. This is due to the fact that they are planning to build a new Stadium. But for the new stadium, LED floodlight is considered (Boyé, 2014).

These two stadium operators indicate that LED technology is currently considered by stadium operators as an alternative technology, hence underline the importance of this study.

4. Potential Options to Increase the Attractiveness of LED

The NPV assessment has revealed higher costs for LED as compared to the currently used technology if the entire costs are carried by stadium operators. However, as the LED technology offers favorable technological and environmental aspects, a cost sharing could be imagined to increase the attractiveness of LED:

Option A: TV stations benefit from LED technology. League organizers, e.g. the German Deutsche Fußball Liga (DFL), could factor the higher costs of LED technology into the next round of TV-contract negotiations and use the additional money to subsidize the technological upgrade to LED.

Option B: The general public benefits from LED as reduced energy consumption leads to lower CO2 emissions in energy production. Based on this argument, stadium operators or the league organizer could negotiate subsidies with governments. The league could also consider applying for EU climate change funds.

Option C: The installation of LED lamps provides a business opportunity for LED lamp producers as well as an opportunity to advertise their products. Stadiums could brand their floodlights and stadium lighting more broadly with the name of the producer which the producer could compensate by lower technology prices.

Renting of LED lights as an alternative model has been considered but is not likely to be economically viable due to high installation costs.

5. Conclusion

In many areas LED has already proven to provide a technologically and financially feasible lighting solution. For floodlighting in big stadiums, this is currently not the case.

Technologically, LED is able to reduce the energy consumption of the lighting in stadiums. It also provides new features to TV broadcasters.

Financially, under the current conditions, the introduction of LEDs to football stadiums is on average not attractive. However, the sensitivity analyses revealed that there is future potential for LED. Technological developments, i.e. the reduction in energy consumption and/or a reduction of production costs and prices would make an investment in LED floodlighting attractive. Moreover, a high operating grade would positively influence an installation.

Currently, stadium operators are aware of the fact that it is still too early for implementing LED floodlights. However, smart installation leading to energy savings and innovative cost sharing models could already today make the use of LED technology attractive. A case by case assessment of economic advantages is highly recommended.

III. Reflection on Learning

1. Previous Knowledge Learned from Masters Program - Masters Knowledge Applied

During the project "Energy Efficiency in Public Lighting", I benefitted greatly from the knowledge developed as part of my Masters in Finance at NOVA School of Business and Economics.

First, when developing an extensive excel model to estimate project NPVs, I could apply the knowledge about cash flow and alternative NPV calculation methodologies.

Second, I applied finance knowledge for evaluating the different financing options. Of great importance was the distribution of financial risk and performance risk. Due to the complexity of the concession contracts with municipalities and the possibility of involving a third party, the knowledge acquired during the course "Project Finance" was of great value.

Third, I benefited greatly from all the practical exercise and team work conducted during the master program. One of the main challenges of projects as the one carried out with EDP, is project management, especially in light of new team constellations. The extensive team work during the master program provided an ideal learning experience and allowed me to master the project management challenges.

In general, I felt very well prepared to master finance and project management related tasks.

2. New Knowledge

The project allowed me to develop new skills and knowledge, in finance, technology, project management, and in client management. After a small consulting project for Deloitte, this was the first sizable consulting project. I realized the importance of a rigorously planned and executed project management. The setting up of weekly meetings, monthly steering meetings and the structuring of different tasks were key factors for the successful project realization.

Regarding the project's content, the approach of first measuring the effective overall economic impact instead of only analyzing either the benefit for EDP or for the municipalities was new to me. Hence, benefits and costs for the entire system were taken into account without responding to the different roles of the parties involved and their sharing of benefits. This was important for analyzing the total benefit of the project before splitting the profits.

Moreover, the tariff analysis that was conducted due to a decrease in energy consumption greatly enhanced my ability to take economic modeling into practice.

I was also able to gain a detailed understanding of technological aspects of the project and learned to quickly familiarize myself with this entirely new subject.

3. Personal Experience

i) Strengths and weaknesses

The project confirmed my strengths in financial modeling as well as analyzing financing options. In addition to the application of my technical skills, I was able to communicate openly with my group members. I thereby benefited from the cross-cultural communication skills that I developed when living abroad in Spain, Portugal, Poland and Australia.

Regarding weaknesses, I once more realized the importance of initial structuring of my work package, which I did not do sufficiently at the beginning of the project. Unconsciously, I was following a too uncoordinated learning by doing approach.

ii) Plan to develop my areas of improvement

In consideration of the weakness mentioned above, for my next projects, I will dedicate sufficient time to upfront project structuring. This includes both, the planning of the technical work as well as project and stakeholder management, e.g. the upfront scheduling of meetings over the course of the entire project.

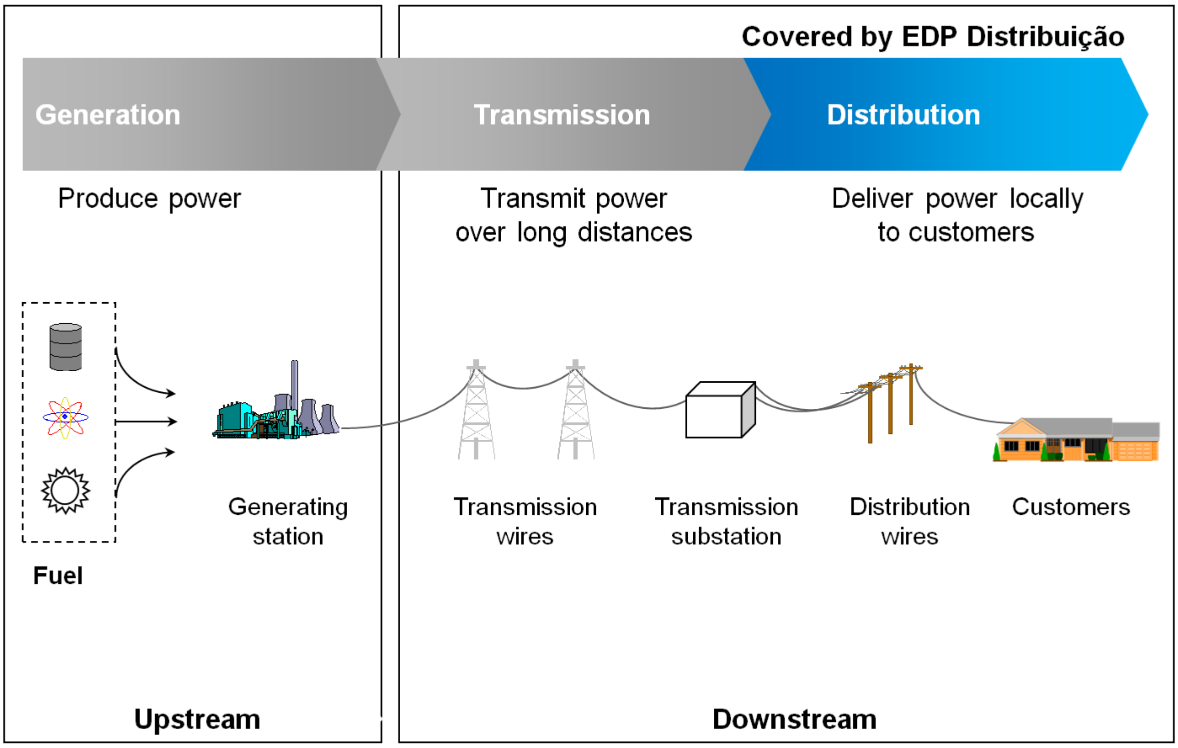
4. Benefit of Hindsight

What added most value: Crucial for the project was a close collaboration with EDP employees. Their experience and know-how was important for developing stable and valuable models. Hence, the developed model itself was vital as all of our results based on that. The numerical outputs were not only important for evaluating the feasibility of the different scenarios but also a base for assessing the different financing options.

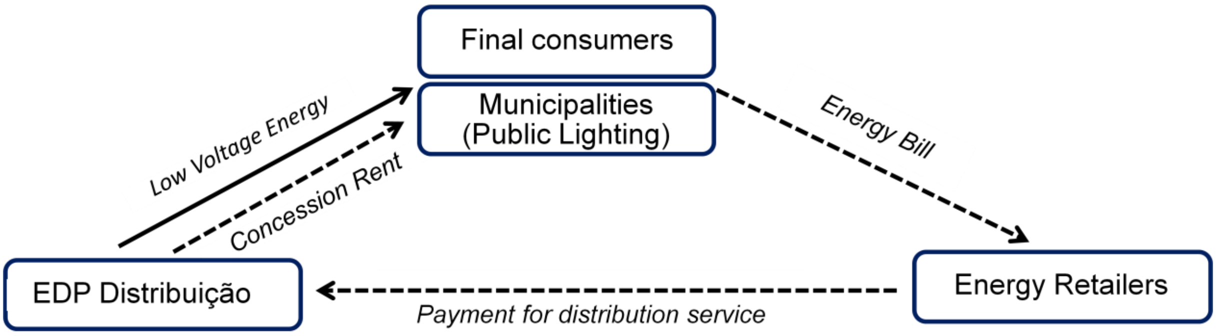
What should have been done differently: A more detailed consideration of further technological development could have been valuable. LED is considered to be a disruptive technology. But as technologies are said to follow an S-curve, this technology may also reach a stage of maturity. Then, a new technology starts growing and starts to become a superior alternative. Regarding public lighting, OLEDs, an advancement of LEDs, could become the technology of the future (for S-curve see appendix 9). Thus, a technological analysis may have been valuable and could have led to the development of a more complex model allowing for a new technology to be considered in the future.

IV. Appendix

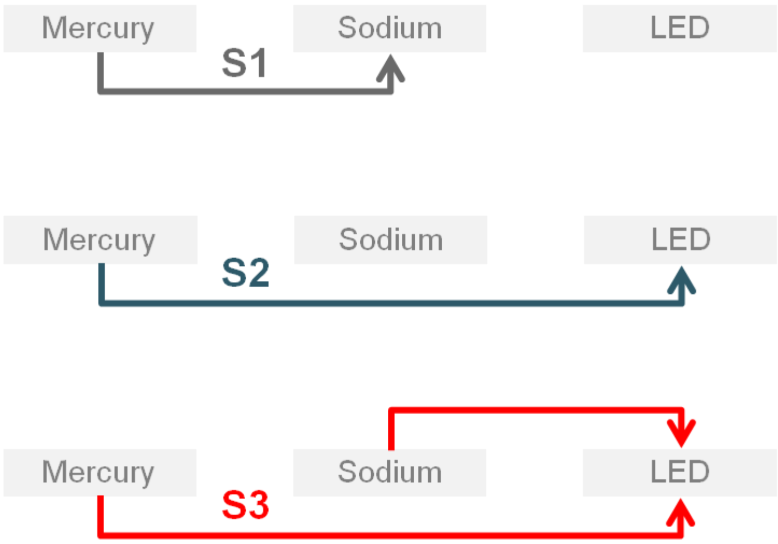
1. Electric Power Value Chain



2. Simplified Supply Chain for Low Voltage Energy



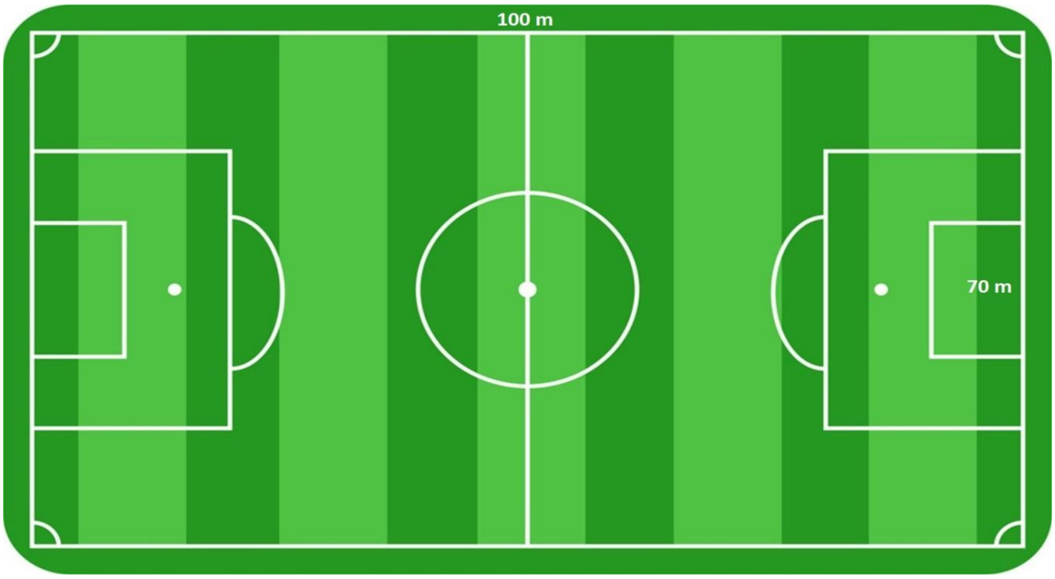
3. Scenarios in Public Lighting



4. Public Lighting NPV and Investment Table

Scenario	NPV (M€)	Investment (M€)
Scenario 1: Mercury to sodium	15	18
Scenario 2: Mercury to LED	65	27
Scenario 3: Mercury and Sodium to LED	114	100

5. Calculation of the needed illumination



Source: amazon.com

- Height of lights: 45m (Assumption)
- Angle of lights: 45° (Assumption)

➔ Surface area “per light element”: 1091,5 m²

- Illumination (in lumen) needed to illuminate the area of 1091,5m² taking into account the FIFA World Cup requirement of 2000 lux: 1,94 M lumen (per light element)[4]

- Field Size: *100m x 70m = 7000m²*
- "Light elements" needed: *7000m² / 1091,5 m² = 6,4*

- Total lumens needed for illuminating the pitch: *6,4 x 1,94M = 12,416 M*

➔ Floodlights with a total of 12,416 million lumens needed to illuminate the entire pitch
➔ For illuminating the entire stadium, including the tribunes, four times more lumen are needed, making it 50 million lumens (Allianz Arena München Stadion GmbH)

6. Assumptions for Energy Efficiency in Stadium Lighting

Category	Assumption
Project Horizon	16 years
Price of KWh	0,11€[5]
LED energy consumption as percentage of metal halide consumption	67% (discussed in sensitivity analysis)
Annual lighting hours	125 (25 matches per season, 6 hours a match; discussed in sensitivity analysis)
Discount rate	10%
Inflation rate	1,5% from 2019 on[6]

Metal halide Assumptions	
Lifespan	5.000h (conservative regarding the frequent switching on and off)
Power	2.000W
Price	800€
Number	224
Lumen	222.000[7]

LED Assumptions	
Lifespan	50.000h
Power	1.000W
Price	1.200€ (discussed in sensitivity analysis)
Number	*Adapted according to illumination need*
Lumen	222.000

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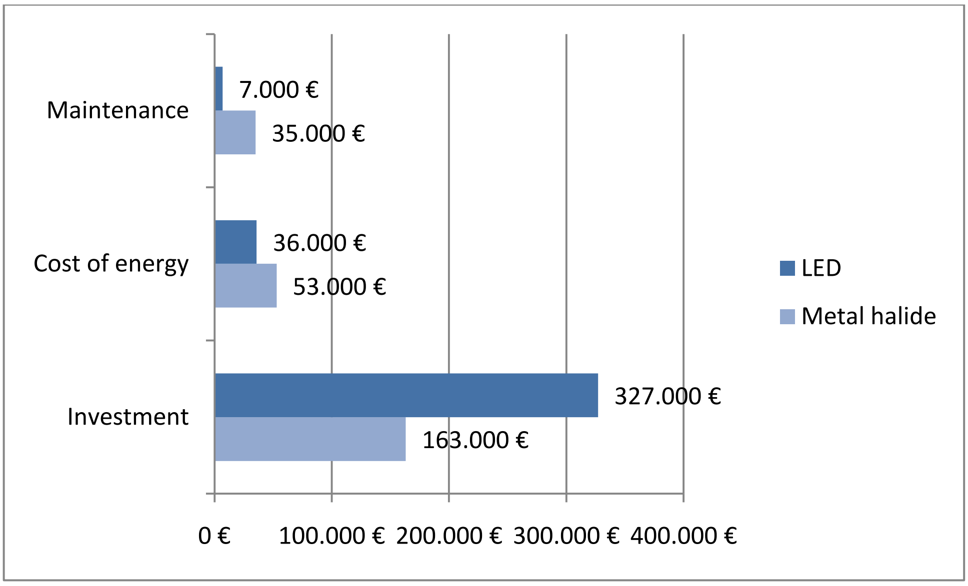
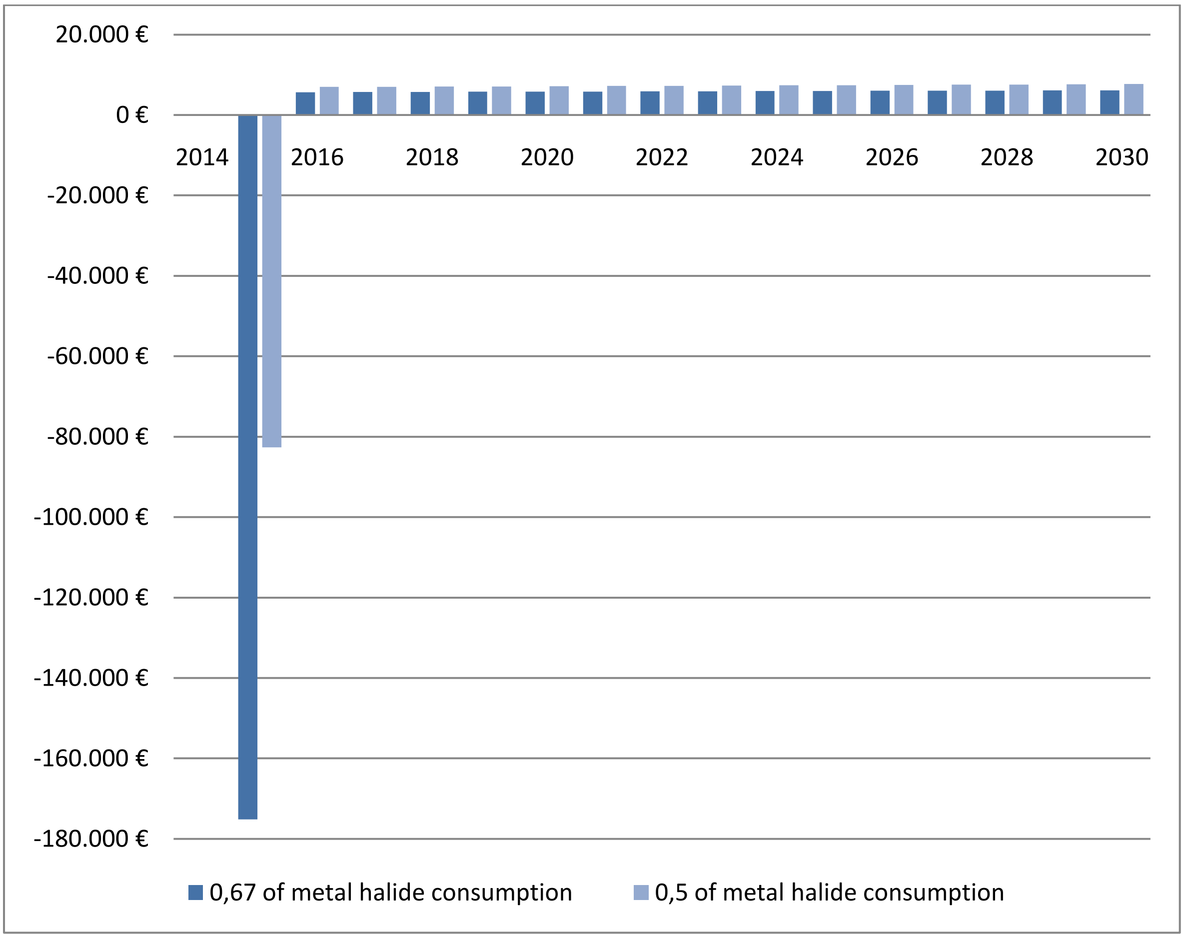
[4] For calculating the surface area and for transferring lux to lumen an online calculator was used (LedRise, 2013)
[5] (Fonseca, 2014)
[6] (International Monetary Fund, 2014)
[7] (Osram, 2014)

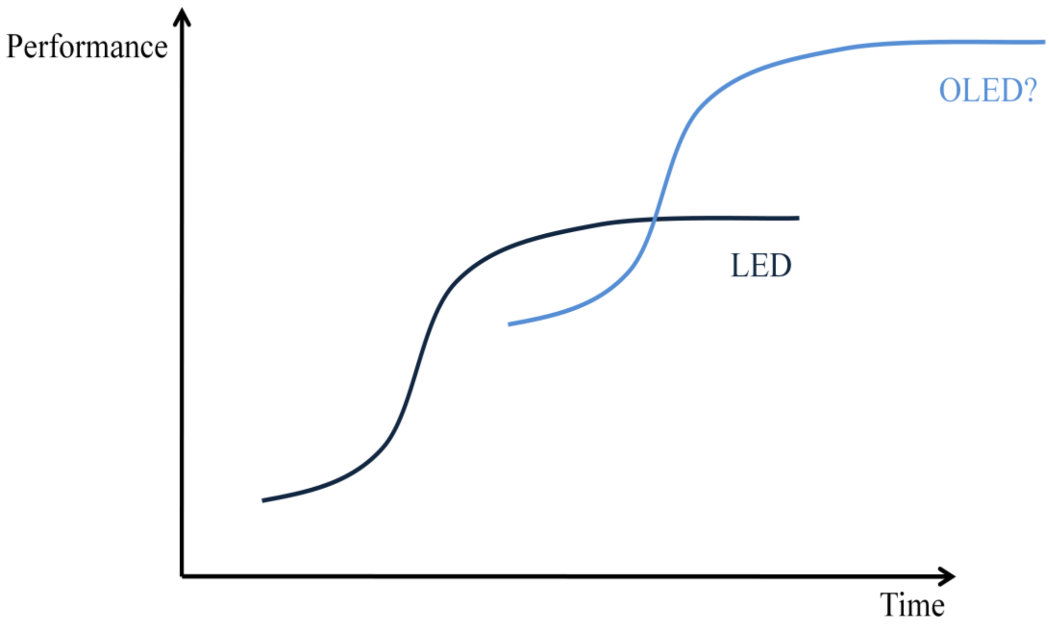
7. NPVs for Investment, Cost of Energy and Maintenance of Base Scenario



8. Cash Flow Graph



9. S-Curve



V. Register of Abbreviations

DFL	Deutsche Fußball Liga
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
EDP	Energias de Portugal
EPC	Energy Performance Contract
ESCO	Energy Service Company
EU	European Union
GWh	Gigawatt hour
h	Hour
LED	Light Emitting Diode
M	Meter
m^2	Square meter
M€	Million Euros
MWh	Megawatt hour
NPV	Net Present Value

VI. Sources

Allianz Arena München Stadion GmbH. (n.d.). Retrieved May 19, 2014, from allianz-arena.de: https://www.allianz-arena.de/de/fakten/detaillierte-zahlen/

Baumann, K. (2014, May 9). E-Mail interview.

Boyé, M. (2014, May 5). E-Mail interview.

Dias, D. (2014, May 21). Telephone interview.

Eclipse Lighting. (2014). Retrieved May 18, 2014, from eclipselighting.com: http://www.eclipselightinginc.com/pages/posts/metal-halide-high-pressure-sodium-to-led-conversion-chart260.php

EDP. (2012). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/aedp/empresasdogrupoedp/Pages/default_new.aspx

EDP. (2013). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/aedp/unidadesdenegocio/distribuicaodeelectricidade/Pages/Distribui%C3%A7%C3%A3oPT.aspx

EDP. (2014, April 4). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/Investidores/accaoedp/estruturaaccionista/Pages/ShareholderStructure2.aspx

EDP. (2014, April 2). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/Investidores/aboutedp/Pages/aedp.aspx

EDP. (2014, April 4). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/Investidores/accaoedp/estruturaaccionista/Pages/ShareholderStructure2.aspx

EDP. (2013). *A world full of energy - Annual report 2012.* Lisbon.

EDP Distribuição & Municipalities. (2001, May 5). Portaria 454_2001.

EDP Distribuição. (2013). A World Full of Energy - Números 2012.

EDP Distribuição. (2014, February 7). Energy Efficiency in Public Lighting Kick Off. Lisbon.

Energias de Portugal. (2012). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/aedp/empresasdogrupoedp/Pages/default_new.aspx

Energias de Portugal. (2014, April 2). Retrieved May 5, 2014, from edp.pt: http://www.edp.pt/en/Investidores/aboutedp/Pages/aedp.aspx

European Commision. (2009). Commision Regulation (EC) No 245/2009. *Official Journal of the European Union* .

FIFA. (2013, October). Retrieved May 15, 2014, from fifa.com: http://resources.fifa.com/mm/document/tournament/competition/01/47/38/17/regulationsfwcbrazil2014_update_e_neutral.pdf

Fonseca, A. A. (2014, April). Interview.

International Monetary Fund. (2014, April). Retrieved May 19, 2014, from imf.org: http://www.imf.org/external/pubs/ft/weo/2014/01/weodata/weorept.aspx?pr.x=37&pr.y=3&sy=2012&ey=2019&scsm=1&ssd=1&sort=country&ds=.&br=1&c=182%2C134&s=PCPI%2CPCPIPCH&grp=0&a=

Krüger, D.-I. D. (2013, August 23). *BMU-Umweltinnovationsprogramm Abschlussbericht zum Vorhaben "Energieeffiziente LED-Fluter".* Retrieved from http://www.umweltinnovationsprogramm.de/sites/default/files/benutzer/36/dokumente/abschlussbericht_arena_ulm_incl_anlagen_korrmj.pdf

LEDdevil. (2014, May 21). E-Mail interview.

LedRise. (2013). Retrieved May 21, 2014, from LedRise.com: http://www.ledrise.com/shop_content.php?coID=19

LEDsmaster. (2013). Retrieved May 22, 2014, from ledsmaster.com: http://www.ledsmaster.com/1000W-Power-LED-Flood-Light-191.html

Lighting research center. (1995-2014). Retrieved May 14, 2014, from Lighting research center: http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/mwmhl/restrikeTimes.asp

Osram. (2014). Retrieved May 21, 2014, from osram.de: http://www.osram.de/osram_de/produkte/lampen/hochdruck-entladungslampen/halogen-metalldampflampen-mit-quarztechnologie/powerstar-hqi-ts17539/index.jsp?productId=ZMP_58229

Röderer, J. (2013). Elf des Tages: Über Mainzer Energiesparer und Flutlicht bei Sonne. *Badische Zeitung* .

Siteco. (2000-2014). Retrieved May 14, 2014, from Siteco: http://www.siteco.com/en/application/references/sports/project/399.html

theenergycollective. (2014, March 21). Retrieved May 21, 2014, from theenergycollective.com: http://theenergycollective.com/todayinenergy/356546/led-bulb-efficiency-expected-continue-improving-cost-declines