WORLD BANK GROUP
ESMAP
Energy Sector Management Assistance Program

LIGHTING BRAZILIAN CITIES:

BUSINESS MODELS FOR ENERGY EFFICIENT PUBLIC STREET LIGHTING

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ESMAP

The financial and technical support by the Energy Sector Management Assistance Program (ESMAP) is gratefully acknowledged. ESMAP — a global knowledge and technical assistance program administered by the World Bank — assists low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, the European Commission, Finland, France, Germany, Iceland, Japan, Lithuania, Luxembourg, the Netherlands, Norway, the Rockefeller Foundation, Sweden, Switzerland, the United Kingdom, and the World Bank.

BRAZEEC

The Energy Efficiency Program for Brazilian Cities (BRAZEEC) is an initiative financed by ESMAP aimed at promoting energy efficiency (EE) actions through the identification of feasible and replicable business models in Brazilian cities in the areas of public lighting, public buildings, urban industries and transportation. The program includes a focus on institutional frameworks to strengthen energy efficiency management at the municipal level.

The program´s overall objectives are to: (i) prepare business models to improve EE in the four above- mentioned areas that can be implemented by various Brazilian cities; (ii) enhance the capacities of stakeholders (municipal and private) to enable them to implement EE business models; and (iii) create a demonstration effect that, in the long term, will expand EE initiatives to other city sectors.

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Abbreviations

ABDI	- Brazilian Industrial Development Agency
ABGF	- Brazilian Guarantees and Fund Management Agency
AFD	- French Development Agency
AgeRio	- Rio de Janeiro State Development Agency
ANEEL	- Brazil's National Electricity Regulatory Agency
BB	- Bank of Brazil
BDMG	- Minas Gerais Development Bank
IDB	- Inter-American Development Bank
BNDES	- Brazilian National Bank for Economic and Social Development
BNDES/Finem	- business financing sector of BNDES
BNDES/PMAT	- Fund for the Modernization of Tax Administration and Basic Social Sectors
BRL	- Brazilian Real (Brazilian Real/R$)
CAPEX	- Capital expenditure
CEF	- Caixa Econômica Federal (Federal Mortgage Bank)
CEMAB	- Maciço de Baturité Intermunicipal Consortium of Energy/Public Lighting
CEMIG	- Minas Gerais Electric Energy Company
CIDES/MG	- Intermunicipal Public Consortium for the Sustainable Development of the Triângulo Mineiro and Alto Paranaíba
CIGIP/AL	- Alagoas Public Consortium for Electric Energy Management and Public Services
CIP and/or COSIP	- street lighting charge (on consumers bills)
CONIAPE/PE	- Inter-Municipal Consortium of Pernambuco Hinterland and Borders
COP-21	- 21st Conference of the Parties
CRI	- Color Reproduction Index
DCL	- Net Current Debt (NCD)
DISCO	- Electricity distribution company
DRC	- Differentiated Contracting Regime
EE	- Energy Efficiency
ESCO	- Energy service company
ESMAP	- Energy Sector Management Assistance Program
FGIE	- Infrastructure Guarantee Fund
FGTS	- Brazilian Employees´ Guarantee Fund
FI-FGTS	- FGTS Investment Fund
FIDC	- Credit Rights Investment Fund
FIP	- Equity Investment Fund
FIR	- Referenced Investment Fund
FPM	- Municipal Participation Fund
G-20	- Group of 20
GHG	- Greenhouse gases

GWh	- Gigawatt hour
HPS	- High pressure sodium lamps
ICMS	- Tax on the Circulation of Goods and Services
IFC	- International Finance Corporation
IFGF	- Firjan Fiscal Management Index
MFIs	- Multilateral Financial Institutions
INDC	- Intended Nationally Determined Contributions
INMETRO	- Brazilian National Institute of Metrology, Quality and Technology
IPI	- Industrialized Products Tax
IR	- Income Tax
LED	- Light Emitting Diode
MDIC	- Ministry of Development, Industry and Commerce
MIGA	- Multilateral Investment Guarantee Agency
MME	- Ministry of Mines and Energy
NCD	- Net Current Debt
NCR	- Net Current Revenue
NDC	- Nationally determined contributions
NGO	- Nongovernmental organization
OPEX	- Operating expenditure
R & D	- Research & Development
PEE	- Energy Efficiency Program
GDP	- Gross Domestic Product
PMI	- Expression of Interest Procedure
PPIAF	- Public-private infrastructure advisory facility
PPP	- Public-private partnership
PR	- Reference equity
PRG	- Partial risk guarantee
PROCEL	- National Program for the Conservation of Electric Energy
PROCEL-RELUZ	- National Program of Public Lighting and Traffic Signals Efficiency
PROESCO	- Energy Efficiency Program
PSL	- Public Street Lighting
R20	- Regions of Climate Action
RAB	- Regulatory Asset Base
DRC	- Differentiated Contracting Regime
RGR	- Reversal Global Reserve
SNIS	- National Sanitation Information System
SPE or SPV	- Special Purpose Vehicle
SSL	- Solid-State Lighting
TJLP	- Long-Term Interest Rate
TWh	- Terawatt-hour
WBG	- World Bank Group

FOREWORD

The public street lighting sector in Brazil has reached a turning point. LED technology is now used on a large scale by several cities throughout the world and offers significant savings in energy and maintenance costs. Since late December 2014, all Brazil´s cities have had full responsibility for their street lighting systems, and thus have more incentives to reduce the rising energy costs involved. However, converting to LEDs is capital intensive, which leads municipalities to raise questions such as: (i) is this technology proven and will it attain its forecast lifecycle and produce the expected energy savings?; (ii) how do street lighting investments fit in with municipalities other social priorities?; and (iii) what are the options to structure and finance a substantial modernization project of the municipality´s street lighting system?

To seek answers to these and other key questions, the World Bank Group, as part of its 'green agenda', examined the benefits, risks and financing models of public street lighting projects in Brazil based on LED technology. We began this task in late 2013 by providing technical support to the cities of Rio de Janeiro and Belo Horizonte to identify areas within the municipal sphere with energy efficiency potential. After identifying public street lighting as one of the most promising areas in these two cities, our study evolved into an analysis of possible financing mechanisms, concluding that public-private partnerships (PPPs) through administrative concession could deliver a number of advantages to large cities.

Given Brazil´s 5,570 highly diversified municipalities in terms of needs, per capita income, technical knowledge and access to finance, the World Bank Group perceived that the PPP model, although appealing to a privileged group of large and medium-sized cities, would be a struggle for smaller cities or those with weaker credit profiles. With this in mind, we launched the study reported here with the aim of identifying business and financing models that could be applicable to a wider range of Brazil's municipalities, and lead to all of them benefiting from the improved street lighting services and energy savings that LED technology can offer.

This report by Meyer, de Gouvello, Freire and Maurer is a first effort to give practical meaning to the above questions. We hope that it will prove useful to government officials, mayors, financial institutions and equipment manufacturers, and others. At the same time, we wish to emphasize the need to define a clear strategy for Brazil based on joint, well-coordinated efforts by the different actors, agencies and government spheres to ensure support for municipalities to achieve these goals.

The World Bank Group reaffirms its ongoing interest in working with these stakeholders in the search for solutions to meet the needs of Brazil's diverse regions and municipalities.

Antonio Barbalho
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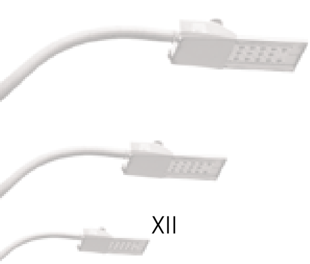

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The report has benefited from substantial contributions by Peter Curley (The Climate Group), Marcel de Costa Siqueira (ELETROBRÁS), Paulo Oliveira (BNDES), Fernando Camacho (BNDES), Fernando de Paiva Pieroni (São Paulo Negócios), Maria Eduarda Berto (Estruturadora Brasileira de Projetos), Clara Ramalho (Lumina Consultoria), Castagnari Consultoria Ltda, Hector Gomez (IFC), Tomas Anker (IFC), Ivan Jaques (World Bank), Peter Mockel (IFC), and Ashok Sarkar (World Bank).

The Pezco Consultoria Ltda team that helped prepare this report comprised Frederico Araújo Turolla, Luís Fernando Rigato Vasconcellos, Helcio Shiguenori Takeda, Jorge Luiz Dietrich, Márcio Fernandes Gabriell, Jorge Oliveira Pires, and André Yoshizumi Gomes.

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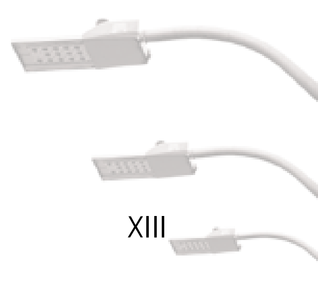


Executive Summary

Introduction

Cities are among the world´s biggest consumers of electric energy, accountable for two thirds of total electricity consumption and for over 70% of global greenhouse gases emissions. Public lighting systems contribute significantly to a city´s energy consumption. In Brazil, for example, public street lighting accounts for more than 4% of the country's total energy consumption. Moreover, the cost of energy for street lighting represents the second most expensive item of most municipalities' budgets, surpassed only by payroll expenditures. Thus, it is clear that energy efficiency projects in the public lighting sector can play an important role in energy conservation, as well as in reducing emissions and alleviating a burden on local authority budgets.

At the global level, member states of the 21st Conference of Parties (COP-21), held in November 2015, submitted their proposals (Intended Nationally Determined Contributions – INDCs) for addressing climate change. Among other goals, Brazil committed to increasing energy efficiency in the electricity sector by 10% by 2030. Up to one-fifth of this target could be reached by introducing more energy efficient technologies across the Brazilian municipal street lighting sector.

Lamps using the new LED (Light-Emitting Diode) technology are emerging as a technically and commercially viable option for investments in energy efficiency in the public street lighting sector. LED lamps are between 40 60% more efficient in terms of energy consumption than the current lamps used throughout Brazil, and they offer substantial reductions in operational and maintenance costs. It is also possible to integrate efficient LED infrastructure with smart monitoring systems, thereby creating the backbone for a "smart city". Furthermore, the higher quality of the new lighting technology can have the positive effect of reducing crime and improving communities' perception of security.

Although more energy efficient and cheaper over their lifetime, LEDs are considerably more capital intensive than the existing lighting technologies predominantly used in Brazil. Municipalities are currently studying the possibility of attracting private capital - for example in the form of PPPs - to carry out retrofit projects, thus relieving local authorities of the burden of using their limited budgets to finance the up-front cost of LEDs. PPP projects are a realistic alternative for large and medium-sized cities with good credit standing; however, the majority of Brazil's municipalities are small and/or face challenging fiscal situations. Given the wide diversity of the country´s municipalities, business and financing models are needed that will enable a universal modernization of the Brazilian public street lighting sector.

This report is focused on identifying business and financing models, which – by taking into account institutional environment and market characteristics – will enable sustainable retrofit projects to be implemented in the public lighting sector throughout Brazil in the near-term, to the benefit of municipal governments, communities, and the environment.

Approach to the Report

The origin of this study dates back to 2013, when the World Bank provided technical support to the Rio de Janeiro and Belo Horizonte municipal government authorities aimed at identifying the areas within those municipalities with the greatest energy efficiency potential. As a result, public lighting was identified as one of the most promising areas, and in 2014 pre-feasibility studies were carried out to identify projects for modernizing the public street lighting systems in the two cities[1].

After confirming the huge potential of this sector in Brazil, in early 2015, the World Bank decided to embark on a broader study to better understand the wider context of the country´s public street lighting sector. This report is the product of that work. The process to develop this report was conducted with the following approach:

1. **Conduct a detailed survey of the Brazilian market:** this included field visits to (i) nine municipalities and consortia, and (ii) electric utilities in three states (Ceará, Minas Gerais and São Paulo). Using information gathered in the field, the team prepared an electronic survey and used this tool to gather street lighting data from a statistically significant sample of more than 300 municipalities across all the Brazilian states.

2. **Develop a methodology to group municipalities:** based on this data collected in the field, combined with other publically available socioeconomic data, the team developed a methodology to group municipalities according to characteristics that were presumed to be the major drivers of business model development for investments in energy efficient public street lighting. Six groups of cities were ultimately identified, representing all 5,570 Brazilian municipalities.

3. **Conduct a market review:** identify the main opportunities and challenges within the existing regulatory, institutional and financial-economic framework of the public street lighting sector.

4. **Identification of business models:** after categorizing cities into six groups, the team identified business models that could meet the needs and capacity of the six different groups of Brazilian municipalities. Once eight business models had been identified, the team identified which of the business models would be best suited to meet the needs of the six groups of cities.

5. **Identification of financing mechanisms:** the next step was to identify financing and credit enhancement mechanisms that could be used to implement the business models. Ten mechanisms are identified in this report, and each are evaluated vis-à-vis their applicability to the eight business models.

6. **Identification of other considerations, gaps and recommendations for next steps:** the team reviewed other important considerations – aside from the business and financing models - that municipalities may need to consider when designing their public street lighting program (e.g., scope of modernization). Finally, the team identified the key barriers standing in the way of a full-scale rollout of LEDs in Brazil, as well as recommendations for how these barriers can be overcome.

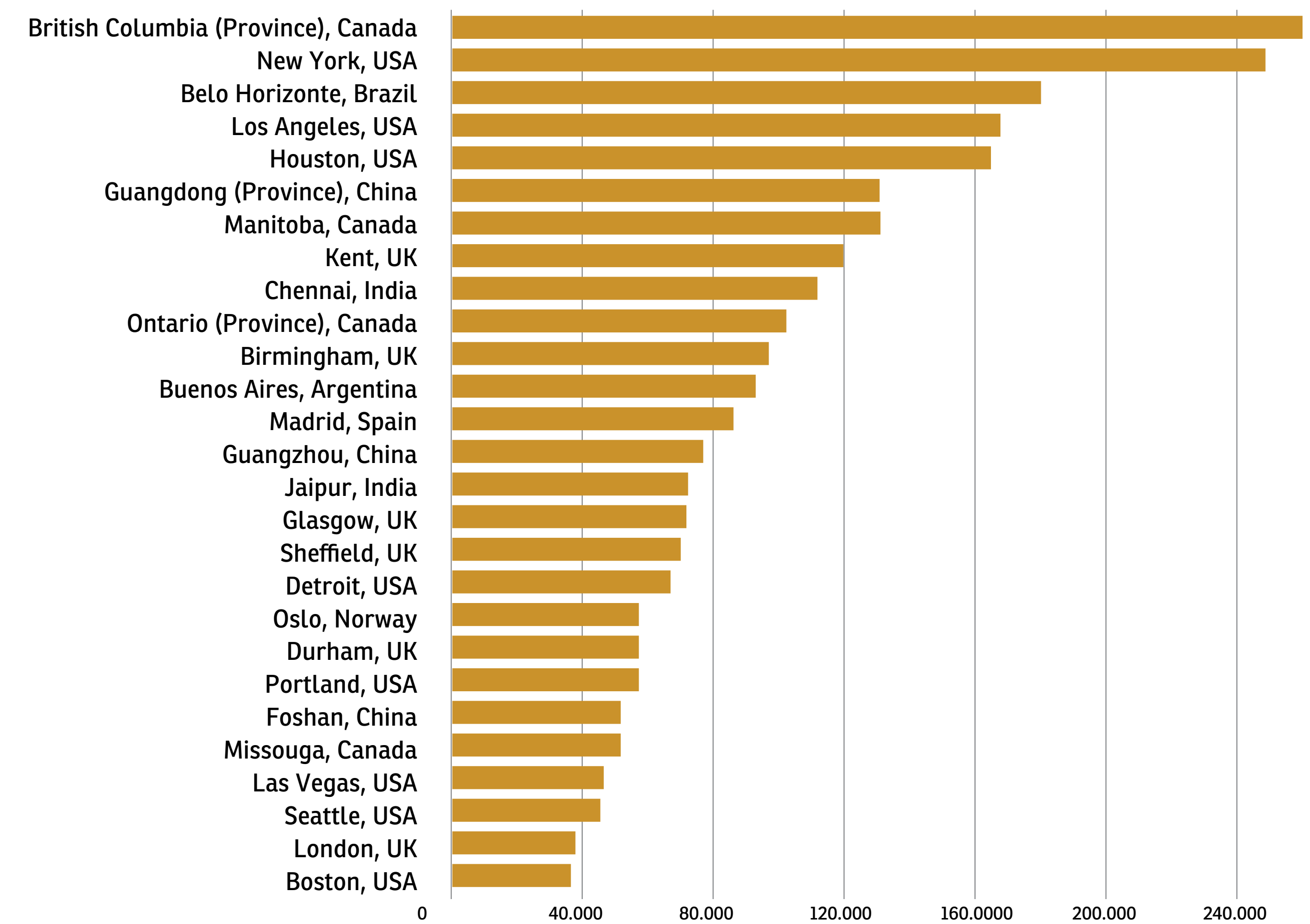
[1] In the course of preparing this report, the World Bank also provided support to personnel in the City of São Paulo engaged in preparing the tender for the modernization of that city´s public street lighting service.

Overview of Global Trends in LED Public Street Lighting

Projects and trials of LED technology for public street lighting have proven to deliver energy savings of 40–70%, and even as much as 80% when combined with "smart" management and control systems[2]. In addition to energy savings and reduced maintenance costs, LED lighting can result in a wide range of other socioeconomic benefits, such as improved lighting quality, enhanced security and increased local economic activity. The adoption of "smart" control systems allows greater flexibility in terms of delivering lighting options that are focused on the daily needs of citizens.

Cities around the world of varying size, geographic location, climate, etc., have begun implementing LED retrofit projects, as shown in Figure 1.

Figure 1 – Largest public lighting LED retrofit projects[3]



Source: The Climate Group, World Bank.

[2] For example, the Climate Group, and international NGO focused on - *inter alia* - promoting energy efficient public street lighting, conducted a study in 2012 in 12 municipalities, showing 50–70% savings. The city of Los Angeles has seen savings of >60% in its city-wide LED street lighting program.
[3] Projects at different planning/implementation stages.

Further improving the attractiveness of LEDs is the fact that prices are rapidly falling (by around 10% annually), as the equipment is benefiting from rapid technological innovation and economies of scale.

These benefits make a LED technology revolution virtually inevitable; however, the pace of scaling up public street lighting to LEDs will depend on cities having the appropriate financing mechanisms in place and the political will to prioritize these projects.

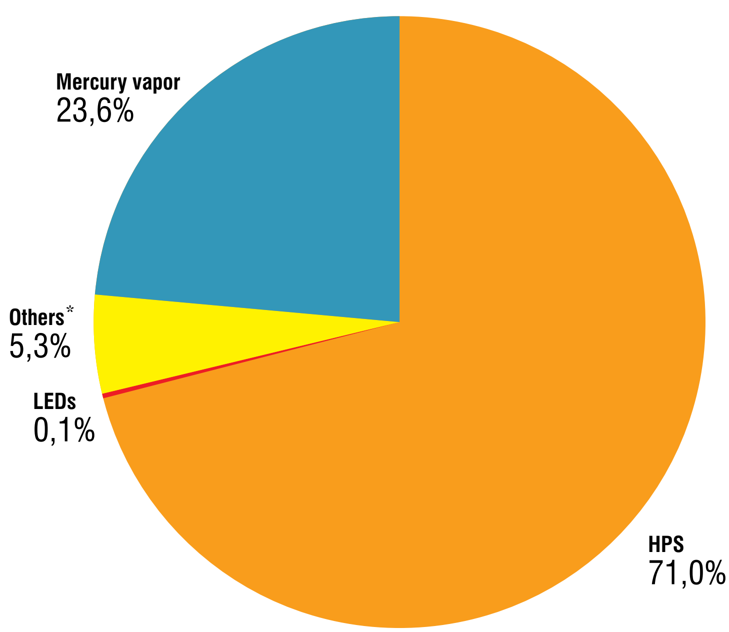
The Brazilian Market: Overview, Opportunities and Challenges

Overview

Public street lighting in Brazil is estimated to consist of over 18 million light points, with a penetration rate of around 95.5% of households. The distribution of installed lighting in Brazil relates directly to demographic concentration: lighting points are primarily concentrated in large cities and along the Southeast and Northeast Atlantic Coast.

The installed lighting inventory consists mainly of high-pressure sodium lamps and, to a lesser degree, mercury vapor lamps. LED technology penetration is very low, although several cities are currently rolling out pilot projects to deploy this technology. Figure 2 shows a massive concentration of HPS and mercury vapor technologies in the Brazilian street lighting system as of 2012. The proportion of LED technology is minimal by comparison.

Figure 2 – Technologies in the National Public Lighting System in 2012, by %



*Multi-vapor metallic, halogen incandescent lamps, amongst others

Brazil´s public street lighting market presents good opportunities for LED retrofits. However, the process is not without its drawbacks. The following two sections present some of the more promising opportunities and difficult challenges in the Brazilian market.

Opportunities

Opportunity 1: High cost of energy and decreasing costs of LED technology

The current high energy costs in Brazil, combined with the declining cost of LED technology, translate directly into a very substantial economic and financial opportunity for Brazil's municipalities.

The average public street lighting energy tariff increased by 38.8% in 2015, following an already substantial increase of 10.9% during the previous year. The trend continues towards additional, albeit smaller, increases in the coming years. The high cost of electricity means that municipalities have strong incentive to invest in technologies that reduce their energy consumption.

At the same time, prices of LEDs are rapidly falling. From 2007 to 2012, the cost per lumen decreased nine times, from US$32 to US$3.45 for every 1000 lumens produced. This reduction was partly due to the increased efficiency of LEDs, which almost doubled from 70 lumens per watt to 130 lumens per watt.

Opportunity 2: Incentives for municipalities to invest in their assets

A recent regulatory change has had a significant impact on Brazil's public street lighting sector: in 2013, ANEEL (National Electricity Regulatory Agency) issued a resolution that all public lighting assets previously in the hands of electricity utilities were to be transferred to municipalities by the end of 2014. This change affected around 42% of Brazil's municipalities, as the remaining 58% of municipalities already owned their street lighting assets. Now that this deadline has passed, all Brazilian municipalities own their public street lighting assets and are responsible for delivering public street lighting services.

The transfer of assets is expected to initially lead to additional costs for the municipalities recently receiving these assets. However, on the positive side, the fact they now own their street lighting assets means that they now have a strong incentive to invest in energy efficient equipment, as they will benefit directly from the resulting reduction in energy costs of their investment.

Another important incentive for municipalities is the potential political benefit that LED street lighting can bring. In the environment of the ongoing macro-fiscal crisis, the mayors of Brazilian cities have few other investment opportunities that can be implemented as quickly and offer immediate benefits to citizens' quality of life, at a negative cost to municipalities over the life of the project.

These incentives create a critical mass of municipalities seeking solutions to modernize their public street lighting. This also creates a large potential market for equipment manufacturers, public lighting installation firms, and O&M firms, among others.

Opportunity 3: Ring-fenced funding to pay for public lighting

A constitutional amendment of December 2002 allowed municipalities and the Federal District to collect for the "Contribution to Public Lighting Costs" (CIP or COSIP, hereafter called COSIP) through customers´ itemized bills. This ring fenced resource for covering the cost of public street lighting must be used to pay for the energy, maintenance, installation and modernization of public lighting equipment. This beneficial structure is not seen in most other municipal sectors, making investments in this sector attractive relative to other municipal infrastructure investments. A World Bank sample survey of 300 municipalities reveals that 81.6% now collect COSIP, and many of the remaining municipalities are currently preparing legislation to introduce this charge.

The existence of COSIP means that a guaranteed resource exists to pay for public street lighting improvements. The funds could be used, for example, as collateral in business models that include financing (municipal loan repayments, municipal payments to PPP concessionaires, etc.).

Opportunity 4: Alignment with public climate policies

As mentioned in the introduction to this report, member countries participating in the COP 21—including Brazil—submitted their INDCs to the United Nations Framework Convention on Climate Change (UNFCCC). Brazil committed inter alia to make efficiency gains in its energy sector of 10% by 2030.

Modernization of Brazil´s public street lighting sector can contribute significantly towards reaching this goal, since the sector currently represents 4% of the country´s total energy consumption. Moreover, a national conversion to LED lighting could produce, at a conservative estimate, energy savings of 50% in the public street lighting sector, thus translating into achieving one-fifth of its INDC by exploiting this potential if a national LED conversion is completed (i.e., national efficiency gains of 2%).

Challenges

Despite the substantial opportunities, modernization of the public street lighting sector in Brazilian cities still faces many challenges. These include:

Challenge 1: Large scale of financing required

LED public lighting projects can offer substantial economic benefits to Brazilian cities, since LEDs are more efficient and have a much longer life than existing technologies; however, they are significantly more capital-intensive. The estimated cost of converting the entire 18 million lighting points in Brazil could be as much as R$28 billion (US$8.6 billion).

This means that a significant amount of capital will need to be mobilized for all Brazilian cities to benefit from the advantages of LED technology. Given that municipal budgets are constrained, city-wide LED projects will only likely move forward if municipalities and/or other agents can access financing at viable interest rates to cover these up-front costs.

A further issue is that the scale of investment required is beyond the reach of purely public resources, meaning that the private sector will need incentives to become significantly involved in modernizing the Brazilian public street lighting network.

Challenge 2: Wide diversity of municipalities

The challenge presented by the scale of the projects is more than financial. The widely differing characteristics of Brazil´s 5,570 municipalities will require the development of a number of different types of projects tailored to these characteristics.

All the projects will need well-designed business models that meet the needs of individual municipalities. At the same time, municipal personnel will need training to improve project management and/or oversight capacity. The heterogeneity of Brazilian municipalities in terms of size, capacities and fiscal situation complicates the task of finding solutions for large-scale implementation.

Therefore, a key challenge is to develop business models to meet the varied needs of Brazilian municipalities, while simultaneously offering the necessary incentives to attract private sector participation.

Challenge 3 – Macroeconomic scenario

Brazil's macroeconomic scenario over recent years has precipitated an unfavorable environment for infrastructure investments in general. Some factors are particularly relevant in the case of public lighting projects.

First, borrowing costs, which were already high, have increased further. For example, the prime interest rate (SELIC) was 14.25% for most of 2015 and 2016—double that of early 2013. Second, the depreciation of the Brazilian Real in 2015 has led to higher costs of imported equipment—a significant drawback given that LED luminaires are not manufactured in Brazil. This volatility in the Brazilian economy increases the perception of risk by potential international investors.

Challenge 4 – Limited options for public funding

In view of the financing requirements and Brazil´s current high interest rates, public funding is important for cities (or their agents) seeking viable financing sources for public street lighting projects.

At the federal level, the National Program for Efficient Public Lighting and Traffic Light Signaling (PROCEL-RELUZ), managed by ELETROBRAS, has been the most important historical source of investment for the sector. Another national program, the Energy Efficiency Program (PEE), administered by ANEEL, has also provided funding for investments in the public street lighting sector, albeit on a much smaller scale. At present, these two programs are not providing significant funding for investing in energy efficiency in the public street lighting system. Recent changes in legislation—particularly Law 13,280 of May 3, 2016, which allocates 20% of the PEE resources to PROCEL—may enable these programs to play more important roles.

Nonetheless, given the amount of capital required for converting the public lighting network to LEDs, other sources of financing will still be needed. While multinational or bilateral bodies can fill part of the financing gap, it will be essential to leverage domestic and/or international private sector financing to develop the LED public street lighting market potential.

Challenge 5 – Restrictions on municipal indebtedness

Although the amount of financing needed by the public sector for modernizing the public street lighting network is significant, there are major funding restrictions on Brazilian municipalities arising from Brazil's Fiscal Responsibility Law, which imposes on municipalities an indebtedness ceiling of 16% of Net Current Revenue (NCR).

There are some exceptions to this law, such as the financing provided by multilateral bodies, federal credit institutions or development banks, providing these resources are used for investments in projects to improve tax administration or the management of financial and patrimonial assets. This exception is also applicable to PROCEL-RELUZ transactions for public lighting projects, presumably for the same rational that, as with the funds earmarked for modernizing the tax structure, investments in energy efficiency should improve a municipality´s fiscal situation by reducing its expenditure over time. However, given the relatively small resources available for PROCEL, this exception is unlikely to have a material impact across the national public street lighting sector.

These restrictions will make it difficult for many municipalities to access financing directly, making it important to identify business models that can offer municipalities "off-balance sheet" solutions for financing LED street lighting projects.

Challenge 6 – Municipal credit risk

Municipal credit risk is one of the toughest challenges, not only in Brazil, but in municipal financing projects throughout the world. Since Brazilian municipalities own their public lighting assets, they are now ultimately responsible for generating the cash flows that will be used to pay investment-related costs. This exposes investors in public street lighting projects to municipal, political and credit risks.

As previously mentioned, COSIP provides a ring-fenced funding source to be used exclusively for public lighting. However, the mere existence of COSIP does not entirely rule out project risk. For example, COSIP revenues could still be undermined if they are frozen or reduced by oversight/control agencies, or if COSIP collection is not sufficient to cover the investment costs throughout the investment cycle. According to the research data collected from 300 municipalities, 44.1% of those surveyed indicated that COSIP was considered to be sufficient to cover municipal expenditure on public lighting, while 31.3% considered that it was insufficient, and 24.6% were unable to assess whether COSIP was sufficient or not. It follows that the municipal law defining the COSIP charge must be well formulated. Recommendations regarding COSIP formulation are presented in the full report.

Depending on a municipality´s profile, lenders or utility companies may demand other types of guarantees before investing in public street lighting projects, even for municipalities with a well-formulated COSIP, particularly those with lower financial capacity.

Challenge 7 – Lack of a clear regulatory framework for public lighting

Public lighting is a network service, as is, for example, the electricity distribution service. As a natural monopoly, these services should be regulated in terms of (i) entry and exit conditions for service providers; (ii) economic regulation; and (iii) service delivery quality. All this requires substantial regulatory capacity, a process that is currently not being led by the state or federal level.

In the absence of an institutional knowledge base for regulating the public lighting service, an alternative is to implement some regulation through a "regulation by contract" approach. In this scenario, concession contracts are prepared in the form of detailed instruments covering a variety of situations that may arise during contract implementation, or issues related to contract extension; however, this process is cumbersome and prone to important, unforeseen exclusions.

Moving to a more robust and efficient system would require regulatory action to address important questions for the market (e.g., operator incentives to invest at an optimal level, the best way to ring-fence COSIP revenues, defining payments in case of changes to exogenous factors such as electricity prices, etc.).

The current lack of regulatory clarity will inherently slow down market growth. Given this vacuum, capacity-building and regulatory standards will need to be developed at the municipal level to ensure that sustainable contracts are implemented under the existing regulation by contract system.

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Mapping Brazil's Municipalities for Public Lighting

The identification of business models that could enable municipalities to benefit from market opportunities and overcome the key challenges is an important step in the development of the Brazilian market. However, prior to identifying appropriate business models, the characteristics of the municipal public lighting market in Brazil needs to be understood.

Brazil has 5,570 highly heterogeneous municipalities with different socioeconomic characteristics (income and development levels) and physical/demographic features. A single universal business model for public lighting projects is clearly out of the question. Therefore, the first challenge is to group municipalities on the basis of their similarities, with the ultimate goal of developing solutions tailored to each group of municipality.

As mentioned in the introduction, the World Bank undertook a detailed survey of over 300 Brazilian municipalities with different population profiles and economic status in order to understand the context in which the public lighting sector operates. Based on data obtained in this research, together with statistical socioeconomic data covering all Brazilian municipalities, the World Bank team then grouped the different cities according to their capacities for developing different business models aimed at securing investment for modernizing the sector.

The set of socioeconomic characteristics considered by the World Bank survey included levels of socioeconomic development, the size and density of the lighting network, fiscal status, the technologies in the existing street lighting inventory, and existing network coverage.

The procedure for grouping municipalities was divided in two phases: (i) statistical cluster analysis; and (ii) identification of homogeneous groups amongst the clusters. The cluster analysis produced 18 initial clusters (homogenous groups), subsequently reorganized/regrouped into six groups based on a qualitative evaluation of the clusters' characteristics, namely project scale and fiscal management. This approach enabled multiple important aspects to be taken into consideration (size, development level, tax situation, lighting network density, sectorial indicators) and, at the same time, identifying a manageable number of municipal groups. For the statistical cluster analysis, the variables presented in Table 1 were used.

Table 1 - Database characteristics

Variable	Definition	Objective/logic for use	Unit	Year
GDP per capita	GDP divided by number of inhabitants of municipality	Proxy of the municipality´s level of development	R$	2012
Consumer units per water supply connection	"Measurement of the water supply network density. A connection consists of the consumer unit/ units linked via a single extension to the distribution network[2].	Proxy of the level of "verticalization" of the municipality, giving an idea of the public street lighting network density. The public water supply system also basically covers the same area as the street lighting network.	Ratio	2013
IFGF	Index for measuring how taxes paid by community residents are managed by the municipal authorities. Composed of five indicators: Own Revenue, Personnel Costs, Investments, Liquidity, and Debt Cost.	Proxy of the level of the municipality´s fiscal management.	Index	2013
NCD/NCR	Ratio between NCD (Net Current Debt– Consolidated Debt deducted from financial assets) and Net Current Revenue (NCR)[5].	"To measure municipality´s level of debt.	Ratio	2015
Number of light points	Estimate of the number of light points in the public street lighting system[6]	Proxy of the size of municipalities; estimate the size of the public street lighting system – also a proxy for assessing the level of investment for a public lighting retrofit project.	Number	2014
> 20% mercury vapor lamps used in the public lighting network [7]	Indicator (yes/no) to indicate whether the municipality uses over 20% of inefficient mercury vapor lamps in its public street lighting network [8]	Efficiency level of the current network in order to assess the possibilities of making savings via a modernization program	Indica-tor	2014
% of the municipality not covered by public street lighting	Percentage of the municipality not covered by street lighting. [9]	Proxy for the amount of investment needed to modernize the existing network versus extension of the network to unserved areas.	Percent-age	2014

Source: IBGE; FIRJAN; National Treasury; Ministry of Cities, World Bank Group.

[4]For example, a building with ten apartments can have a single connection serving ten consumer units. Therefore for this building the consumer units per connection ratio is ten.
[5]There are cases where the municipality may have a negative NCD, i.e., cash availability exceeding financial liabilities. In this case, a negative NCD NCR index indicates how much cash the municipality possesses in relation to Net Current Revenue.
[6]Using current available data and estimates using a regression model when data unavailable.
[7]Technology used in the network estimated from the use of a proportion of more than 20% mercury vapor lamps.
[8]Using current available data and estimates using a regression model when data are unavailable.

The final grouping results are presented in Tables 2 and 3.[10] More detailed information about the clustering and grouping approach can be found in Annex 3.

Table 2 – Main characteristics of the groups

Group	Number of municipalities		Scale (Light points)	Fiscal Management
	total	%		
A	47	1		
B	88	2		
C	329	6		
D	887	16		
E	3.406	61		
F	813	15		

Source: World Bank Legend: Yellow = good; Orange = moderate; Red = limited

Table 3 – Municipal groups (statistics)

Group	Population			Light points			Required Investments (R$)[11]		
	Total (millions)	%	Average	Total (millions)	%	Average	Total (billions)	%	Average (millions)
A	59.9	29	1,274.,015	5.1	27	107,499	7.7	27	161.3
B	23.8	12	270,041	2.8	15	31,490	4.2	15	47.2
C	14.7	7	44,701	2.1	11	6,303	3.2	11	9.5
D	23.0	11	25,967	2.2	12	2,437	3.3	12	3.7
E	64.4	32	18,921	5.1	28	1,493	7.7	28	2.2
F	18.6	9	22,894	1.2	7	1,533	1.8	7	2.3
TOTAL	**204.4**	**100%**	**36,704**	**18.4**	**100%**	**3,302**	**27.8**	**100%**	**5.0**

Source: World Bank Group and Pezco Consultoria.

Tables 2 and 3 show that the municipalities in Groups A and B have a good scale of public lighting (over 20,000 points) as well as strong fiscal management. These two groups represent only 3% of the country's municipalities, although they contain 41% of the population and 42% of the light points. On the opposite end of the spectrum, cities in Group E have a smaller scale (less than 2,000 light points) and moderate fiscal management, and this group includes the highest number of cities and populations of all the groups, representing 61% and 32% of the country, respectively, and approximately 20% of Brazil's light points.

[9]In these variables we used data from a sample survey of Brazilian municipalities conducted for the World Bank Group by Castagnari Consultoria Ltda, given that no data was available for the entire universe of municipalities.
[10]List of cities in each group is provided at <https://www.esmap.org/node/57817>.
[11] Equipment prices based on World Bank Group surveys in June 2015. Prices are estimated at R$ 1,500 per point (excluding "smart" controls). Prices do not include the potential impact on the scale of procurement. Official exchange rate of May 13, 2016 at BRL 3.5/US$.

Business Models for Public Street Lighting in Brazil

A detailed understanding of the current market makes it possible to identify business models to meet the requirements of these six groups of municipalities. Eight business models were proposed that could be deployed to serve the needs of the six municipal groups, as described in Table 4.

Table 4–Summary of business models

Model	Description
M1 – Municipal PPP	Municipalities tender a PPP for provision of energy efficient public street lighting using LEDs. A consortium of companies is awarded an administrative concession by the municipality to provide these services over a 5–35 year period. Management concession to retrofit the public street lighting network and deliver efficient public lighting services.
M2 – PPPs with Municipal Consortium[12]	Municipalities form a municipal consortium, which then becomes the legal body to tender a PPP for energy efficient public street lighting on behalf of all municipalities within the consortium. Since consortiums are not able to borrow under Brazilian law, the consortium would create a Special Purpose Vehicle (SPV) that would be able to undertake financing on behalf of all municipalities in the consortium.
M3 – Municipal Financing	Issuance of municipal bonds or loans, enabling those municipalities that either do not want to tender a PPP for LED street lighting or that lack the technical or financial capacity to do so, an option to finance the necessary investments for conversion to LEDs.
M4 – Electric Utility Programs	Involves the utility company financing LED procurement on behalf of municipalities, leveraging COSIP (and potentially other) resources from consumers´ electricity bills (i.e., on-bill financing approach).
M5 – Energy Service Companies (ESCOs)	ESCOs obtain financing in the market and make the necessary investments for municipal LED retrofitting. Operation and maintenance remain the responsibility of the municipality.
M6 – Centralized Procurement	Creation of municipal consortia to centralize LED equipment procurement and benefit from the resulting economies of scale for the cost of LEDs. Each municipality remains responsible for financing the investment individually.
M7 – Self-Funding	Municipalities use surplus revenues in any given year to fund investments in LED street lighting over a longer period of time, without obtaining any up-front financing.
M8 – Transfer of Luminaires	Interim solution consisting of redeploying HPS (or mercury vapor) luminaires made redundant after a city converts to LEDs, transferred to municipalities with limited prospects to convert their own systems to LED in the near future.

Source: World Bank

[12] Note that although the formation of a municipal consortium is a necessary precondition for the M2 model, aggregation (to scale up the network, reduce transaction costs, etc.) could be achieved through the use of municipal consortia in several other models.

A more detailed description of the eight business models is provided in Section 6 of the report, including a summary of their different characteristics, a structuring diagram, the groups of municipalities to which they can be applied, the advantages, disadvantages, risks and mitigation factors of each model, as well as the identification of key stakeholders for each project phase of project development. An abbreviated summary of the business models can be found in Annex 1.

Table 5 shows the connection between the municipal groups and the respective business models. It is important to emphasize that several business models can be used in most of the municipal clusters, depending on local government preferences and the circumstances of each city.

Table 5 - Mapping business models tailored to each group

Groups	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO(s)	M6 Centralized Procurement	M7 Self-funding	M8 Transfer of Luminaires
A	Suggested							
B	Suggested	Possible	Suggested					
C		Suggested	Suggested	Possible	Suggested	Suggested	Possible	
D				Suggested		Suggested	Suggested	
E				Suggested	Possible		Suggested	Suggested
F				Possible		Possible	Suggested	Suggested

Source: World Bank Group, Pezco Consultoria

Legend: = Suggested; = Possible.

Financing Mechanisms and Improving Credit Risk

Each of the business models described above contains specificities that affect which financing options could be deployed. For example, models such as M1 and M5 may appeal to the private sector, while others such as M3 rely on municipalities to play a preponderant role in financing the modernization and future operation of the street lighting network. Table 6 provides an overview of the financing instruments identified as having potential to finance LED street lighting projects in Brazil.

Table 6 - Mapping financial instruments tailored to business models

Mechanism	Description
COSIP	A tax collected by utility companies through consumers' electricity bills and passed to the municipality to cover the current expenses and expansion costs of its public street lighting system. It is an "earmarked" fund and cannot be used for any other purpose.
Loans from Public Banks (BB, CEF)	These institutions (Banco do Brasil and the Caixa Econômica Federal) are physically present all over Brazil and play an important role in providing loans for municipal infrastructure projects (many local authorities are active clients). The CEF possesses decentralized, qualified technical teams that could assist smaller municipalities to review their public lighting modernization projects..
BNDES-Finem	This is a line dedicated to energy efficiency projects, replacing the previous PROESCO line from BNDES. BNDES-Finem accepts transactions with values equal to or greater than R$5 million, covering up to 70% of financeable items.
Private Equity	This entails private capital investment as shareholder equity in a Special Purpose Vehicle (SPV), aimed at financing a public street lighting system retrofit.
Credit Enhancement Mechanisms	Credit enhancement mechanisms can be essential for financing public lighting retrofits. Even when the COSIP tax is well-formulated and offers strong guarantees for lenders, there might be a perception of residual risk of insufficient COSIP resources and, thus, exposure of investors to municipal credit risk.
Development Banks (domestic and multilateral)	Institutions such as BNDES, DesenvolveSP, AgeRio, BDMG, the World Bank, IFC, CAF, IDB, etc, provide several instruments focused on financing energy efficiency projects, potentially including public street lighting projects. DesenvolveSP, AgeRio and BDMG also provide technical assistance to assist municipal governments with project design and structuring public-private partnerships.
Sector Financing Lines	Sector-specific funds such as PEE and PROCEL Reluz have played important roles in public lighting retrofits. However, regulatory changes have reduced the amount of resources available to these financing lines.
Loans from Private Banks	This is a modality where private commercial banks (domestic or foreign) provide loans directly to municipal governments or to agents acting on their behalf for lighting sector retrofits. For loans to the public sector, municipalities are subject to the applicable indebtedness limits.
Debentures, FIDIC, FIP, Green Bonds	These instruments enable funds to be raised for large-scale projects in national or international capital markets in higher volumes and at more competitive cost.
FI-FGTS	FGTS funding has supported several urban infrastructure projects. In view of recent institutional changes it would make sense to consider street lighting modernization projects as a part of urban infrastructure. The allocation of FI-FGTS funds requires the approval of the Fund´s Board of Trustees (Conselho Gestor). These funds are not currently available for any of the business models selected.

The applicability of these financial instruments to the eight business models is shown in Table 7.

Table 7 - Mapping financial instruments tailored to business models

Financial Instrument / Business Model	M1 - Municipal PPP	M2 - PPPs for Municipal Consortium	M3 - Municipal Financing	M4 - Electric Utility Program	M5 - ESCOS	M6 - Centralized Procurement	M7 - Self-financing	M8 - Transfer of Luminaires
COSIP or Municipal Budget	●	●	●	◕	●	●	●	◕
Loans from Public Banks (BB, CEF)	◑	◑	◕	◑	◔	◕	○	◔
BNDES - FINEM	◔	◔	◑	◑	●	◑	○	◔
Private Equity	●	●	○	○	●	○	○	○
Credit enhancements (e.g. WorldBank)	◕	◕	◕	◔	◔	○	○	○
Development Banks (domestic, multilateral)	◕	◕	◑	○	◔	◔	○	○
Sector Financing Lines (PEE, RELUZ, PROCEL)	○	○	◕	●	◔	◔	○	◔
Loans from Private Banks	◕	◕	◔	○	◕	◔	○	○
Bonds, FIDC, FIP, GReen Bonds	◕	◑	◔	○	◔	○	○	○
FI-FGTS	○	○	◔	○	○	○	○	○

Source: World Bank

Legend: Full circle = more adequate; Empty circle = not applicable

More details on financing and risk mitigation mechanisms – including mechanisms to mitigate noncredit risks (technical, operational risk, political, etc.) – are provided in Section 7 of the report.

Gaps in the Market, and Recommendations.

Most of the business models and financial instruments described require some type of institutional support to speed up implementation at the national level.

The results of our study indicate that, without some type of intervention in the market, the most probable scenario would be the use of the "self-funding" business model for over 90% of the cities, with 50% of total light points (i.e., Model M7; Groups D, E and F). This would imply a very slow retrofit of Brazil's public street lighting sector, and reduce the economic and social benefits that LEDs technology can provide (energy savings, public safety, improvement of services for community residents, etc.).

Therefore, it is essential to identify gaps and seek solutions to include the highest number of Brazilian cities in this technological revolution. Section 9 of the main report lists barriers and gaps that can undermine the overall development of the system in six areas: (1) regulatory/legal framework; (2) public policies; (3) financing; (4) capacity-building; and (5) technology, and provides recommendations for overcoming each of the existing barriers.

Not all of the recommendations can be completed in the short term, and some are more critical to the development of the LED street lighting market than others. In order to facilitate stakeholder uptake and implementation of the above recommendations, this report categorizes the recommended actions in terms of their indicative timeframe for implementation and their level of priority, as shown in Table 8 below.

Table 8 – Prioritization of recommendations and indicative implementation timeframe

Short-term (<1 year)	
Highest priority recommendations	**Important recommendations**
Identify and designate federal, state, and/or municipal leaders to be responsible for leading coordination of EE street lighting initiatives and for helping municipalities to overcome barriers	Create standardized project evaluation tools
Create new credit lines and/or instruments for municipalities unable to attract (sufficient) private investment.	Create guidelines for implementing or adjusting COSIP
Design investment funds offering new, standardized EE asset class to attract a variety of investors at scale	Arrange seminars for exchanging ideas between the audit counts on the most controversial subjects affecting public lighting contracts
Create instruments for mitigating municipal credit risk	Introduce new databases for providing key data related to EE street lighting projects for cities and potential investors (city street lighting inventories, COSIP collection information, etc.)
Standardization/certification of LED equipment	

Medium-term (1–3 years)

Highest priority recommendations	Important recommendations
Identify possible actors with regulatory knowledge to fill regulator gap, or at least to provide regulatory advice to municipal governments when necessary	Standardization of the legal framework cities can use to earmark COSIP funds
The federal government interprets and clarifies what are the legal uses of COSIP (e.g., for expenditures electricity, O&M, expansion, modernization).	Establish a uniform approach for oversight agencies to verifying the legal provisions applied to different procurement bidding modalities.
Standardize business models	Federal government should design a national strategy for EE street lighting, including targets for converting the national public street lighting network to LEDs
Standardize financial contracts/instruments	Explore new instruments that may reduce foreign exchange risk that are affordable and available over the longer term (e.g. partial indexation in US$)
Create an industrial policy for national production of LEDs (review import taxes, etc.)	Create national or state technical assistance programs
	Introduce standard templates for EE public street lighting contracts
	Ensure efficient and effective flow of information between the municipal audit courts to promote consistency
	Standardize equipment guarantees provided by suppliers
	Increase use of other technology risk mitigants available in the market (e.g., insurance)
	Increase national production by creating credit lines for the national production of LEDs

Long-term (>3 years)

Highest priority recommendations	Important recommendations
Revise the legislative framework for public consortia to allow direct financing of the public consortium´s legal entity	Provide electric utilities different incentives to promote EE street lighting by altering the form of compensation for energy distributors, namely through decoupling sales (and MWh) and revenues
Pass new legislation that allows exceptions to be made in municipal debt thresholds in order to enable greater investments in EE public lighting (similar to exceptions that were provided to debt under the PROCEL program)	

This analysis shows that there are a handful of high-priority activities that could be implemented in the short-term to help catalyze the LED street lighting market in Brazil. These include (i) identifying and designating national leaders for leading coordination of EE street lighting initiatives, (ii) creating new public credit lines, (iii) designing investment funds offering standardized EE asset class to attract private-sector investors at scale, (iv) creating instruments for mitigating municipal credit risk, and (v) finalizing the standardization/certification of LED equipment. Other important steps will need to be taken in the medium and long-term to expand the market, such as standardization of business models and contracts, establishment of new industrial policies to promote domestic LED production, and revision of the legislative framework for public consortia to increase their feasibility (e.g., allow them to take on financing obligations directly).

Conclusions

In an increasingly urbanized world, solutions for climate change and other global problems will depend heavily on public policies and projects developed at the city level. By developing energy efficiency projects in cities, which represent over two-thirds of energy consumption and over 70% of emissions, it is also possible to achieve impacts on a global scale.

As for the public lighting situation in Brazil, huge potential exists for energy efficiency projects that can have a significant impact on energy consumption and on mitigating climate change, in addition to the myriad other benefits, including reduced operational and maintenance costs, better lighting quality, increased perception of security, creating a smart-city platform, etc.

However, it is no simple task to make this kind of energy efficiency project a reality, and no single recipe can be applied to all our cities. The complex nature of the public street lighting services in Brazilian cities presents many challenges and opportunities that need to be faced in the quest for more efficient technologies.

Brazilian cities, although aware of the benefits, are faced with a series of economic, financial and regulatory barriers to developing their public street lighting projects. This is the case not only at the local level (e.g., the large amount of investment needed while facing restrictions under the Fiscal Responsibility Law), but also at the macroeconomic level, where extremely high interest rates prevail and where depreciation of the national currency is an ever-present concern.

At the same time, Brazilian cities face strong incentives to investment in this sector, given the mounting costs of energy, the continued reduction in costs of LEDs, and in most of the municipalities, the existence of specific funds available through the COSIP charge on utility bills. The 40%+ municipalities that recently became owners of their public lighting assets also need to identify options to efficiently operate and maintain their street lighting networks.

With this initial survey of Brazilian municipalities, it has been possible to identify groups with different capacities and needs. The classification of Brazil´s 5,570 municipalities into six groups is a first step towards proposing solutions tailored to their needs. The eight business models presented in this report take into account the characteristics of the various groups of municipalities, proposing structures and sources of financing to enable entire public street lighting systems to be scaled up. Before selecting a particular business model, it is important for municipal governments to carry out a critical assessment of their own needs and capacities for designing and/or managing the operations inherent in each model.

Once the business model has been chosen, the next step is to identify the best sources of finance for progressing the operation, including, whenever necessary, additional mechanisms such as guarantees for mitigating municipal credit risk. This report presents 10 financing and credit enhancement instruments, and maps the compatibility of these instruments with the business models.

In order to speed up the implementation of energy efficiency projects in public street lighting, the report identifies gaps and barriers in the current market, and proposes a series of "next steps" to fill the gaps and overcome barriers. Most of these recommendations require governmental intervention; therefore, it is important that a national level entity take a leadership role in the sector. Recent changes at the federal level – including, for example, the creation of an Executive Secretariat in the Investment Partnerships Program (PPI) and the increased funding for changes to PROCEL – potentially provide opportunities for new federal agencies to play a more active role in promoting this agenda.

The World Bank Group stands ready to continue to support the Brazilian government and other stakeholders to accelerate investment in energy efficiency in the public street lighting sector.

1 - Introduction

Cities are among the world´s largest consumers of electric energy, accountable for two-thirds of total electricity consumption and for over 70% of global greenhouse gases emissions[13]. Public street lighting systems contribute significantly to a city´s energy consumption. In Brazil, the cost of energy for public lighting already represents the second most expensive item of most municipalities' budgets, surpassed only by payroll expenditures. Furthermore, new regulations require all the municipalities to own the city's public lighting assets, making public lighting one of the few sectors in which local authorities have direct control over energy-consuming assets (contrasted with other high energy-consuming sectors such as transport). As a result, the local authorities will have every incentive to invest in and implement lighting projects by themselves.

In Brazil, the current public street lighting inventory primarily consists of mercury and HPS lamps, which over time will tend to be replaced by more efficient technologies such as Light-Emitting Diodes (LEDs). This new technology is already in operation in some major cities in other countries. The availability and increasing spread of LED technology offers a unique opportunity for Brazilian cities to reduce their energy consumption. This is especially important and beneficial to cities, considering the sharp increase in energy prices in recent years.

The advantages of this new technology are not limited to energy efficiency. It also offers significant reductions in operating and maintenance costs, as well as important co-benefits such as reducing crime and increasing the community´s perception of security.

In spite of the substantial benefits associated with the conversion of the installed public lighting network in Brazilian cities, major economic-financial and institutional obstacles still need to be overcome. Although LEDs are more efficient, they are considerably more capital-intensive than existing technologies. Although LED prices are falling at a rapid pace (estimated at 10% per year), the relatively high costs of the investments required remain a major challenge to converting Brazil's public street lighting networks.

In order to reap the benefits of conversion to LED, it is necessary to design and implement business models that can enable the necessary investments. These business models must take into account the diversity of Brazil's municipalities. Furthermore, consideration must be given to designing financial solutions that can raise private sector capital while mitigating municipal credit and project performance risks.

[13] Commonly known as GHG (Greenhouse Gases).

Given the unquestionable benefits of LEDs and the fact that LED prices continue to fall, the transition to LED technology is almost inevitable, although the pace of conversion is uncertain. This report seeks primarily to identify business and financing models that, by taking into account the institutional environment and characteristics of the Brazilian market, will enable the necessary resources to be catalyzed to advance sustainable projects in the short- and medium-term, to the benefit of municipalities, communities, and the environment.

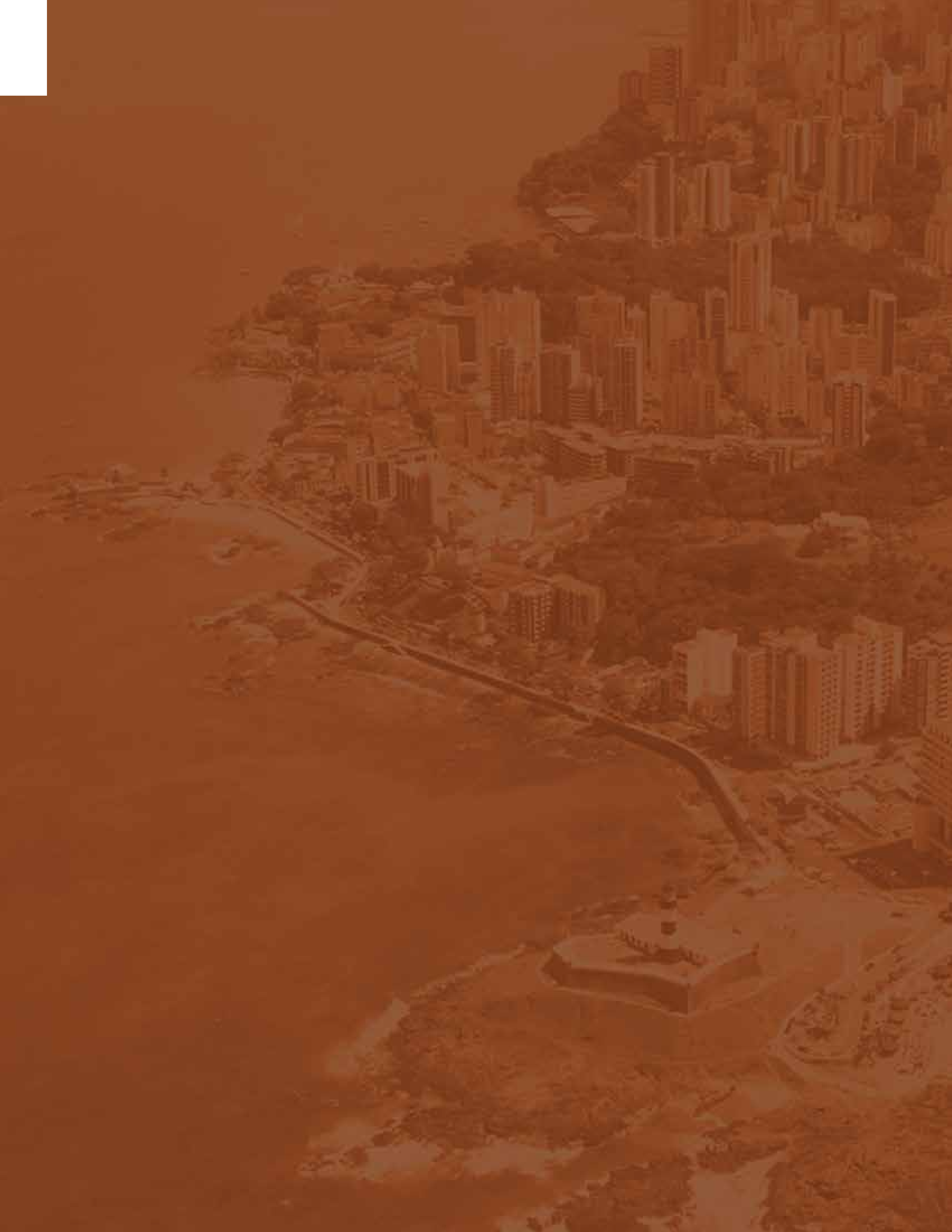
This report makes use of studies that have already been conducted by the World Bank Group specifically on the public street lighting network in Brazil. These include: pre-feasibility studies on the cities of Rio de Janeiro and Belo Horizonte;[14] a sample survey of the public lighting situation in Brazilian municipalities[15]; field visits by World Bank consultants in five areas of Brazil[16]; and a *cluster* analysis and review of preliminary business models carried out by Pezco Consultoria. The study also benefited from previous World Bank and the International Finance Corporation (IFC) studies on other countries and regions.

The remainder of this report is divided into eight sections:

- Section 3 - reviews international trends in public street lighting with the new LED technologies, drawing attention to their benefits and describing international experience with them.
- Section 4 - describes the public lighting market in Brazil, focusing on lighting coverage indicators, installed technology, current energy consumption, etc., and outlines the opportunities and main challenges that need to be overcome in order to scale up the Brazilian network using LED technology.
- Section 5 - consists of a brief review of the technical task of mapping Brazilian municipalities in terms of their public lighting networks, and describes the procedure for classifying the municipalities in homogeneous clusters, followed by assembling them in six different groups to facilitate the development of business models.
- Section 6 - outlines the proposed eight business models corresponding to the suggested groups of municipalities.
- Section 7 - provides an overview of the financial instruments that can be used in the business models.
- Section 8 - considers ideas for designing a public street lighting project, focusing specifically on the scope for system automation/remote management and possible infrastructure improvements for the lighting sector and the city.
- Section 9 - summarizes the main gaps and barriers for developing this market, and contains recommendations on how to narrow these gaps and overcome the barriers.
- Section 10 - sets out the conclusions of the report.

This section is followed by three annexes, which detail technical aspects and provide more data to support the analyses.

14 Pre-feasibility studies were carried out by World Bank Group teams, completed in August and September 2014.
15 "Study of the situation of public illumination in Brazilian municipalities", a sample survey involving face-to-face interviews in 300 municipalities by Castagnari Consultoria Ltda, under contract to the World Bank in 2015.
16 The visits between March and April 2015 included, among others: Uberlândia-MG, Hortolândia-SP, Consortium Cides-MG and Aracoiaba-CE.



2 - Overview of Trends in Public Street Lighting using LEDs.

The development of solid-state lighting technology[17] has provided major opportunities to reduce energy consumption and achieve better results with the use of new lighting equipment in residential, commercial and public environments. The costs of the many applications of the new technology have been falling significantly in terms of equipment and maintenance costs.

The focus of these developments is the public sector, which is now beginning to benefit from the new solid-state technology used in public street lighting networks. There is great potential for savings across the public street lighting sector, accompanied by a range of benefits for the community as a whole, such as better security and environmental quality. The following describes some of the international trends.

2.1 - LED Technology

The main public street lighting technologies currently employed in Brazil are based on metallic, mercury and HPS lamps that use glass tubes and internal gas. Table 9 compares LED technology with other currently available selected technologies[18].

Table 9 - Summary of LED features compared with other technologies

Type of lamp	Technical luminosity efficiency[19] (lumens/watt)	Perceived nocturnal luminous efficiency (lumens/watt)[20]	Color Reproduction Index (CRI)	Lamp useful lifespan (hours)	Price (R$)[21]
High pressure sodium (HPS)	50-150	32-95	24	15,000-24,000	$316
Metallic vapor	70-130	104-194	96	8,000-12,000	$320
Mercury vapor	35-65	38-70	17	10,000-15,000	$285
LEDs	70-160	133-304	70-90+	40,000-90,000	$1,500

Source: Adapted from Pike Research *Smart Street Lighting*, published in the 3rd quarter of 2012, and from interviews with key players.

[17] Solid-State Lighting (SSL).
[18] There are other technologies available, such as low pressure HPS and induction, that were not included in this study for sake of simplification.
[19] Photopic vision (P) is that adapted to high luminance levels such as daylight.
[20] Scotopic (S) vision is that adapted to low levels of luminance, such as at night. Scotopic vision is much more sensitive to white light such as that produced by LEDs and inductive fluorescent lamps, and less sensitive to the yellowish light of HPS lamps. Therefore, the visual impact on the pupil of a lumen produced by an LED luminaire is much greater at night than the same lumen produced by an HPS. The relative impact is expressed by the S/P correction index which adjusts the photopic vision to the perception of luminosity in the pupil of the human eye. The conversion between technical (photopic) light efficiency and perceived (scotopic) light efficiency is described in more detail in Annex 2.
[21] Prices based on a survey made by World Bank Group teams in June 2015. The official exchange rate of the day (05/16/2016) of R$ 3.5/US$ was used.

As can be seen in Table 9, LED luminaires and good quality high-pressure sodium lamps (HPS) are almost equivalent from the point of view of technical luminous efficacy. However, HPS luminaires do not produce the luminous frequencies to excite the human eye at the same level as LEDs. Thus, LED luminaires have proven to be superior, after taking into account how light is perceived by the human eye in the dark, i.e., the 'perceived night-time luminous efficiency'[22]. Moreover, LED-based luminaires have special optics that generate a better directed light beam pattern, producing improved luminosity on public roads, with fewer dark areas between poles. Ultimately, this means that lower-powered luminaires are sufficient to illuminate the same area, thus increasing the potential efficiency gains with LEDs.

LED-based technologies also provide better color reproduction, instant start-up, better system integration, and reduced operating costs. The Color Reproduction Index (CRI measuring how well the human eye is able to distinguish colors) of LEDs is 70-90% compared to the daylight index of 100%. By way of comparison, mercury and HPS lamps have a CRI of 55% and 24%, respectively. Metal halide lamps, despite their CRI of 96%, have a considerably shorter lifecycle than LEDs.In fact, LED lamp life is at least twice that of metal halide and mercury vapor lamps, and 1.5x that of HPS lamps. This implies lower replacement costs and a consequent reduction in operational and maintenance costs. The savings that can be made with LED lighting can be substantial.

Another benefit of LEDs is that they ignite virtually instantaneously, which increases their efficiency when the lamps are switched on and when network fluctuations or voltage drops occur. LED luminaires can also be installed in conjunction with intelligent control systems which enable light points to be individually controlled, including dimming, increasing the current to increase lighting output to compensate for the natural depreciation of the LEDs over time, immediate detection of performance problems, real-time monitoring of the entire lighting system and, finally, the use of remote metering. All these features have been proven to reduce energy and operating costs.

Finally, unlike mercury vapor and HPS lamps, LED lamps do not contain heavy metals, meaning that the risk of environmental contamination is lower, especially if their electronic components comply with the RoHS standard.[23]

2.2 - Economic and Financial Benefits of LEDs

LEDs can generate substantial economic and financial benefits for cities that install them for public street lighting. The benefits range from energy savings to reduced operational and maintenance costs due to the longer lifespan of LEDs compared to other current technologies.

The Climate Group (an International NGO) was one of the first organizations to conduct studies in large cities with LED-based public lighting projects to evaluate the performance of the new technology. The Group studied 12 cities around the world, including New York, Toronto, Hong Kong, London, Sydney, Adelaide and Calcutta and was able to demonstrate that LED technology can achieve energy savings of 50–70%, and as much as 80% when combined with intelligent management and control systems. According to this study, adopting intelligent control systems produced greater flexibility in terms of lighting options and improvements in the quality of public lighting services for the community.

In 2013–14, the World Bank also carried out detailed studies of the economic and financial viability of LED projects for public lighting, focusing on two Brazilian

[22]The conversion between the technical / photopic luminous efficacy and perceived scotopic light efficacy is described in more detail in Annex 2.
[23] Restriction of Hazardous Substances (RoHS) originated in the EU under Directive 2002/95/EC and restricts the use of six hazardous materials found in electrical and electronic products.

cities: Rio de Janeiro and Belo Horizonte. These studies revealed very substantial potential benefits from investments in LED public lighting, with an internal rate of return (IRR) sufficiently attractive to attract private sector interest. Box 1 contains the results of the LED pre-feasibility study in Rio de Janeiro.

To disseminate the knowledge acquired from these two studies to other Brazilian cities and the world as a whole, the World Bank created a model to enable cities to estimate the costs and economic/financial benefits of an investment project involving the installation of LED public street lighting, taking into account the specific characteristics of each city. This tool is available free of cost[24].

BOX 1 - Pre-feasibility Study for the Use of LEDs in the City of Rio de Janeiro

In 2014, the World Bank - in collaboration with the city of Rio de Janeiro - completed a pre-feasibility study to identify possible implementation and financial structuring options for investments in LED public street lighting in Rio de Janeiro. The study capitalized on lessons learned and work done under the Low Carbon City Development Program (LCCDP) for Rio de Janeiro, funded by ESMAP and PPIAF - two World Bank trust funds[25].

The WB study addresses four themes: project design, legal and institutional frameworks, financial and economic viability, and financing options for the municipality. Although the study focuses primarily on Rio de Janeiro, many of the findings could assist other cities in Brazil and around the world to assess the feasibility of implementing an energy-efficient street lighting system.

The study also evaluated, in 2014, the financial and economic viability of an LED-based project (with smart-systems) in Rio de Janeiro. The rate of return and the financial and economic analyses were updated in July 2015 to take account of important changes in project assumptions (i) increased electricity prices; (ii) R$/US$ exchange rate fluctuations; and (iii) increased national production of LEDs[25]. The results of the studies are shown in Table 10.

The financial analysis for Rio de Janeiro estimated an investment of around R$390 million over a five-year period (2017–2021) to cover the costs of LED equipment, the intelligent system and installation. The study estimated that it would be possible to save up to 57% in electricity and operational and maintenance costs (the latter involving labor to service equipment and replace burned out lamps) of R$1.2 billion over a 15-year period. The project would also save around 2.2 GWh of electricity for the city, resulting in a reduction of 655,000 tons of carbon emissions (tCO_{2e}). The payback period was estimated at 6.5 years, with an IRR of 27%. Moreover, the study estimated that the returns would be highly favorable, thus providing an incentive for the private sector to consider financing the project if the municipality were interested.

This study showed that investing in LED street lighting is a great opportunity for Rio de Janeiro to reduce energy consumption, save on electricity and O & M expenditure, and improve public lighting provision for the inhabitants of the city. Rio de Janeiro recently published its Strategic

[24]The CityLED Tool can be found on the World Bank ESMAP (https://www.esmap.org/node/57817).
[25] Interviews with manufacturers indicate that they are interested in increasing the level of LED manufacture in Brazil providing a minimum scale is reached to make sales worthwhile. This could be the case with the implementation of public lighting PPP projects currently underway in São Paulo and Belo Horizonte.

Plan for 2017–2020, which includes a LED public lighting project[26].

Table 10 - Summary of results of the pre-feasibility study for the city of Rio de Janeiro

Project analysis	Unit	Financial analysis July 2015 (base case)
Key assumptions		
Total luminaires replaced in project	n	318,733
Years to implement project	n	5
Period of analysis	years	15
Include smart system?	flag	Y
After-tax cost per point in year 1 (technology + infrastructure)	BRL	1,365
Cost of electricity at year 1	BRL/year/MWh	420
Real annual increase of electricity tariff	%	0
% electricity saving to LED with project	%	57%
WACC (net of inflation)	%	6%
Exchange rate	BRL/USD	3.2
Social cost of carbon dioxide (CO2e)	BRL/tCO2e	96
% domestic manufacturing	%	50%
Estimate project results		
Total project investment over 15 years (CAPEX + fees)	million BRL	390
Total financing savings (electricity + O&M) over 15 years	million BRL	1,173
Total GHG reductions over 15 years	tCO2e	655,954
Total electricity saving over 15 years	GWh	2,189
Payback period (non-discounted)	years	6.4
RoI	%	201%
NPV over 15 years (million BRL)	million BRL	380
IRR	%	27%

Source: World Bank

[26]Available at: <http://visaorio500.rio/pdf/book-planjamento-estrategico.pdf

2.3 - Other Benefits Associated with the Improvement of Street Lighting Systems with LEDs[27]

The availability of a public lighting service near homes is important to the quality of life of residents and the city in general. Improved night lighting also benefits people for activities such as tourism and entertainment since it effectively extends working hours.

Good street lighting has also been linked to reduced crime levels[27]. In addition, a study by Arvate et al. (2016) reveals that its presence significantly reduces the number of traffic deaths in Brazilian cities, particularly in poorer parts of the country[28].

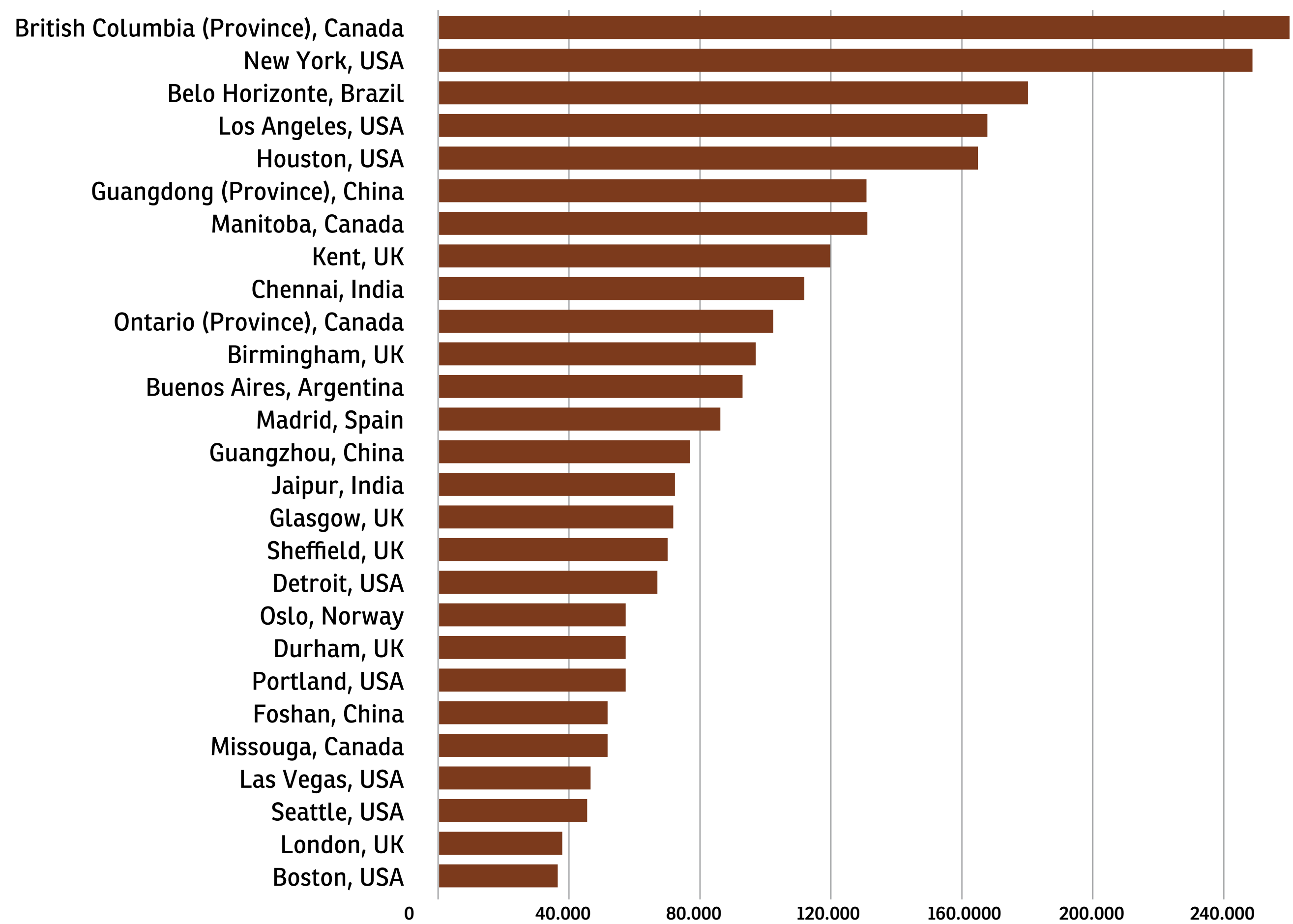
Moreover, innovation in street lighting is an important step towards creating "smart cities", where public lighting solutions will be interconnected to interact dynamically with other urban infrastructure sectors such as energy and transport (European Commission, 2013). Lighting services based on LED technology tend to support enhanced network integration and are therefore better suited to the electronic realities of the more advanced cities.

[27]For more details on reducing crime as the result of improved street lighting see Welsh and Farrington (2008).
[28]In this case, the study estimates that in Brazil full public street lighting coverage in a municipality not previously covered would prevent 48.1 violent deaths per 100,000 inhabitants. In the northeast region of the country, when previously unserved municipalities are totally covered, an estimated reduction would be 13.4 violent deaths per 100,000 inhabitants.

2.4 - International Examples

There are several projects currently underway involving the conversion of the public lighting system of major cities to LED. Figure 3 shows some of the largest projects[29] being implemented or at the planning stage.

Figure 3 – Largest public lighting LED retrofit projects[30]



Source: The Climate Group

[29]This does not include, e.g. the São Paulo project where bidding for the concession is in progress
[30]Projects at different planning / implementation stages.

The case of Los Angeles, the city with the largest number of LEDs installed so far, is described in more detail in Box 2. The situation in some of the other abovementioned cities is described in Section 6 (Business Models). For more details on international LED retrofit programs, see the report "*Proven Delivery Models for LEDs Public Lighting*" (Makumbe et al., World Bank Group, 2016).

Box 2 - Energy Efficiency in a Big City: The Case of Los Angeles

During the first phase of the program for retrofitting Los Angeles' public lighting network, 140,000 light points were replaced with LED lamps over a four-year period. This resulted in a 63.1% reduction in energy consumption, and carbon emissions were reduced by 47,600 tons per year. The savings generated by conversion to LEDs amounted to US$ 8.9 million, which enabled the city to repay its loan (with a maturity of seven years) sooner than anticipated. The program's motto is "*Bright Nights, Safe Nights*".

Source: City of Los Angeles, Bureau of Street Lighting. Available at: <http://bsl.lacity.org/led.html>.

Some countries are implementing national programs, including India and Malaysia. Both countries have announced ambitious LED implementation programs - involving fully replacing their public lighting networks by 2018 and 2020, respectively[31]. Brazil has not yet defined national policies in this regard; the municipalities, now owners of the public lighting assets, are responsible for making their own decisions on whether or not to convert to LED technology.

[31]Goldman Sachs data (2015); for India the source is: <http://ens-newswire.com/2016/01/11/indias-on-a-mission-to-convert-street-lights-to-leds/>.

3 - Public Street Lighting Market in Brazil

This section provides an overview of existing public street lighting coverage in Brazil based on the following indicators: the installed lumino-technical systems; electricity consumption; tariff evolution; recent changes in the institutional environment; specific street lighting sector public policies; and, finally, the current situation in terms of technical standardization in Brazil.

3.1 - General Aspects

Public street lighting in Brazil is estimated to consist of more than 18 million light points, with a penetration rate of around 95.5% of households. In 2015, the entire public lighting system accounted for 4.3% of the country's electricity consumption (14.3 TWh), at a cost of R$3.5 billion (excluding taxes). The installed lumino-technical system largely consists of high-pressure sodium lamps and, to a lesser degree, mercury vapor lamps. LED technology penetration is very low.

3.1.1 - Coverage of the public street lighting service

The lighting network has a high level of coverage and penetration, with a higher number of households served by public lighting than by other public services such as street paving or the presence of sidewalks (Table 11).

Table 11 - Characteristics of the vicinity of Brazilian homes - selected public services

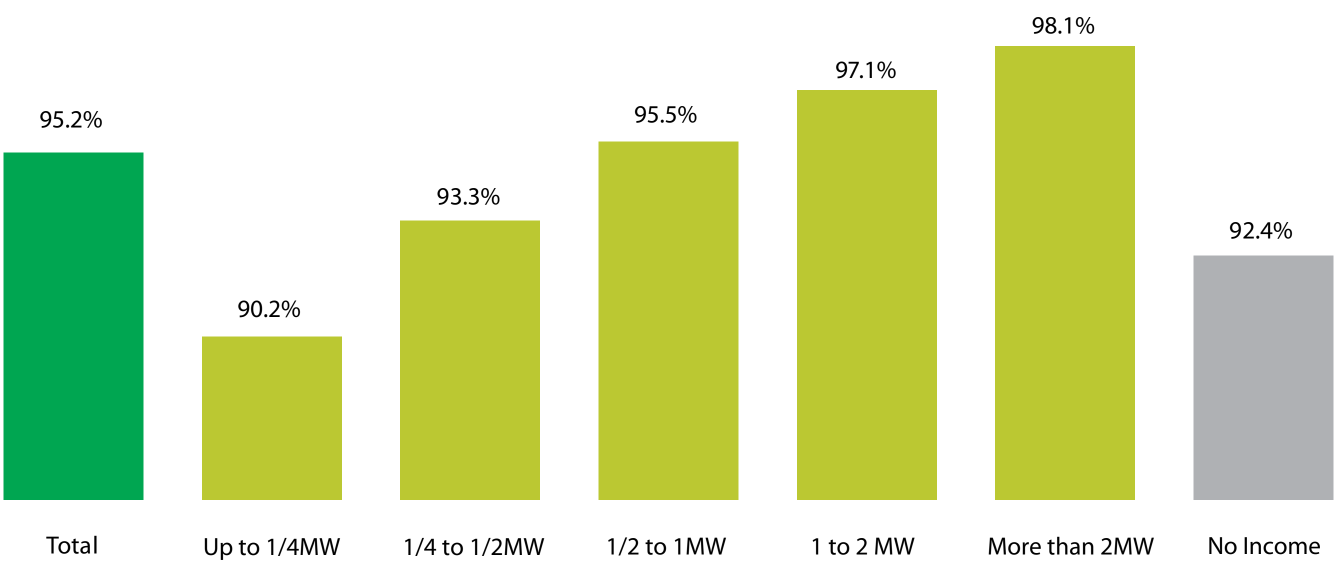
	Lighting of public areas	Street paving	Existence of sidewalk
Percentage of homes served in Brazil	95.5%	81.0%	68.5%

Source: IBGE - Demographic Census 2010 - Urban characteristics of the vicinity of homes

Notwithstanding this percentage of homes benefiting from public lighting, 2.1 million homes were unserved in 2010. The highest coverage of homes is in the Center-West (97%), and the lowest in the North (89.2%). However, it is important to note that there are significant variations in coverage depending, for example, on the size of municipalities. Those with up to 20,000 inhabitants provide public lighting services to an average of 94.9% of homes, while larger municipalities with populations of over 500,000 have an average coverage of 97.1%.

In terms of household income, households with up to one quarter of a minimum wage have an average coverage rate of 90.2%, while those receiving two times the minimum wage or more have a 98.1% rate. Figure 4 shows the coverage by household income segment[32].

Figure 4 - Coverage of public lighting for % of households, by household income



Source: IBGE - Demographic Census 2010 - Urban characteristics of the vicinity of homes. Calculations and compilation by Pezco Consultoria.

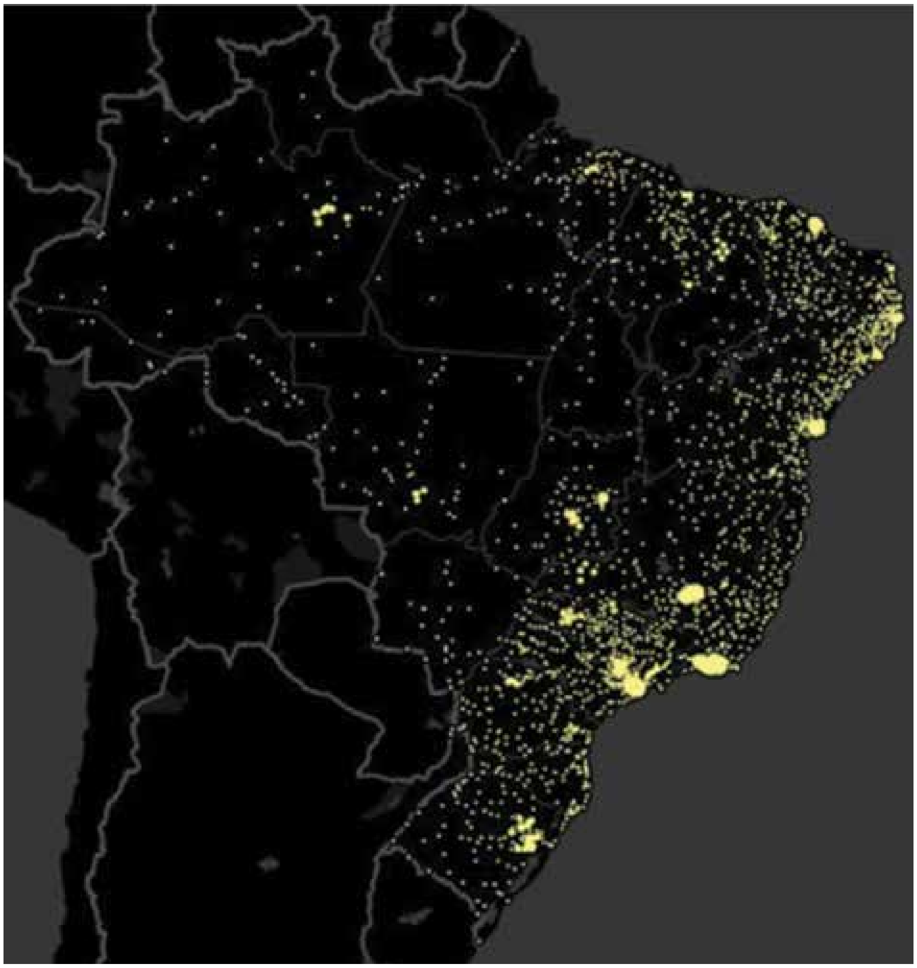
[32]Income in Brazil is generally described in terms of the national minimum wage. The amount of the minimum wage amount is defined by the Federal Government and updated annually (R$ 880.00 per month in 2016).

There are still challenges for public street lighting coverage, especially with regard to coverage for lower income populations. Although this study addresses issues related to conversion of public lighting to more efficient technologies rather than to network expansion, the unserved population may possibly benefit from PPP projects. The savings generated as the result of scaling up could be used to fund further expansion of the network.

3.1.2 - Installed technology

The distribution of installed lighting capacity in Brazil relates directly to the demographic concentration represented by large cities and along the Atlantic Coast - principally in the Southeast and Northeast, as shown in Figure 5.

Figure 5 - Concentration of light points in Brazil



Source: Pezco Consultoria using Tableau Software

Table 12 summarizes the national profile and its five regions in terms of installed technology, based on the two available sources.

Table 12 – Number of lamps in the National Public Lighting System, by %

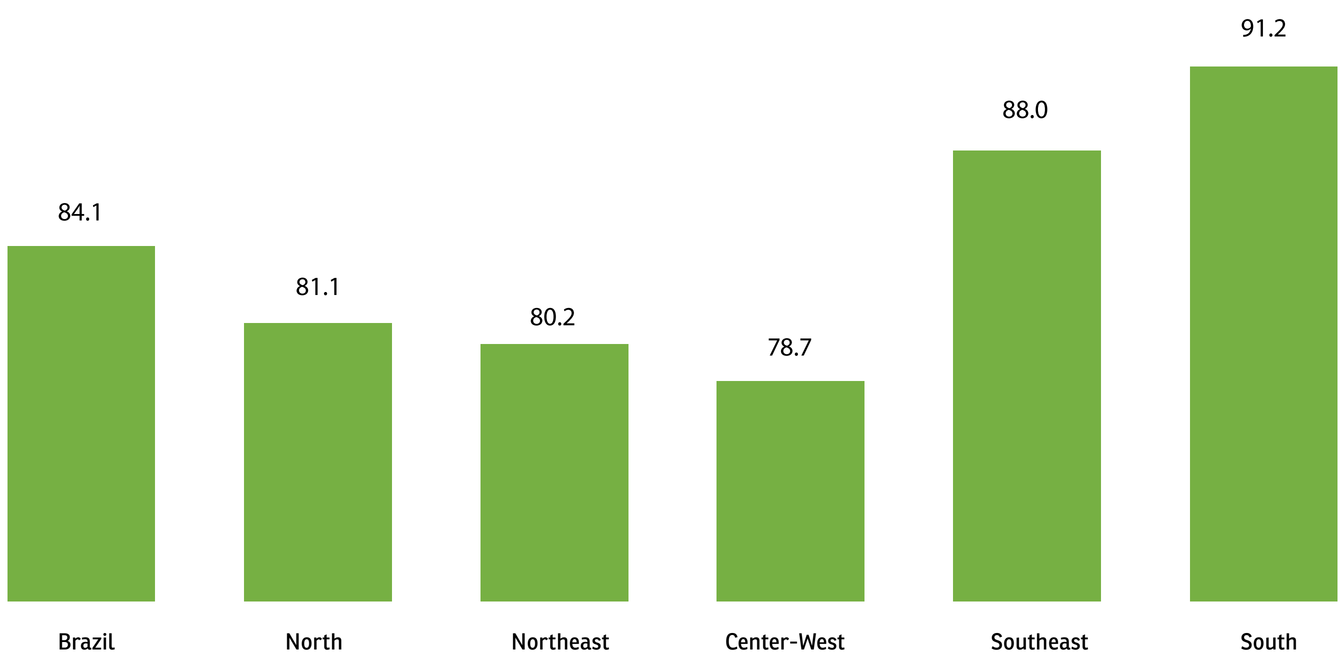
Eletrobras Cadastre (2012)

	Brazil (%)	North (%)	Northeast (%)	South (%)	Center-West (%)	Southeast (%)
Mercury vapor	23.6	31.3	20.7	23.9	23.0	24.4
HPS	71.1	64.5	68.6	71.4	72.2	72.5
LEDs	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Others[33]	5.3	4.2	10.7	4.7	4.9	3.1

Table 12 shows a massive concentration of HPS and mercury vapor technologies in the Brazilian street lighting system. The proportion of LED technology was minimal by comparison.

Knowledge about new solid-state lighting technologies is already fairly widespread in Brazil (see Figure 6).. The World Bank survey of 300 municipalities in May 2015 shows that 84.1% of Brazilian municipalities are aware of LED public street lighting technology.

Figure 6 - Percentages of municipalities familiar with LEDs in public street lighting



Source: World Bank Group

In Brazil, around 16% of municipalities are not familiar with the idea of LED technology for public lighting. In the Center-West the percentage is over 20%. These numbers indicate that there is still work to be done to ensure that knowledge of the new technology reaches a significant number of municipalities, city mayors and public agents.

[33]Multivapor metallic, halogen and incandescent lamps, among others.

Box 3 – Technology and Population Preferences

In order to gain experience of local situations, World Bank consultants visited five different areas in Brazil between March and April 2015. One of the cities surveyed was Fortaleza, the capital of the state of Ceará and fifth largest city in Brazil, with a population of 2.6 million (2014) and 183,800 light points.

The public lighting service of the city was observed to be well-structured, with registered and geo-referenced points and a specific Master Plan.The lighting service structure partly reflects the fact that the city assumed responsibility for public lighting in 2001, in anticipation of the nationwide transfer of lighting assets that took place around 14 years later. Maintenance, extension and improvement of the system is outsourced to a private company.

One particularly interesting point from the consultants' research in Fortaleza was the observation that the local population prefers 'white' light, with better color reproduction. Thus, although the city has 345 LED points, mainly serving roads, streets and places of touristic interest, the use of metal halide lights (54,400 points) still prevails to achieve the white light desired by residents.

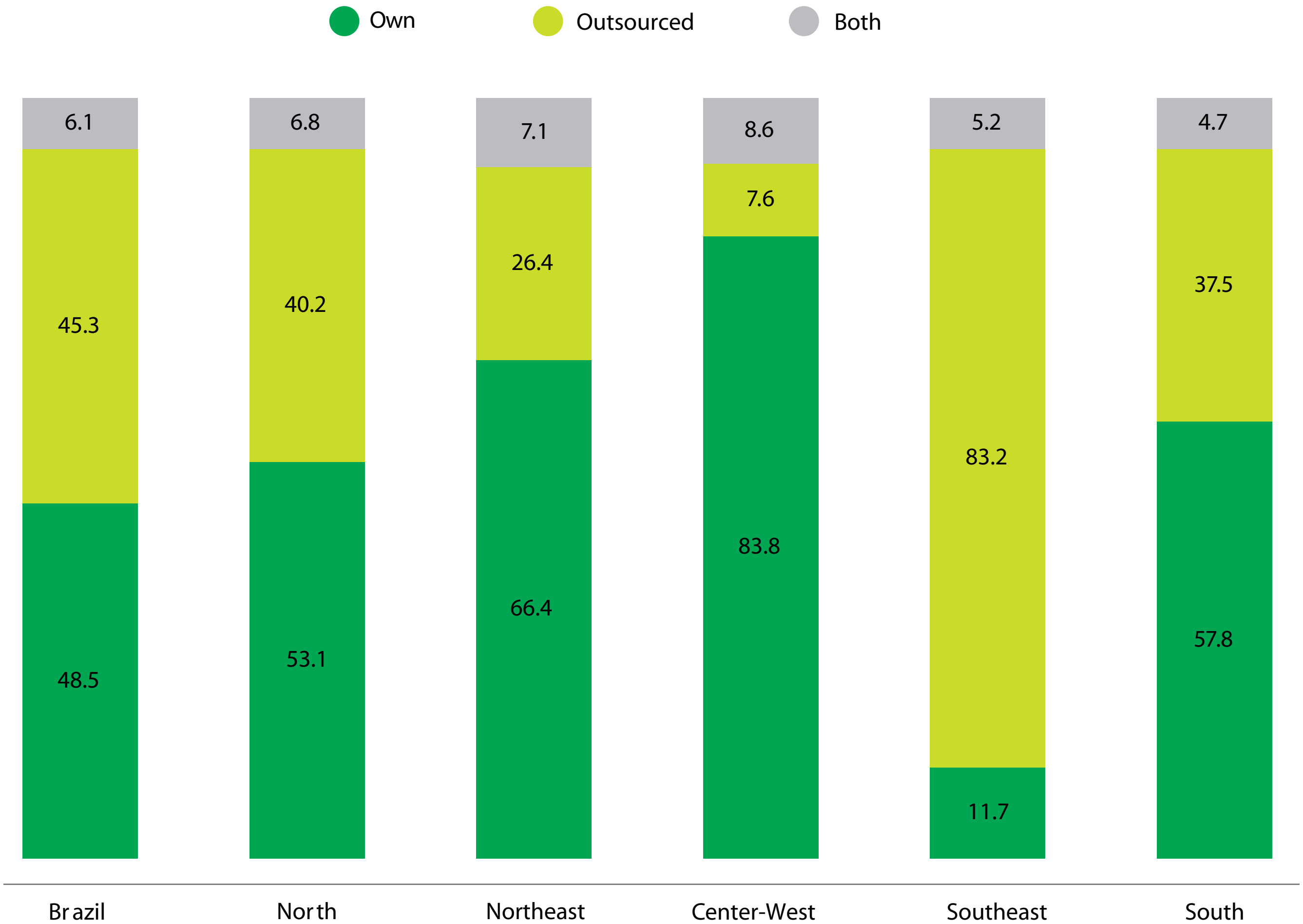
It is worth noting that using metal halide technology to obtain white light is inefficient compared to LED technology. Large cities such as Fortaleza could provide what their populations genuinely want (the benefits of white light) in a more economical and sustainable way if they were to invest in converting their system to LEDs.

3.2 - Bidding Schemes for Public Street Lighting

The public street lighting system in Brazil is usually managed by a combination of public stakeholders (municipalities) and private practitioners. At one end of the spectrum municipalities may be responsible for all aspects of management, including investments in system expansion, modernization, maintenance and operation. At the other extreme, the municipality may transfer virtually all the management responsibilities (except oversight) for the system to private outside operators through the award of a concession. Intermediate solutions can include municipalities that outsource only certain responsibilities to private sector companies.

According to the aforementioned World Bank Group survey, private sector participation in maintenance contracts is fairly widespread, presumably in accordance with Law 8666 and/or bidding (pregão) regimes. While around half of Brazilian cities outsource at least some of their maintenance services, there are substantial regional variations. Meanwhile, administrative concession contracts for public street lighting services are increasingly common, although these are confined to a small number of Brazilian cities.

Figure 7 - Responsibility for maintenance of public street lighting (% of municipalities)



Source: World Bank Group

This section contains a brief overview of the most common instruments used by Brazilian municipalities to contract goods and/or services for public street lighting efficiency projects, summarized in Table 13.[34]

[34]The common concession system (Law 8,987 / 1995) is not included in this report because it enables the private sector to participate in large contracts that are remunerated by consumer tariffs. Given that public lighting projects are not a specific service provided to ordinary consumers, but to municipalities, the common concession system does not apply to this sector. In the same way, the sponsored concession system is also not considered because the corresponding contract provides that part of the concessionaire´s remuneration derives from the charging of user fees.

Table 13 - Bidding regimes for energy efficiency projects in public lighting systems

Instrument	Characteristics
Law 8.666/1993	• Conventional public management contracts, with a one-year term, extendable by up to 48 months. • Bidding or competition required for all engineering contracts worth over R$1.5 million. • Criteria to determine the winning bidder: lowest price; best technical quality; combination of price and technical quality; highest bid or offer. • Processing time depending on complexity of goods and/or services to be tendered — from one month (goods) to six months (goods + services).
Auction (Pregão) (Law 10.520/2001)	• Designed to facilitate the purchase of joint goods and services by municipal governments, using the "reverse auction" procedure. • Lowest bid is the only selection criterion. • One-year contract, extendable for up to 60 months. • A simple process that can be concluded in less than a month after publication of the public tender notice
PPP—Administrative Concession (Law 11.079/2004)	• Concession contract in which the final contractor of the services is the public agency which remunerates the "concessionaire" monetarily and without charging user fees. • The selection criteria are: lowest end-user tariff; combination of lowest tariff and best technical quality; lowest payment by public agency; combination of lowest payment and best technical quality. • PPP concession agreements can last 5–35 years, renewable. • Estimated timeframe for implementing a PPP project: 15–20 months.

3.3 - Opportunities for LEDs in the Brazilian context

The current public street lighting network presents opportunities for LEDs; however, the process also faces challenges.

This section provides an overview of the most important opportunities and most significant challenges in the Brazilian market.

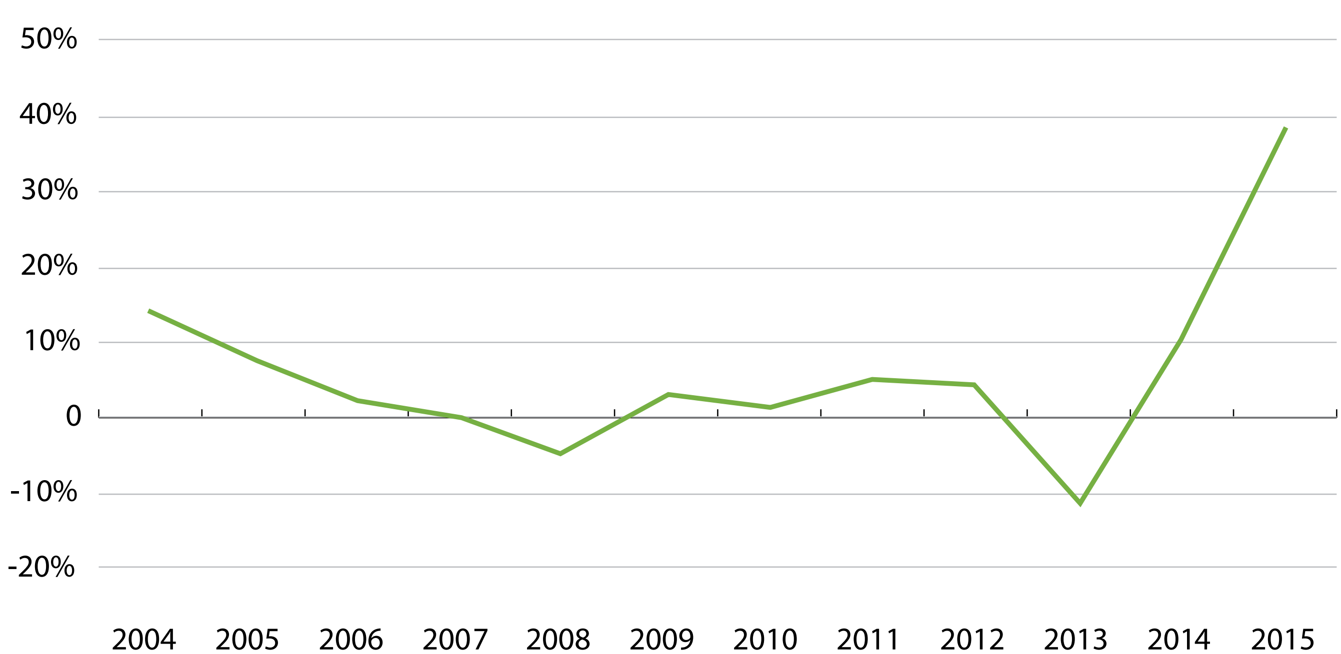
3.3.1 - Opportunity 1 - Energy and equipment prices moving in opposite directions

3.3.1.1 Electricity prices

The opportunity for investing in Brazil´s public street lighting sector is affected by a scenario in which electricity and equipment prices are moving in opposite directions. While LED equipment prices tend to be increasingly cheaper as the result of technological innovations (with a consequent reduction in the capital outlay required for converting to LEDs), electricity prices in Brazil continue to rise.[35] It follows that projects that help reduce energy consumption offer obvious benefits.

The average cost of public street lighting electricity increased by 38.8% between 2014 and 2015 (from R$ 0.18 / kWh to 0.25 / kWh) after an already substantial increase (10.9%) in 2013. Figure 8 shows the annual variation of the public street lighting energy tariff.

Figure 8 – Average electric energy tariff for public street lighting, % variation



Source: ANEEL; Pezco Consultoria

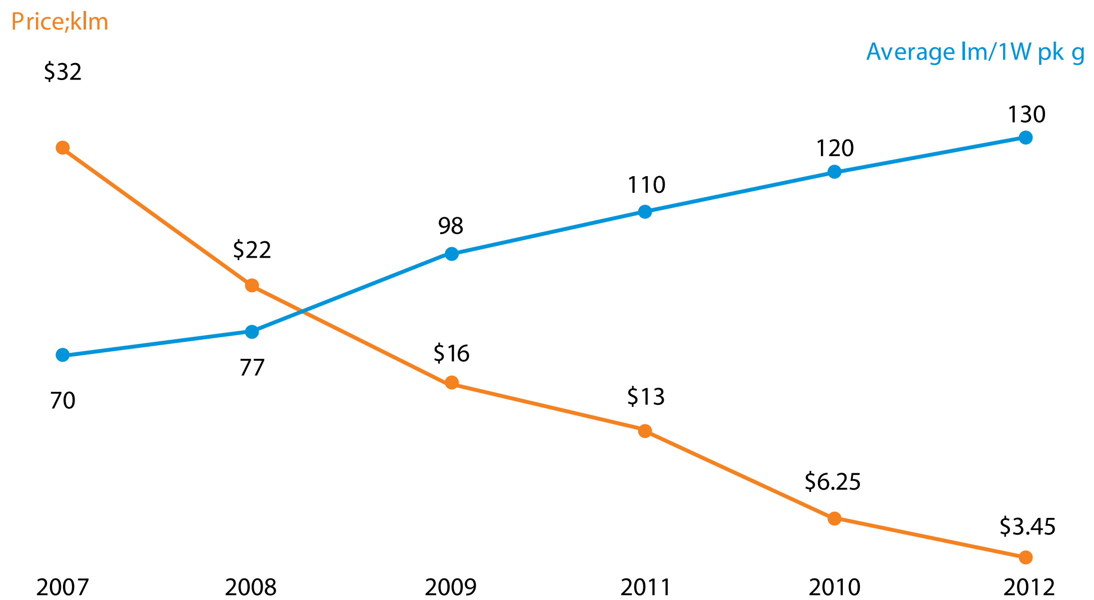
[35]Electricity tariffs are set by the National Electricity Energy Agency (ANEEL). This federal regulatory agency allocates tariffs per group of users according to voltage. Public lighting falls into Subgroup B4, divided into: a) B4a: the tariff applied when the public street lighting assets are municipally-owned (i.e. the present situation of all Brazil´s municipalities). b) B4b: the tariff applied while the public lighting assets were owned by the distributors. It is estimated that this tariff was 9.6% higher than B4a, with the difference representing the remuneration for distributors´ operation and maintenance of the public lighting system. This tariff is being phased out in accordance with ANEEL Normative Resolution 414/2010.

Unlike other consumer categories, where billing is done on the basis of actual, measured consumption and calculated according to a set tariff, public lighting utilities are not required to install meters. This means that, in many cases, electricity consumption of the public lighting network is estimated on the basis of the quantity and power rating of the installed lighting equipment[36]. The total power of the installed equipment is multiplied by a fixed number of hours of daily use to calculate the estimated price of kWh / day consumed by the public street lighting services[37].

3.3.1.2 - Equipment prices

LED prices for public lighting are rapidly falling in terms of US$ per lumen. From 2007 to 2012, the cost per lumen fell around nine times, from US$32 to US$ 3.45 per 1,000 lumens. This price reduction was partly due to the increased luminous efficiency of LEDs, which doubled from around 70 lumens per watt to 130 lumens per watt, as shown in Figure 9. Experts suggest that price reductions are in the range of 8–10% per year, and some studies forecast that price reductions could be as much as 16% per year[38].

Figure 9 - Average price of LEDs (US$ per 1,000)



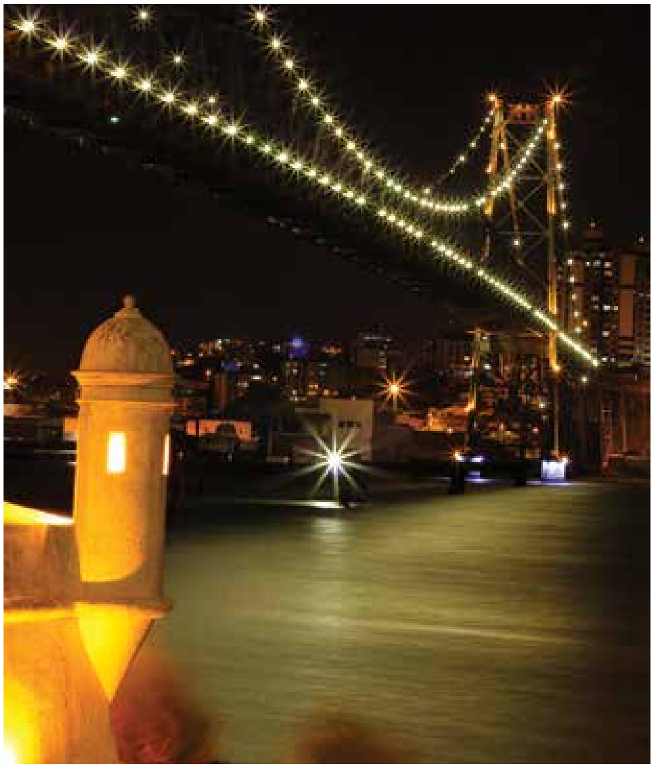
Source: Strategies Unlimited

International LED prices for recent public lighting projects in the United States, China and Mexico range from US$250 to US$500 per light point. The costs in India, which has a strong local LED manufacturing industry, are as low as US$150-200 per point, although with lifespan specifications below the Global Lighting Challenge standards. See Annex 4 for details.

The final price of LEDs is likely to depend on the scale of projects. Bloomberg studies suggest that prices tend to stabilize for projects involving more than 100,000 luminaires. This is the case, for example, of Los Angeles, which achieved prices of US$300 per point on highways and US$245 on smaller roads (2012 prices).

There is still a significant gap between the above-mentioned prices and the retail prices of LED lamps in Brazil. This is basically due to low local content in

[36] Also called measurement by agreement (avença).
[37] ANEEL determined that public lighting is to be used for 11 hours 52 minutes a day except in the case of public parks and / or tunnels, which normally have their own consumption measure. Municipalities can submit to ANEEL requests showing a deviation from the forecast standard. The city of Rio de Janeiro was able to prove to ANEEL an average daily consumption of 11 hours 32 minutes.
[38] FOOTE, J .; WOODS, E. (2014)."Smart street lighting: LEDs, communications equipment and network management software for public outdoor lighting: market analysis and forecasts. " Navigant Research.



luminaires (typically 30%), and to taxes of around 75% on imported components (i.e., double those levied on domestically-manufactured high pressure sodium lamps). Furthermore, market prices in Brazil have not yet been impacted by the potential for lower costs generated by large-scale projects, which are still in their infancy.

Given the falling prices, adoption of LED technology for public street lighting is virtually inevitable over time. However, the pace of full-scale conversion will depend on a city's financial status and the political will that is needed to prioritize these projects.

3.3.2 - Opportunity 2- Incentives for municipalities to invest in their lighting assets

Current regulatory and economic conditions in Brazil are major incentives for municipalities to invest in the modernization (and efficiency) of their public street lighting systems. This section focuses on two key incentives: (i) economic and financial incentives created by regulatory changes related to the transfer of public lighting assets to the municipalities; and (ii) political incentives presented by a combination of the relatively short time needed for implementing new public lighting compared to other infrastructure projects, and by the prospect of immediate positive impacts on community residents.

3.3.2.1 - Regulatory changes

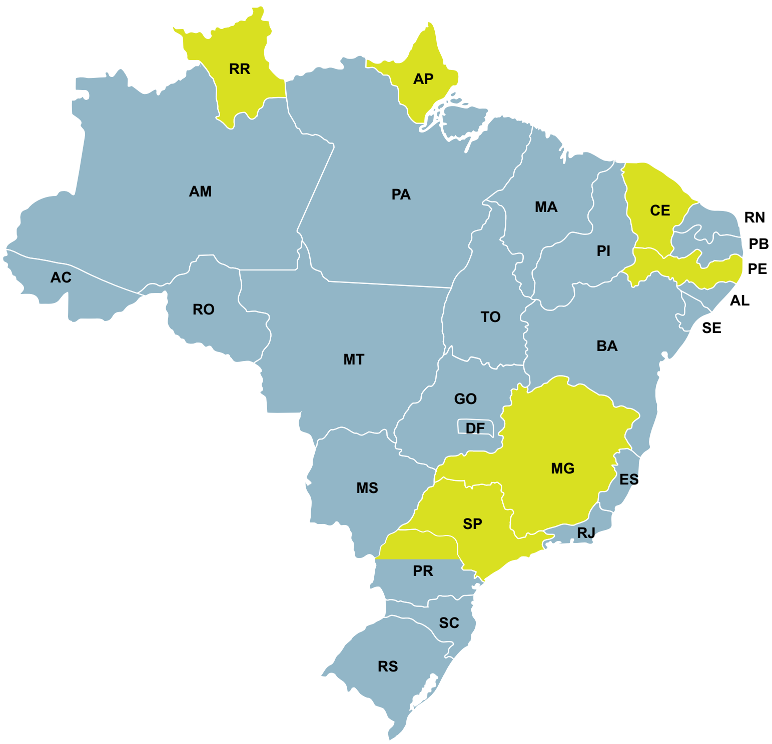
Municipalities, as owners of the assets, are responsible for regulating the public lighting market. However, for historical reasons, certain municipalities did not claim ownership and, as a result, the services remained the responsibility of the city's electric utility. Most of these municipalities whose assets were under the responsibility of the electric utility were in the states of São Paulo, Minas Gerais, Ceará, Pernambuco, Amapá, Roraima and parts of Paraná; together they represent around 42% of all Brazilian municipalities.

Following a series of normative resolutions and public consultations, ANEEL Resolution 587, issued in 2013, determined that by the end of 2014 all public lighting assets were to be transferred to the municipalities, with cities assuming the management of all the activities related to the provision of public street lighting services previously carried out by the electric utilities.

Since the transfer, public lighting assets can no longer be included in the balance sheets of the old owners (utility companies) and cannot be calculated in the energy distribution Regulatory Asset Base (RAB), and therefore have no further impact on ANEEL-calculated tariffs.

Figure 10 shows the asset transfer situation in Brazil (states highlighted in yellow have recently exercised their rights of ownership).

Figure 10 - Most recent municipalities to transfer their public street lighting assets



Source: ANEEL[39]

The public lighting assets transferred to the municipalities generally included the following individual components[40]: a reactor; lighting arm; light fixture; lamp (sodium, mercury, metallic vapor, LEDs); photoelectric relay; and, in certain cases, a pole. It is important to note that not all the assets needed to provide the services were transferred to municipalities. This is a source of potential economic loss for the municipalities given that prior to the transfer of assets they shared some of the distributors' resources, such as vehicle maintenance.

The vertical disintegration of the public street lighting service entails new transaction costs for municipalities involving the transferred assets, and it raises a number of issues that cities must now confront directly, such as: coordination with the energy grid operator; technical/economic regulation of the street lighting service; and the need to invest in equipment, etc.

The transfer of the public street lighting services may incur additional costs for municipalities, especially in view of the widespread lack of trained and experienced personnel to manage the new assets. However, because the municipalities now own the assets and are obliged to pay the costs of running the services, they now have an economic incentive to invest in public lighting energy efficiency with the goal of reducing the burden of electricity costs on municipal budgets.

3.3.2.2 - Political opportunities

There is also evidence that the Brazilian population greatly values the significant improvement in the perception of security that lighting modernization with LEDs can provide. In light of the current macro-fiscal crisis, Brazilian mayors have few other opportunities during their four-year mandates to

[39]Available at: <http://www2.ANEEL.gov.br/aplicacoes/audiencia/arquivo/2013/107/documento/voto_48500.002402-2007-19.pdf.
[40]Items included in energy distributors' Fixed Assets in Service (AIS).

implement actions that can have immediate and positive impacts on communities' quality of life than LEDs for public street lighting.

These incentives create a critical mass of municipalities in search of solutions for improving their public street lighting systems. This results in a large potential market for, among others, lighting manufacturers, managers, installers and financiers.

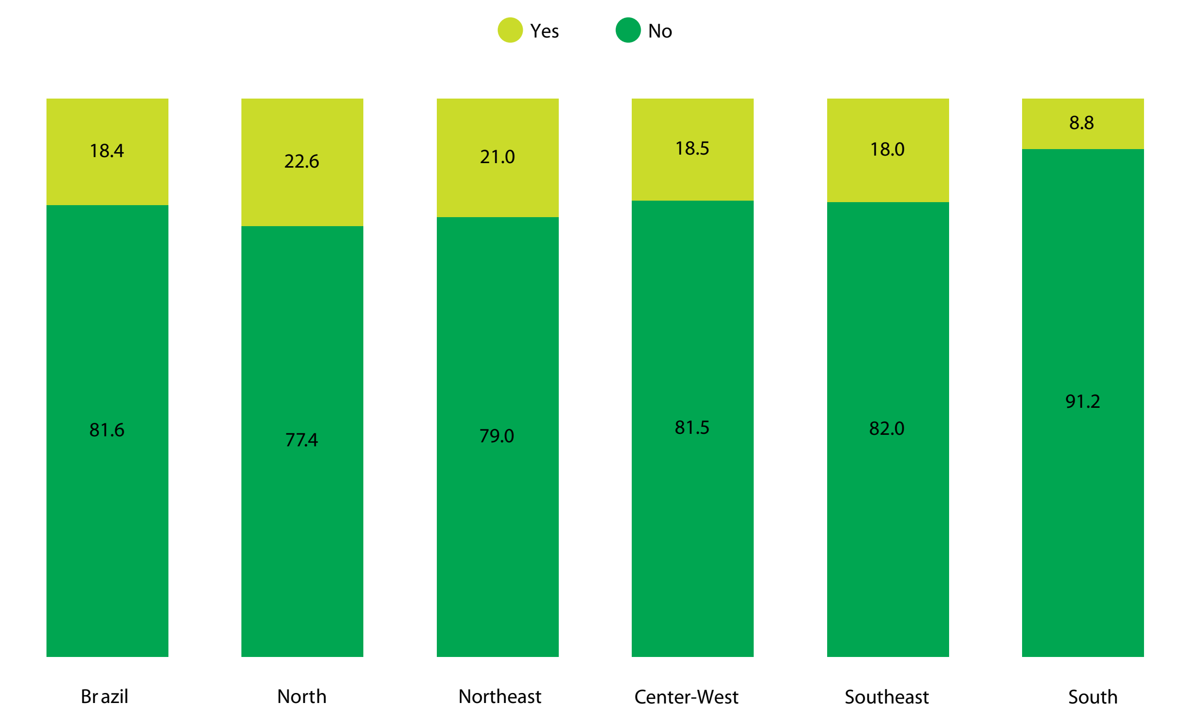
3.3.3 - Opportunity 3 - Source of specific funds to pay for public lighting services

A constitutional amendment of December 2002 allowed the collection of the Contribution for Costs of the Public Lighting Service (COSIP) by municipalities and the Federal District[41] for the exclusive purpose of paying for public lighting services[42]. The municipalities have the right to pass local laws to define the value of COSIP, and for the charge to be added to customers´ electricity bills. A large number of Brazilian municipalities depend on COSIP for raising resources for the maintenance of the street lighting system and supporting new street lighting investments.

The purpose of COSIP is to finance the supply of electricity, as well the installation, maintenance and improvement of public lighting equipment. Municipal legislation can also earmark any surpluses from COSIP to remunerate the costs associated with PPP projects involving energy efficiency. Although there have been a few judicial inquiries challenging the legality of the collection of COSIP, it has been upheld to date.

The World Bank sample survey of Brazilian municipalities showed that 81.6% of the municipalities already charge COSIP, and - in most other cities - legislation is being drafted to implement COSIP.

Figure 11 - COSIP contribution to public lighting, by % of municipalities



Source: World Bank Group

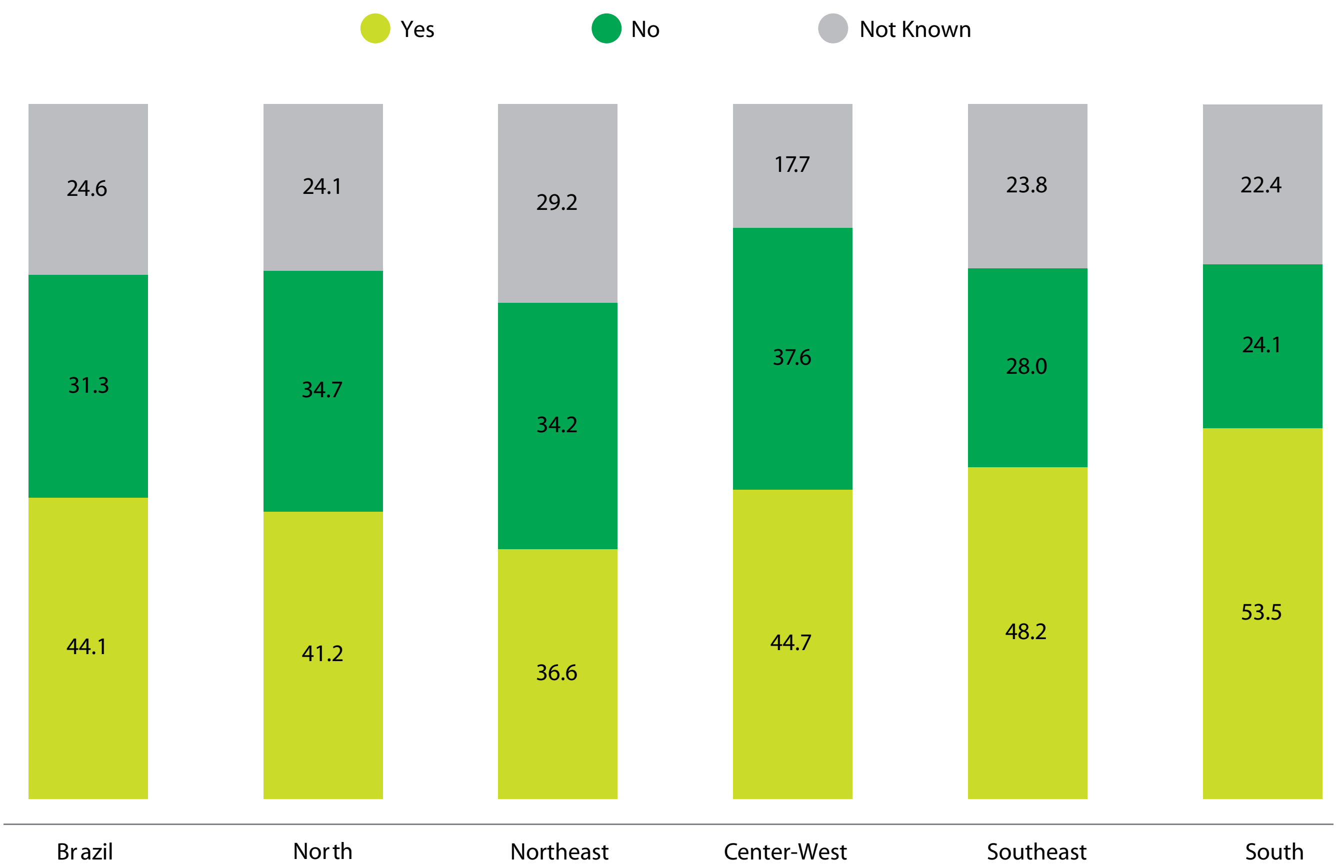
[41]Federal Constitution Amendment 39, of 2002, which amends Art. 149.
[42]Article 149a was introduced in the Federal Constitution through Constitutional Amendment 39 of 2002, after years of judicial disputes over the type of tax that could be levied to collect revenues for defraying the costs of street lighting. Now that the collection of COSIP by the municipalities has constitutional endorsement, it has become more difficult to contest it. In the course of this study we found only two previous cases in the Federal Supreme Court questioning the constitutionality of local COSIP rules: in both cases the Court ruled that the contribution could be collected provided that the municipal legislation was in accordance with Article 149-A of the Federal Constitution (precedents AC 3087 MC-QO/MG and RE 573675/SC).

The implementation of COSIP increases the attractiveness of investments in energy efficiency in the sector, since the "contribution" represents a specific source of funds to finance public street lighting. It can be regarded as a form of credit guarantee in cases where municipalities source private sector financing.

However, the mere fact that COSIP exists does not necessarily reduce the perception of risk of a specific project. The municipal law that defines COSIP must be carefully designed. COSIP revenue should, for example, be sufficient to cover the value of the financial commitments for street lighting costs, including a buffer to avoid the possible risk of an imbalance between the city's total financial commitments for this sector and the amount of revenue raised through COSIP[43].

Sample survey data reveal that in 44.1% of municipalities the contribution is sufficient to cover the costs of municipal street lighting, while in 31.3% of municipalities the revenue raised from this source is considered insufficient. Moreover, 24.6% of city respondents were unable to assess whether the charge was sufficient or not.

Figure 12 - Sufficiency of COSIP to cover PL costs, by % of municipalities



Source: World Bank Group; Castagnari Consultoria

[43]For example, COSIP must take into account variations in energy costs and any other factors in order to avoid value imbalances.

Box 4 - Design of COSIP contribution for Public Street Lighting

Given the importance of standardizing COSIP for leveraging public street lighting projects, Table 14 outlines recommendations for the design of this contribution that could be considered by municipalities.

Table 14 -Recommendations for COSIP design

Indexation Mechanism	• COSIP should to be indexed to electricity prices and other costs related to O&M, so that O&M tariff and/or services increases do not place municipalities at deficit risk. • If COSIP is indexed only to consumers' consumption, the budget for public lighting will be vulnerable to electric price variation.
Regular Readjustment Mechanism	• Municipalities should to establish in their own Municipal Law, a clear readjustment mechanism (potentially automatic) for all consumption ranges. This may mitigate (although it will not completely avoid) political interference risks regarding COSIP's collection.
Possibility forecast of escrow account	•Earmarking COSIP's resources to an escrow account substantially reduces municipal credit risk perception. • Therefore, it is recommended that municipalities considering to attract investments for a modernization project include this possibility in the law defining COSIP.
To explain the Purpose of COSIP's resources	• There are some legal debates regarding the acceptable uses for COSIP's resources, for example, questioning its use only for O&M, or if it would be applicable for retrofit investments. Municipal legislation must be clear in this sense to avoid future problems.
Rules for COSIP's collection	• It is important for the municipality and the electric utility to implement a robust agreement that makes clear COSIP's collection and passthrough mechanism (executed by the electric utility on behalf of the municipality). Furthermore, municipalities should have capacity to supervise this process.

Source: World Bank

The field visits undertaken during the preparation of this report and subsequent research revealed substantial variability in the way the contribution is collected.

For example, some of the first regulatory norms covering COSIP were designed to establish a uniform type of collection according to the formula: individual COSIP value = total monthly cost of public street lighting service divided by the total electricity consumption for public street lighting by the municipality. This required monthly recalculation of end-user COSIP values and is regressive (i.e., small consumers pay the same amount as large consumers). Meanwhile, at the other end of the spectrum, a substantial number of laws in force differentiate the value of the contribution according to consumption categories (some list over 50 different classifications).

In terms of how COSIP is calculated, there are two main approaches to calculating and collecting COSIP: (i) municipalities that calculate COSIP according to a fixed value; and (ii) municipalities that calculate COSIP as a percentage of an indexed variable (such as the energy tariff).

In approach (i), the use of a fixed amount can cause political issues if the law fails to indicate how a future adjustment will be made in case the costs of street lighting outweighs the value of COSIP collected. In such a case, the municipality must approve a new law or decree to make adjustments to COSIP collection. Many municipalities currently face this problem due to the substantial increases in electricity costs, and they are now running deficits because current COSIP revenues do not cover public lighting expenditure.

In approach (ii), COSIP-related legislation contains two major trends related to adjustment of the charge: (a) indexing based on changes to the energy tariff (the majority); and (b) indexing to inflation (the minority). It is worth noting that neither of these two options fully covers increases in non-electricity related public street lighting costs – such as operation, maintenance, and system expansion costs - although some of these costs may be taken into account if inflation indexation is used.

Finally, several cities run *reduced charging regimes* (or exemptions) to benefit low-income end-users. In the vast majority of the cases studied, cities have defined a minimum consumption band that is exempted from the payment of COSIP on the basis of electricity consumption versus household income. The "minimum" consumption band varies significantly from municipality to municipality. Given that, in most cases, COSIP is added to consumers' electricity bills, a more harmonized and straight-forward approach would be that the definition of "low income" for COSIP is aligned with the Social Electricity Tariff (SET), (the SET involves discounts or exemptions for families enrolled in the Federal Government's Unified Registry for Social Programs).

None of the COSIP-related laws studied were capable of fully meeting all the requirements for achieving a progressive, socially-responsible, flexible charge that could be adapted to variable public street lighting costs over time. Nonetheless, the approaches taken by the cities of São Paulo and Belo Horizonte could possibly serve as examples to help improve the design of COSIP in other municipalities (see data from 2016 in Table 15).

Table 15 - Examples of COSIP design for São Paulo and Belo Horizonte

Municipality	Bands/classes	Value	Reajustment	Exemption
Belo Horizonte	By consumption: <=100KWh/mth 101-200 KWh/mth 201-300 KWh/mth 301-500 KWh/mth 301-500 KWh/mth W/O meter	Variable: 1,00% of TCIP 4,00% of TCIP 6,00% of TCIP 8,00% of TCIP 10,00% of TCIP 60,00% of TCIP/year	According to B4a tariff adjustment	None
São Paulo	By category: Residencial Commercial	Fixed: R$ 9,32 BRL R$ 29,30 BRL	Annually by same index used for read-justing the electrical energy tariff	*Locations without public street lighting *Residential clas-sified by ANEEL for "Low-income Social Tariff"

* TCIP = Tariff B4a x 1.0909

In short, COSIP is an effective tool in enable significant resources to be leveraged for investments in scaling up public street lighting. It also helps reduce municipal credit risk perception by potential investors. However, the mere existence of COSIP is not sufficient to guarantee financial security. Municipal legislation needs to be well-formulated and take into consideration possible issues arising from COSIP collection, especially the need for clarity regarding the way the charge is collected and the allowable uses for COSIP funds.

3.3.4 - Opportunity 4 - Alignment with the public climate policy

At the global level, the countries participating in the 21st Conference of the Parties (COP-21) submitted in November 2015 their proposals for contributing to the alleviation of climate change — INDCs.[44] The resulting Paris Agreement generated commitments based on the INDCs to be fulfilled all countries that ratified the agreement, including Brazil. Among other objectives, Brazil undertook to achieve efficiency gains in the electricity sector of around 10% by 2030.

Modernization of Brazil´s public street lighting sector can contribute significantly towards reaching this goal, since the sector currently represents 4% of the country´s total energy consumption. Moreover, a national conversion to LED lighting could produce, at a conservative estimate, energy savings of 50% in the public street lighting sector, thus translating into one-fifth of its INDC by exploiting this potential (i.e., national efficiency gains of 2%).

[44]Intended Nationally Determined Contributions.

3.4 - Challenges for LEDs in the Brazilian Context

Despite the great opportunities, there are still institutional challenges to investing in the conversion of Brazilian cities´ public street lighting systems. These include the large scale of investment required, the diversity of the country´s municipalities, the current macroeconomic situation, difficult access to public financing, limited municipal financial capacity, municipal credit risk, and the lack of a regulatory framework for public-private sector contracts in public and private lighting projects.

3.4.1 - Challenge 1 - Large scale funding required

As explained in Section 3.2, LED public lighting projects can provide very substantial economic benefits to Brazilian cities since LEDs are more efficient and last longer than any other current types of lamp, regardless of the fact that the technology is significantly more capital intensive. Thus, while LED projects can be very attractive from an economic standpoint, they can only be developed if cities and other stakeholders can access a sufficient amount of financing at affordable rates.

As described in Section 4.1, Brazil's overall public street lighting infrastructure consists of more than 18 million light points, entailing an estimated retrofit cost of R$28 billion (US$8.6 billion[45]).

Therefore, a large-scale amount of investment is needed to cover the capital expenditures required to convert the entire Brazilian street lighting inventory to LEDs. Government resources will not be able to cover these costs, meaning that the private sector will play an important role in achieving the investment levels needed to modernize the Brazilian system to LEDs. Bringing in private sector capital while ensuring the cost of capital is low enough to ensure project viability will likely require a coordination of multiple actors, including *inter alia* the government, multinational players, and the private sector.

Section 7 of this report aims to provide an initial review of potential mechanisms that could be used to raise financing for LED investments. Section 9 offers additional recommendations to help close the financing gap.

3.4.2 - Challenge 2 - Large diversity of municipalities

The challenge presented by the large scale of the projects required is more than financial. Exploiting this huge potential will require the development of a large number of projects tailored to the different characteristics of Brazil´s 5,570 municipalities.

Projects will need well-designed, appropriate business models to meet the needs of different municipalities. Municipal personnel will also need training to increase project management and/or oversight capacity. The heterogeneity of Brazilian municipalities in terms of size, staff capacities and fiscal status complicates the task of preparing solutions for large-scale implementation (the diversity of municipalities is discussed in more detail in Section 1.5).

[45]Exchange rate of 3.24 R$/ US$ (September 27, 2016).

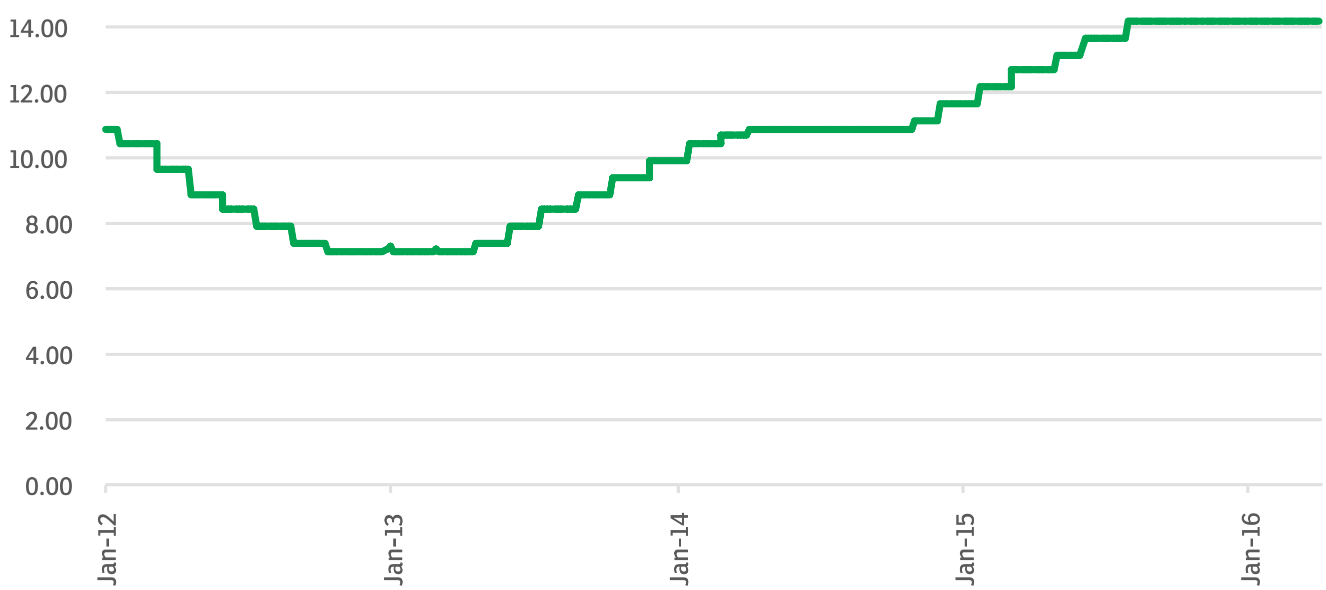
A major challenge is to develop business models that meet the varied needs of Brazilian municipalities while simultaneously offering the necessary incentives to attract private sector participation. Section 6 of this report provides a list of eight potential business models that could be used to implement LED street lighting projects across the full range of Brazilian municipalities. Section 9 offers additional recommendations to help disseminate business models and increase municipal capacity to implement them.

3.4.3 - Challenge 3 - The macroeconomic situation

Brazil's macroeconomic scenario over recent years has precipitated an unfavorable environment for infrastructure investments in general. Some factors are particularly relevant in the case of public street lighting projects, particularly borrowing costs, the costs of imported equipment and the risk of future exchange rate fluctuations.

First, borrowing costs are relatively high - and recently have risen considerably in recent months. The reference value of the SELIC basic interest rate in 2015 and 2016 was 14.25% per annum[46], more than double the rate of early 2013. The trajectory from early 2012 is shown in Figure 13.

Figure 13 - Basic annualized interest rate (SELIC) in %



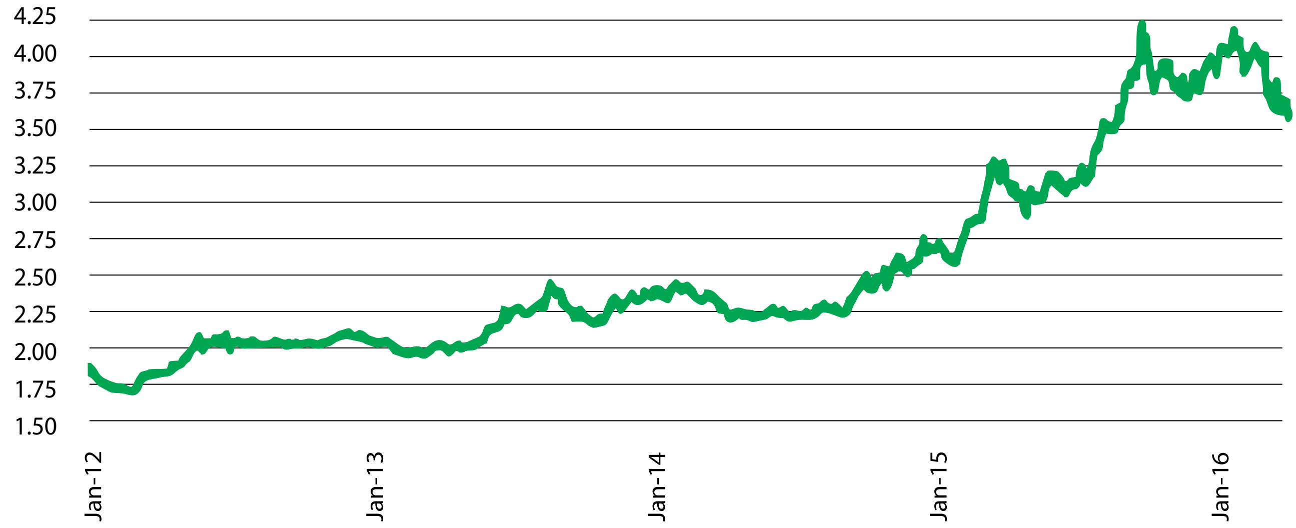
Note: Annualized daily rate based on 252 business days.

Source: Central Bank of Brazil, Series No. 1,178; Pezco Consultoria

Second, exchange rate changes have recently resulted in the depreciation of Brazil's currency (the Real), thereby increasing the costs of imported equipment. In the absence of domestic LED production, these costs naturally increase the risks faced by potential international investors. Uncertain political and economic developments in Brazil have contributed to exchange rate volatility. Figure 14 shows exchange rate movements since early 2012.

[46]The effective annualized rate as shown in the figure was 14.15% per annum. The SELIC target, a policy variable in the inflation targeting regime, was 14.25% per annum.

Figure 14 - Exchange-rate (Brazilian R$/US dollar)



Note: Average official daily rate.

Source: Brazilian Central Bank, Series No. 1; Pezco Consultoria

Although overcoming macroeconomic challenges is largely beyond the scope of this paper, the combination of information provided in Sections 6,7 and 9 offers suggestions of how public and private resources could be used together to decrease the financing cost of these projects such that they can be viable.

3.4.4 - Challenge 4 - Restricted public credit lines

In view of the financing requirements and Brazil´s high interest rates, public funding is important for cities (or their agents) seeking viable financing sources for public street lighting projects.

At the federal level, the National Program for Efficient Public Lighting and Traffic Light Signaling (PROCEL-RELUZ), managed by ELETROBRAS, has been the most important source of investment for the sector. Another national program, the Energy Efficiency Program (PEE), administered by ANEEL, has also provided funding for the electricity sector, albeit on a much smaller scale.

At present, these two programs do not provide significant funding for investing in energy efficiency in Brazil's public lighting system. However, recent changes in legislation - especially Law 13,280 of May 2016, which allocates 20% of the resources from the PEE to PROCEL - may enable these programs to make a more substantial contribution. Box 5 below provides more information on these two public financing lines.

Nonetheless, given the large amount of capital required for converting Brazil's public street lighting network to LEDs, other sources of financing will need to be tapped. While multinational or bilateral bodies can help fill the financing gap, it will be essential to leverage domestic and/or international private sector financing to develop the existing potential.

Sections 6 and 9 of this report offer suggestions of how public sector financing could be increased, particularly looking at the potential role that electric utilities could play in financing small- to medium-scale projects going forward.

Box 5 - Public Funding Lines

PROCEL-RELUZ

The National Program of Public Lighting and Efficient Traffic Signaling (PROCEL-RELUZ) is one of a number of programs created under the broader PROCEL program. It was created by ELETROBRAS in 2000 using resources from the Global Reversion Reserve (RGR),[47] a federal fund composed of resources collected from electric utilities.

Under PROCEL-RELUZ projects were submitted by public entities to the electric utilities who then negotiated financing with ELETROBRAS. ELETROBRAS then established tri-partite framework agreements with utilities and municipalities participating in the program. The program aimed at "promoting energy efficiency and night lighting for urban public spaces, contributing to reduce the consumption of electricity and improve the safety of public roads and quality of life in Brazilian cities" (ELETROBRAS, 2015, p.39). PROCEL-RELUZ funded projects for the replacement of incandescent, mixed and mercury vapor lamps with high-pressure sodium and metal halide lamps, as well as other energy efficient interventions in the system.

The financing of ELETROBRAS using RGR funds covered up to 75% of project value, with the balance representing the contribution of the electric utility or municipality. PROCEL-RELUZ provided financing to electric utilities, who then provided loans to municipalities, bearing the risk of municipal default. Between 2000 and 2014, 2.78 million public light points were replaced under PROCEL-RELUZ. ELETROBRAS provided a total of R$521 million, while electric utilities invested counterpart funds totaling R$173 million.

Since January 2014, no new RGR financing for PROCEL-RELUZ has been approved due to regulatory changes in the overall RGR program itself. However, the Federal Senate recently approved Law No. 13,280 of May 3, 2016, which proposed the earmarking of 20% of the resources from PEE to fund PROCEL (approximately R$100 million annually). These funds could potentially be used to revitalizing the PROCEL-RELUZ or a substitute program. However, it is not expected that all these new funds involved will be channeled into public street lighting improvements.

PEE — Energy Efficiency Program

The Energy Efficiency Program (PEE) is an investment obligation written into the concession contracts of Electric utilities since 2000. It provides for the investment of at least 0.5% of electric utilities' Net Operating Revenue into energy efficiency activities (as well as an additional 0.5% to Research & Development investments). Out of these funds, initial PEE rules required utilities to direct at least 60% of PEE funding to projects in low-income households. Electric utilities are responsible for selecting energy efficiency projects for submission to ANEEL for approval.

[47]Law No. 5.655/71, section 4; Law No. 9.427, section 13. This tax was designed to "provide funds for reversion, merger, expansion and improvement of energy public services." It was incorporated into the rates for distribution to be paid by users of the electrical utility's system (WRI). RGR funds were used by Eletrobras to fund PROCEL.

ANEEL has recently established a mechanism for the competitive selection of energy efficiency projects eligible to receive PEE funds- the Public Call for the Selection of Energy Efficiency Project Proposals. The idea is to encourage electric utilities to choose energy efficiency activities that have better cost-benefit ratios and that contain mechanisms for monitoring the efficient allocation and leveraging of resources. In addition, the rules for allocation of funding under PEE has changed, and the 60% requirement for investment in low-income households no longer applies.

Between 2013 and 2015, electric utilities only submitted two LED projects under the PEE program: in Salvador-BA and São Luís do Paraitinga-SP, totalling investments of around R$4.4 million. In 2016, a public lighting project was approved as part of the Public Call for the Selection of Energy Efficiency Project Proposals — Joaçaba Municipality (R$ 2.8 million). This small number of projects shows that, although public calls for tender are not strategically targeted at public street lighting schemes, certain projects are selected based on the initiative of interested parties.

3.4.5 - Challenge 5 - Restrictions on municipal indebtedness

Although municipalities (or their agents) have to borrow to finance investments in LED technology, there are currently significant fiscal and indebtedness restrictions on Brazilian municipalities arising from the application of the Fiscal Responsibility Law,[48] which places restrictions on financing and bank credit.

If the public entity (e.g., a municipality) chooses, or needs, to resort to indebtedness - especially for investments - it has to mandatorily comply with the restrictions imposed by Brazilian government regulations for public sector financing, namely the Fiscal Responsibility Law. This and other instruments are designed to control access by public entities, including municipal authorities, and others to banking credit.

The limits apply to both the financial institution and the public entity itself. From the standpoint of the financial institution concerned, national regulations apply to the operating margin of public sector bodies and entities, limiting the amount of credit operations based on their Reference Equity (*Patrimônio de Referência*).[50] From the borrower's standpoint (i.e., the public entity) the rules focus specifically on the amounts involved and set borrowing limits linked to the purpose and final use of the resources,[51] even in situations not subject to contract values.

Table 16 summarizes the main restrictions that the Fiscal Responsibility Law imposes on credit operations between federative entities and financial institutions. The main basis for applying these restrictions in Brazil is Net Current Revenue (NCR).[52] The NCR forms part of the arrangements governed by the Fiscal Responsibility Law.

[48]Law No. 101/2001, Resolutions of the Federal Senate (40/2001 and 43/2001) and National Treasury Secretariat Directives (396/2009, 138/2010 and 306/2012).
[50]Limited to 45% of the Reference Equity or the capital outlay margin of the Reference Equity portion, widely used by the state development agencies and development banks (BNDES), since the outstanding amount will be deducted from the Reference Equity for calculating all the operating limits. The practical result is that the financing contract is placed in the category of transactions that are not subject to the value ceiling.
[51] In this case financing for basic sanitation and housing programs.
[52]Net Current Revenue (NCR) = sum of property, agricultural, industrial and services taxes, as well as other current transfers and revenues of the federative entity.

Table 16 - Main restrictions on credit operations imposed by the Fiscal Responsibility Law

Parameters	
Municipal debt target: Debt over Net Current Revenue (D/NCR)	1.2
Limits	
Credit transactions/year	16% of NCR
Debt service	11.5% of NCR
Forecast tax revenue	7% of NCR
Guarantees	22% to 32% of NCR
Restrictions: credit transactions	Beginning 180 days from end of political mandate

Source: Nascimento; Debus (2002); Pezco Consultoria

The restriction of 16% of the NCR to the limit of credit operations per year does not apply to credit operations contracted by states and municipalities with the Federal Government, multilateral credit agencies or official credit or development institutions, providing the borrowings are to be used for financing investment projects for improving fiscal, financial and asset management.

Other borrowing situations that have exemptions under the Fiscal Responsibility Law include:

- financing in Brazilian currency the counterpart of projects that are financially supported by multilateral credit organizations in which the international bidding notice mandatorily includes a financing clause;
- financing with BNDES/PMAT funds for tax modernization;
- financing guaranteed formally and exclusively by commercial sales or trade notes (duplicatas) issued by the beneficiary of the credit transaction;
- credit operations undertaken by development banks and agencies based exclusively on Reference Equity considerations; and,
- credit operations possessing a formal, comprehensive and solidarity guarantee from the National Treasury.

It is interesting to note that PROCEL-RELUZ's operations in the public street lighting sphere have been processed differently with respect to the Fiscal Responsibility Law restrictions. Financing operations conducted by electric utilities to municipalities using proceeds from the PROCEL-RELUZ were not subject to the indebtedness limits of the municipalities established by the federal regulation[53]. The perceived logic of this is that, as with the BNDES/PMAT funds available for tax modernization, energy efficiency-related investments can improve a municipality's fiscal situation by reducing its expenditures over time. Despite this allowable exception, in practice the National Treasury demanded municipal governments meet certain fiscal criteria in order to benefit from this exception, leading to many municipalities

[53]Enshrined in Law 9,991/2000.

facing de facto restrictions to obtain financing from PROCEL-RELUZ.

Section 9 of this report offers initial suggestions of how municipalities seeking to invest in energy efficiency projects with positive economic and financial returns could have easier access to credit.

3.4.6 - Challenge 6 - Credit risk and municipal political risk

Mitigation of municipal credit risk presents a challenge to obtaining investment finance for LED public street lighting projects. Given that the municipality is ultimately responsible for generating cash flows to defray investment costs, investors in public lighting projects acting on behalf of municipalities will be exposed to credit risks and to municipal political risk.

Regarding credit risk, investors are exposed to the risk of lack of municipal budgetary funds needed to pay off debts and other liabilities. If COSIP revenues are available, the credit risk is significantly reduced, given that COSIP is a guarantee for payment. However, even when COSIP is charged, the amount collected from consumers may be insufficient to cover payments due to investors. A well-designed COSIP would help avoid this shortcoming (Section 4.3.3, Box 4).

In the event that a municipality does not receive COSIP revenue, the risks are greater since the funds available for financing public street lighting projects would be at the mercy of the regular budget allocation process and its possible contingencies.

Finally, political risks are always a threat in partnerships with the public sector. For example, changes in local legislation could negatively impact a municipality's ability to service its debt. Another example risk would be the possible freezing or confiscation of a municipality's revenues (including COSIP) by oversight/ control bodies such as the Attorney General's Office, the Public Ministry or the Comptroller General.

Since few Brazilian cities have a national or international credit risk rating as a basis for assessing their financial soundness, the alternative proposed by this report is to analyze credit risks using the following indicators: (i) the Net Current Debt/ Net Current Revenue (NCD/NCR) ratio; and (ii) the Firjan Fiscal Management Index (IFGF). These indicators and the classification of cities following their application are addressed in Section 5. Section 7.2 outlines mechanisms to minimize and mitigate these risks.

3.4.7 - Challenge 7 - Lack of a clear regulatory framework for public lighting

Public lighting is a network service, as is, for example, the electricity distribution service. As a natural monopoly, these services must be regulated in terms of (i) entry and exit conditions for service providers; (ii) economic regulation; and (iii) service delivery quality.

Unlike the power sector, which has almost 100 years of regulatory experience, the public lighting sector is a relative newcomer to regulation. Problems and friction between the granting authority (municipality) and the concessionaire are likely to become more frequent as the sector is disintegrated.

In the absence of an institutional knowledge base for regulating the public street lighting service, an alternative is to implement regulation (as far as possible) through "regulation by contract." In this event, utility contracts are prepared in the form of

detailed instruments covering a variety of situations that may arise during contract implementation or extension. These points were carefully taken into account during the preparation of concession contracts by São Paulo and Belo Horizonte; however, this process is cumbersome and prone to important, unforeseen exclusions.

Regardless of this careful preparation and thorough analysis, areas still remain to be defined and negotiated in the future, such as ordinary tariff revision procedures, extraordinary revisions to restore economic-financial balance, sharing efficiency gains resulting from technological innovation, and the risks of expropriation, expiration, or cancellation of the concession involving subsequent payment of compensation to the concessionaire.

Not all of these hypotheses can be foreseen in the contract (nor in the traditional regulation), and there is a clear need to put in place mediation, conflict resolution and arbitration procedures. While larger municipalities may develop these regulatory capacities or hire specialized support in the event of conflicts or economic/financial balance reviews, it is unlikely that small and medium-sized municipalities would be in a position to do the same.

The smaller and medium-sized municipalities might be encouraged to seek ways to acquire this expertise jointly either via associations of municipalities, or through agreements with state regulatory bodies. The latter would need to familiarize themselves with the nuances of public street lighting, but at least they would already possess regulatory expertise and experience.

In order to change to a more efficient system, a series of regulatory questions would need to be considered (e.g., operator incentives to invest at an optimal level for themselves and municipalities, the best way to ring-fence COSIP revenues, defining payments in case of changes to exogenous factors, such as electricity prices, etc.) and new functions would be needed in the market, including regulation, strategic planning, monitoring, quality control, awarding and supervising concession contracts — all vital activities for ensuring the proper functioning of any service contracted under a concession regime.

All this requires substantial regulatory capacity, a process that is currently not being led by the state federal level. Given this vacuum, one short-term solution is to develop capacity-building and regulatory standards at the municipal level to ensure that sustainable contracts are implemented under the existing *regulation by contract* system. In the medium term and in the absence of federal-level regulation, state regulatory bodies could assist municipalities to prepare concession contracts.

Section 9 of this report offers initial suggestions of how to improve the regulatory framework in light of the recent structural changes in the public street lighting sector.

The remainder of this report provides information on the Brazilian market and proposes the most suitable business models and financial solutions for meeting the requirements of this market. As indicated above, the main objective of this report is to seek to provide solutions to overcome Challenge 1 (large scale of financing required), Challenge 2 (large diversity of Brazilian municipalities), and Challenge 6 (municipal credit risk). However, throughout the remainder of the report and particularly Section 9 (Conclusions) recommendations are offered to begin to address all the aforementioned challenges, as well as recommendations of how to best capitalize on the unique opportunities in the Brazilian market.

4 - Mapping Brazilian Municipalities for Public Lighting

The identification of business models that could enable the large diversity of Brazilian municipalities to benefit from the opportunities and overcome the key challenges is an important step in the development of the Brazilian market. However, prior to identifying appropriate business models, it is necessary to understand the characteristics of the municipal public lighting market in Brazil.

This is not a simple exercise. Brazil has 5,570 highly heterogeneous municipalities with different socio-economic characteristics (income and development levels) and physical/demographic features. A single universal business model for public lighting projects is out of the question. The first challenge is therefore to group municipalities based on their similarities with a view to developing solutions tailored to each type of municipality.

4.1 - Survey of Public Street Lighting

In order to understand better the context of the public street lighting sector in Brazil, the World Bank Group undertook an in-depth survey during the first half of 2015 of more than 300 Brazilian municipalities with different population profiles and economic situations.

This survey was divided into two activities: (i) field visits to nine municipalities and consortia, and (ii) visits to energy distributors in three states (Ceará, Minas Gerais and São Paulo[54]).

The visits involved a structured questionnaire with 12 key questions for classifying municipalities regarding the source of resources for public street lighting, existing technology, equipment maintenance, the existence of technical staff, services management and bidding procedures, and, inter alia, the respondents´ experience of, or interest shown in, consortia and PPPs for public street lighting.

The sample for collecting public street lighting data on Brazilian states and macro-regions was based on a random selection of Brazilian municipalities divided into two groups: i) municipalities with populations of 30,000 or over; (ii) municipalities with less than 30,000 inhabitants.[55]

In order to ensure a full picture of all the states in the Brazilian Federation, at least four municipalities per state were selected from the universe of 300. Data on the Federal District was also included.

4.1.1 - Data collection

Data collection was performed using a structured questionnaire based on questions formulated by the World Bank team. Specialists in this type of survey were also charged with contacting by telephone the individuals in the municipalities responsible for providing the relevant data.

[54]These states belonged to the group of states to which lighting assets had been transferred, and included municipalities that were directly in charge of the assets as well as those where the transfer process was still underway.
[55]Population count for 2014 by the Brazilian Institute of Geography and Statistics (IBGE).

Table 17 – Municipalities surveyed, by region

Region	Number of municipalities surveyed		
	Under 30,000 inhabitants	Over 30,000 inhabitants	Total
North	26	20	46
Northeast	53	44	97
Center-West	18	8	26
Southeast	50	36	86
South	20	25	45
TOTAL	167	133	300

Source: World Bank; Castagnari Consultoria

The municipalities surveyed contain 35.9% of Brazil´s urban population according to IBGE (2014), and included municipalities served by more than 30 different energy distribution companies.

The findings of the field and data sampling surveys provided a clearer understanding of the general context of Brazil´s public street lighting market and provided the basis for the subsequent analysis, mapping and classification of municipalities ready for the preparation of business models. More information on the data collection results is available in Annex 3.

4.2 - Formation of Clusters

Some of the survey findings were used to create part of the database of the variables submitted to statistical analysis for classifying/grouping Brazilian municipalities in terms of their public street lighting networks.

Seven variables were considered for this study: three from the survey data (scale of the street lighting network, level of modernization of the existing network, and current coverage); and four from publicly-available sources (socioeconomic development level, density of the public street lighting system and the municipality´s fiscal situation (two variables)). In order to organize these sets of characteristics, it was decided to use the clustering methodology, which involves grouping municipalities based on the similarity of features.

The procedure for grouping municipalities was divided in two phases: (i) statistical *cluster* analysis, followed by (ii) identification of homogeneous *groups* of clusters. This approach enabled multiple important aspects to be taken into consideration (size, development level, fiscal situation, public lighting network density, sectorial indicators) while ensuring a manageable number of final groups for further analysis in terms of business and financing models.

The purpose of *cluster* analysis is to group the sample units of interest (individuals, companies, cities, countries, etc.) into categories so that there is a high level of similarity or homogeneity between the components of the cluster and, at the same time, a clear distinction between the groups. The *cluster* analysis technique is often used when the data classification structure is not known ex-ante and when little or no previous analysis exists.[56] The variables listed in Table 18 were considered for the cluster statistical analysis phase.

Table 18 - Database characteristics

Variable	Definition	Objective/logic for using	Unit	Year of data
GDP per capita	GDP divided by number of inhabitants of municipality	Proxy of the municipality´s level of development	R$	2012
Consumer units per water supply connection	Measurement of the water supply network density. A connection consists of the consumer unit/units linked via a single extension to the distribution network.[57]	Proxy of the level of "verticalization" of the municipality, thus of the public street lighting network density. The public water supply system often covers the same area as the public lighting network.	Ratio	2013
IFGF	Index for measuring how taxes paid by community residents are administered by the municipal authorities. Composed of five indicators: Own Revenue, Personnel Costs, Investments, Liquidity, and Debt Cost.	Proxy of the level of the municipality´s fiscal management.	Index	2013
NCD/NCR	Ratio between NCD (Net Consolidated Debt) and Net Current Revenue (NCR).[58]	To measure municipality´s indebtedness level.	Ratio	2015
Number of light points	Estimate of the number of light points in the public street lighting system.[59]	Proxy of the size of municipalities, and to estimate the size of the public street lighting system — also a proxy for assessing the level of investment needed for a public lighting retrofit project.	Number	2014
More than 20% mercury vapor lamps used in the public street lighting network [60]	Indicator (yes/no) to estimate whether the municipality uses more than 20% of inefficient mercury vapor lamps in its public street lighting network.[61]	Efficiency level of the current network in order to gauge the possible level of energy savings via a modernization program	Indicator	2014
Percentage of the municipality not covered by public street lighting	Percentage of the municipality not covered by public street lighting.[62]	Proxy for the amount of investment needed to modernize the existing network versus extension of the network to unserved areas.	Percentage	2014

Source: IBGE; FIRJAN; National Treasury; Ministry of Cities, World Bank Group

Note: The population was not considered, in view of the high correlation with GDP (95.6%)

[56]A more detailed description of the study methodology is provided in Annex 3. The Gross Domestic Product (GDP) variable was considered but discarded because of the high correlation between GDP and the number of light points.
[57]For example, a building with ten apartments can have a single connection serving ten consumer units, thus for this building the ratio of consumer units/per connection is ten.
[58]There are cases where the municipality may have negative NCD (i.e., cash availability exceeding financial liabilities. In this case, a negative NCD/NCR index indicates how much cash the municipality has in relation to its Net Current Revenue.
[59]Using current available data and estimates using a regression model when data unavailable.
[60]Technology used in the network estimated from the use of a proportion of more than 20% mercury vapor lamps.
[61]Using current available data and estimates using a regression model when data unavailable.
[62]In these variables we used data from a sample survey carried out by the World Bank Group on Brazilian municipalities, given that no data was available for the entire universe of municipalities.

Through this analytical method, 18 clusters (homogeneous groups) were identified. See Table 47 in Annex 3 for further details on the clusters, the number of municipalities and the mean values of the variables in each group.

4.3 - Homogenous Groups

The second step of the process involved a procedure to assemble the 18 clusters into six groups, by employing a qualitative evaluation of the characteristics considered to be key drivers of the implementation of similar business models. This grouping process mainly considered fiscal management characteristics and the number of light points. The results of this grouping analysis are presented in Table 19.[63]

Table 19 - Grouping of clusters according to key characteristics

Group	Number of municipalities	Scale (light points)	Fiscal management	
			Average IFGF	NCD/NCR
A	47	> 50.000	> 0.6	> 0
B	88	20.000–50.000	> 0.6	> 0
C	329	< 20.000	= 0.6	< 0
D	887	< 5.000	> 0.6	< 0
E	3.406	< 2.000	> 0.4	< 0
F	813	< 2.000	< 0.3	> 50

Light yellow = good; Light orange = moderate; Red= limited

Source: World Bank Group; Pezco Consultoria

The regrouping of the clusters in order of relevance is presented in Table 20 — number of municipalities, resident population, light points and estimated capital expenditure required for LED conversion.

[63]The list provided in Annex 3 nominally identifies the municipalities contained in each group, also informing the cluster in which they were originally classified.

Table 20 - Municipal groups in order of relevance

Group	Population			Light points			Required investments (R$)		
	Total (millions)	%	Average	Total (millions)	%	Average	Total (billions)	%	Average (millions)
A	59,9	29	1.274.015	5,1	27	107.499	7,7	27	161,3
B	23,8	12	270.041	2,8	15	31.490	4,2	15	47,2
C	14,7	7	44.701	2,1	11	6.303	3,2	11	9,5
D	23,0	11	25.967	2,2	12	2.437	3,3	12	3,7
E	64,4	32	18.921	5,1	28	1.493	7,7	28	2,2
F	18,6	9	22.894	1,2	7	1.533	1,8	7	2,3
TOTAL	**204,4**	**100%**	**36.704**	**18,4**	**100%**	**3.302**	**27,8**	**100%**	**5,0**

Source: Compilation and estimates by the World Bank Group and Pezco Consultoria[64].

Tables 19 and 20 above show that the municipalities in Groups A and B have a good scale of public street lighting (over 20,000 points) as well as strong fiscal management. These two groups represent only 3% of the country's municipalities, although they contain 41% of the population and 42% of the light points. Group C has a relative good scale of lighting (typically more than 20,000 points) and relatively good fiscal management. This group represents 6% of Brazil's municipalities, 7% of its population and 11% of the country´s light points. Group D is characterized by its relative low scale (typically less than 5,000 points) with relatively good fiscal management. It includes 16% of Brazilian municipalities, 11% of the population and 12% of the light points in the country. Cities in Group E have a smaller scale (less than 2,000 light points) and moderate fiscal management. This group includes the highest number of municipalities and populations of all the groups, representing 61% and 32% of the country, respectively, and approximately 20% of Brazil's light points. Finally, the cities in Group F are typified by their small scale public lighting (under 2,000 light points) and limited fiscal management, representing 15% of the country´s cities, 9% of its population, and 7% of all the country´s light points.

[64] Equipment prices based on a survey by World Bank Group in June 2015. Prices are estimated at R$1,500 per light point (excluding "smart" controls) Prices do not include the potential impact on the scale of purchases. Official exchange rate of from R$ 3.5/US$ (05/13/2016).

5 - Business Models for Public Street Lighting in Brazil

5.1 - Overview of the Primary Functions Considered in Business Models

Any business model for public street lighting modernization projects involves similar functions performed by different stakeholders in each model. This section presents some of the most important functions for a public street lighting project, including: generation of resources, energy supply, equipment supply, planning and bidding procedures, financing, purchase and installation of lamps, system operation and maintenance. Table 21 outlines these functions and identifies the key stakeholders involved.

Table 21 – Functions and key stakeholders for public street lighting projects

Function	Stakeholder (s)
a) Generation of resources for improving street lighting	Consumers, via COSIP
b) Energy supply at the light point	Electric utility company
c) Supplying equipment to the project	LED manufacturers
d) Planning and bidding	Municipality or private sector
e) Obtaining financing	Municipality or private sector
f) Purchasing lamps	Municipality or private sector
g) Implement installation	Municipality or private sector
h) Operation and maintenance	Municipality or private sector

Source: World Bank

The first three functions and actors listed in Table 21 — resource generation, power supply, and equipment supply — remain virtually the same regardless of the project´s business model. To avoid repetition of data in the section Models 1–8, details of these three functions, risks and mitigating factors are contained in following Table 22.

Table 22 – Key stakeholders applicable to all the business models

Functions	Stakeholders	Details	Project risks	Mitigating factors
Generation of resources for payment of services	Consumers	COSIP (included in electricity bills) paid on time or if necessary to the municipality; enjoy the benefits of better public lighting services; provide feedback about quality of the service.	Failure to enjoy benefits; dissatisfied with the civil works.	To launch outreach campaigns and introduce systems to receive and resolve complaints; to prepare with the electric utility company a robust procedure for collecting COSIP.
Energy supplied at the light point	Electric utility company	Provide energy at the light point; sign an operation agreement with the SPV; collection and transfer COSIP receipts.	Energy supply shortage; failure to fulfill agreements with the municipality regarding collection of COSIP.	Ensure clarity in the operational agreements; increase the capacity of the municipality to oversee the charging process related to electricity billing and COSIP collection.
Supply of equipment for the project	Manufacturers	Provide equipment to the project.	Low quality and/or high cost of equipment.	Ensure performance guarantee of the equipment, ideally for a minimum of 10 years (e.g., the end of the useful life of the LEDs); to provide support to the authorities and/or public banks to increase domestic manufacturing of LEDs with a view to reducing import costs of the same; reduce taxes on national production of LEDs (for limited time).

Source: World Bank

The remaining five functions — planning and bidding, financing, lamps purchasing, lamps installation, and system operation and maintenance — are specifically detailed for each business model in the next section.

5.2 - Introduction to Business Models

Following the classification of municipalities, this study identified eight business models based on fiscal, demographic and scale variables, as well as interviews with selected key stakeholders and an analysis of Brazilian and international documentation. The eight business models are as follows, and are described in detail in this section:

- M1 — Municipal Public-Private Partnership (PPP)
- M2 — PPPs with Municipal Consortium[65]
- M3 — Municipal Financing
- M4 — Electric Utility Programs
- M5 — Energy Service Companies (ESCOs)

[65] Note that while the formation of a municipal consortium is a necessary precondition for the M2 model, aggregation (to create scale, reduce transaction costs, etc.) could be achieved by using municipal consortia in several other models.

- M6 — Municipal Consortium or Central Procurement Agent
- M7 — Self–Funding
- M8 — Transfer of Luminaires

The range of options provided in the eight business models are meant to provide feasible solutions for energy efficient public street lighting for the wide variety of Brazilian municipalities.

5.3 - Presentation of Business Models

This section contains a detailed description of these eight business models, focused on:

1) A description of the model and cash flows;
2) Main agents, risks and mitigating factors;
3) A brief description of the model's advantages/ disadvantages; and
4) Suggestions of which groups of municipalities (from the aforementioned categories A–F) would be good candidates for implementing each model.
5) Evolution of the model in Brazil

At the end of the section, two tables summarize the functions and main actors involved in each model and map the application of the eight models to the six groups of municipalities identified in Section 5.

Model M1: Public-Private Partnership (PPP)

Description of the model and cash flow

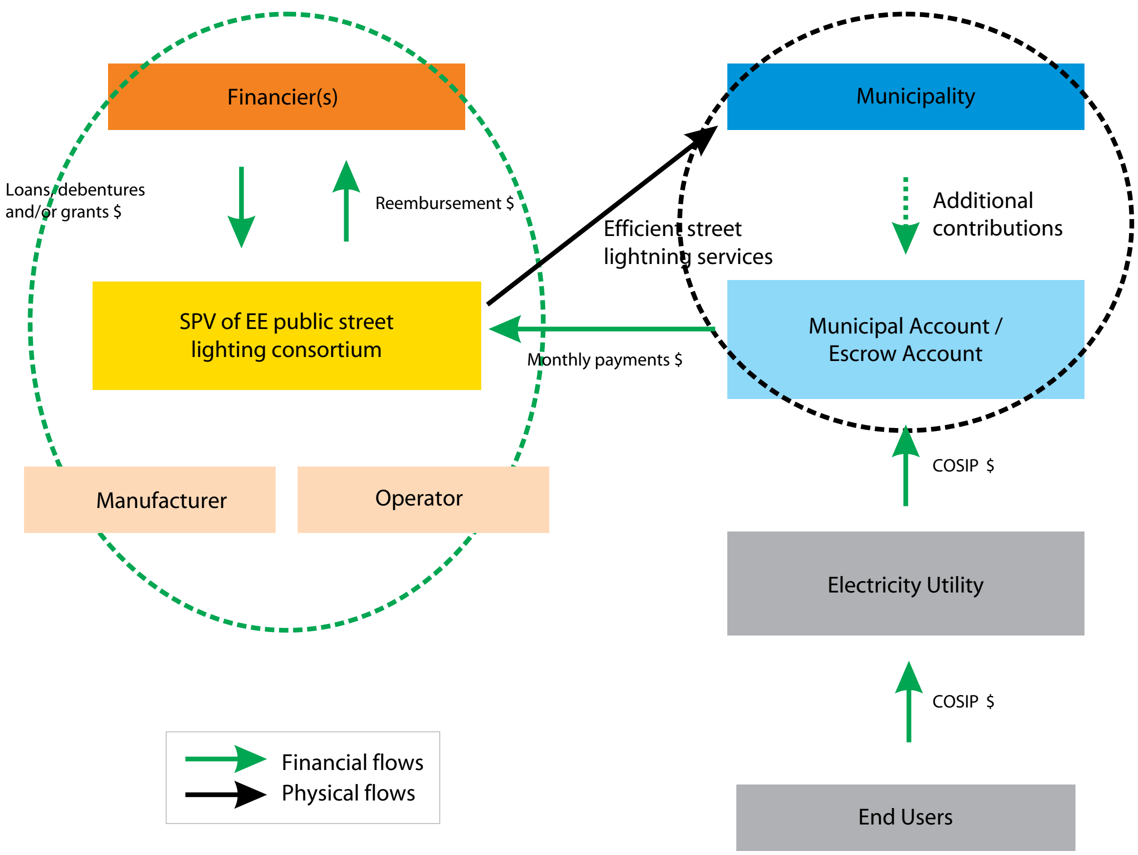
The PPP model is characterized by the presence of a concessionaire, to which the municipality grants an administrative concession covering a wide range of responsibilities.[66] PPPs can be used to undertake all the tasks involved in modernizing a municipality´s public street lighting network and in providing efficient services to the municipality, to include the installation, maintenance and operation of the system for the duration of the contract.[67] The contract term for an administrative PPP can vary from five to 35 years.

The concessionaire is normally a Specific Purpose Vehicle (SPV) formed by the winning consortium, which may include, but is not limited to, an operator and an equipment manufacturer. The concessionaire is responsible for seeking financing to cover initial equipment costs, while the municipality is responsible for reimbursing the concessionaire via monthly payments. The selection of the concessionaire is by public tender, in which the main criterion of success is the minimum value offered by pre-qualified candidates. Contracts can include fixed-payment schedules and performance clauses and can be subject to periodic reviews specified in the concession agreement.

If the municipality has implemented COSIP, payments to concessionaires would primarily be funded by COSIP revenues from electricity consumers. If allowed by municipal law, the COSIP revenues could be collected directly by the concessionaire and transferred to a municipal fund or escrow account. The concession agreement would contain clauses governing payments from these accounts. In the event of COSIP funds not being sufficient to make the monthly payments (or in the absence of COSIP), the municipality may need to call on the municipal budget to cover remaining payments due. Figure 15 illustrates the cash flows and the main actors involved in a sample PPP model.

[66]Authorized by Law No. 11,079 of 2004, amended by Law No. 12,766, of 2012, the management concession corresponds to the contract in which the final contractor of the services is the public authority, which reimburses the concessionaire monetarily without charging tariffs or public prices to the user. The other approach permitted by the same law is the Sponsored Concession, in which part of the concessionaire remuneration comes from the collection of user fees.
[67]Concession contracts could also include ancillary services, such as 4G mobile telephony, WiFi, monitoring services, etc. The apportionment of profits from these revenues must be specified in the concession agreement.

Figure 15 - Example of the structure of a PPP model



Main actors, risks and mitigating factors

Table 23 summarizes the principal actors in each of the key stages of the PPP model. It also shows the main risks that could affect the project throughout the process, and contains recommendations for mitigating such risks.

Table 23 – Matrix of functions and actors in the M1 — municipal PPP model

Model M1 – Municipal PPP				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Municipality	Prepare public notice and organize bidding process for contracting public lighting concessionaire.	Lack of sufficient qualified staff to prepare the public notice and/or assess proposals; lack of competition to ensure maximization of financial resources.	Capacity-building or standard manual.
	Audit Court	Analyze and validate documents/comply with requirements published in the public tender notice.	Delaying or suspending process.	Higher involvement of audit court in preliminary consultations and at the initial stages of the process.
	Consortia of companies	Companies constituted to compete for the concession; submit project bid at a competitive price.	Lack of interested parties in the bidding process.	Municipality strike adequate balance between risk and return in the public bidding documents.
Obtaining finance	Public street lighting concessionaire	Plan and implement investment project; leverage resources for the investment.	Impossibility to obtain financing; financing not sufficiently viable to support the project throughout its duration.	Provide risk reduction mechanisms (e.g., guarantees and insurance against technical and credit risks); requirements to improve quality of bids (e.g. demanding proof of ability to undertake project).
Lamp procurement	Financiers	Provide funding at competitive rates for the CAPEX.	Lack of interest in investing; high interest rates.	Provide data to facilitate understanding of the risks involved.
Implementation and installation	Public street lighting concessionaire	Conduct bidding process for lamps.	Lack of capacity to cope with technical subjects; lack of adequate guarantees for the equipment.	The public tender must follow best national/international practices; bidding to include international competition; specialist advice.
Operation and maintenance	Public street lighting concessionaire	Manage the lamps exchange process and related services (civil works, disposal of existing lamps etc.).	Lack of expertise about the public lighting network, resulting in delays and/or cost increases.	Preparation of robust technical studies; capacity building.
Planning and bidding	Public street lighting concessionaire	Provide efficient public street lighting services	Inability to make energy savings and to meet the standard demanded by the municipality.	Technical and performance guarantees.
	Municipality	Regulate and oversee public street lighting services.	Lack of capacity- building; political interference.	Regulatory and contractual capacity-building; provision of transparent contract mechanisms to limit political interference.

Source: World Bank.

Advantages and disadvantages

One of the advantages of the PPP model is that the municipality can receive a full guarantee from the concessionaire to cover the useful lifespan of the LEDs (normally 10–15 years), since the concessionaire is responsible for purchasing, installing, operating and maintaining the lights over the entire concession period. Moreover, PPPs explicitly permit contract payments to be linked to project performance. This can result in economic and financial savings, since any consortium formed to provide equipment and services will have an interest in maximizing energy efficiency gains that will benefit both parties[66]. All these factors, when combined, can potentially reduce the performance risks faced by the public authority.

Despite its advantages, the PPP model has some drawbacks, such as the time and transaction costs involved in preparing a PPP. These can be substantial, particularly since there are few examples of PPPs in the public lighting sector to guide municipalities and auditors (e.g., the government Audit Courts) in the process of structuring and evaluating contracts.

Identification of groups to which the model would apply

Only some of the municipal groups identified in this study would be in a position to award concessions for public lighting services using the PPP mechanism. Structuring a PPP requires the municipality to initiate technical training of its personnel and make a substantial investment in studies, as well as passing specific legislation (e.g., establishing an escrow account for COSIP). It also requires the municipality to undertake monitoring procedures and ensure compliance with special accounting requirements under Brazilian law.

On the basis of this assessment, potential candidates for PPPs in public street lighting include cities in Groups A and B, and perhaps some of the larger cities in Group C[69]. Including only Groups A and B, this represents a total of 135 municipalities (2.4% of the total cities in Brazil). Regardless of the relatively small number, these municipalities contain 40.9% of the country's total population. Furthermore, the R$1.9 billion worth of investments required for retrofitting the street lighting systems of these municipalities with LEDs amounts to 42.4% of the investment needed for the entire country.

Evolution of the model in Brazil

Several municipalities have begun to adopt the PPP model in the form of administrative concessions. Table 24 presents a summary of PPP projects in the Brazilian market as of October, 2016.

[68] This applies to cases where the public street lighting concessionaire is responsible for paying for the electricity consumed. In cases where the municipalities continue to exercise its responsibility (e.g., the Belo Horizonte PPP), the contract could include explicit incentives (e.g. a bonus) for efficiency gains that exceed agreed values.

[69] Note that at present 50 municipalities have begun organizing PPPs on an individual basis. However, smaller municipalities not belonging to Groups A or B have also been investing in the PPP solution.

Table 24 - PPP projects in Brazil (according to project stage)

Status of PPP	Number	Awarding Municipalities
Contract signed	5	Urânia-SP; São João de Meriti-RJ; Caraguatatuba-SP; Guaratuba-SP; Belo Horizonte-MG
Winner declared	4	Araguaína-TO; São José de Ribamar-MA; Marabá-PA; Mauá-SP
Bidding in progress	7	Contagem-MG; Goiatuba-GO; Campo Maior-PI; Goianésia do Pará-PA; Guaíra-SP; São Cristóvão-SE; Teixeira de Freitas-BA
Public consultation. Completed	18	Almirante Tamandaré-PR; Atibaia-SP; Feira de Santana-BA; Guarapuava-PR; Lins-SP; Maceió-AL; Nova Iguaçu-RJ; Aparecida de Goiânia-GO; Dois Vizinhos-PR; Dourado-SP; Inhumas-GO; Patrocínio-MG; Pederneiras-SP; Porangatu-GO; São Bernardo do Campo-GO; Uberlândia-MG; Vespasiano-MG; Vitória-ES
Public hearings initiated	3	Muriaé-MG; Guanambi-BA; Penedo-AL
Request for Expressions of Interest (PMI) closed	17	Bertioga-SP; Boa Vista-RR; Camaragibe-PE; Governador Valadares-MG; Içara-SC; Ituiutaba-MG; Jaboatão dos Guararapes-PE; Sorriso-MT; Várzea Grande-MT; Cariacica-ES; Esmeraldas-MG; Garopaba-SC; Hortolândia-SP; Maringá-PR; Niterói-RJ; Pará de Minas-MG; Rio Verde-GO
Request for Expressions of Interest (PMI) initiated	15	Carolina-MA; Delmiro Gouveia-AL; Imbituba-SC; Jacundá-PA; Rolim de Moura-RO; Salto-SP; Salvador-BA; Açailândia-MA; Água Boa-MT; Araçatuba-SP; Araucária-PR; Distrito Federal; Gurupi-TO; Palmeira-PR; Porto Nacional-TO
Modelling initiated	5	Betim-MG; Caruaru-PE; Formosa-GO; Ribeirão Preto-SP; Guarulhos-SP
Publication of intent	16	Angra dos Reis-RJ; Aracaju-SE; Diadema-SP; Florianópolis-SC; Foz do Iguaçu-PR; Iracemápolis-SP; Ponta-Grossa-PR; Santos-SP; Sete Lagoas-MG; Sombrio-SC; Sorocaba-SP; Valparaíso de Goiás-GO; Votuporanga-SP; Catanduva-SP; Palmas-TO; Porto Alegre-RS
Cancelled / Suspended	95	Canela-RS; Cuiabá-MT; Uberaba-MG; Consórcio CIGIP-AL (Água Branca; Anadia; Barra de Santo Antônio; Barra de São Miguel; Batalha; Belém; Belo Monte; Boca da Mata; Branquinha; Cacimbinhas; Cajueiro; Campestre; Campo Grande; Canapi; Capela; Carneiros; Colônia Leopoldina; Craíbas; Delmiro Gouveia; Dois Riachos; Estrela de Alagoas; Feira Grande; Flexeiras; Igaci; Inhapi; Jacaré dos Homens; Jacuípe; Japaratinga; Jaramataia; Jequiá da Praia; Jundiá; Lagoa da Canoa; Major Isidoro; Mar Vermelho; Maragogi; Maravilha; Marechal Deodoro; Mata Grande; Matriz de Camaragibe; Minador do Negrão; Murici; Novo Lino; Olho d'Água do Casado; Olho d'Água Grande; Ouro Branco; Palestina; Pão de Açúcar; Pariconha; Paripueira; Paulo Jacinto; Pilar; Pindoba; Poço das Trincheiras; Porto Calvo; Porto de Pedras; Porto Real do Colégio; Quebrangulo; Rio Largo; Santana do Ipanema; Santana do Mundaú; São José da Laje; São Luís do Quitunde; São Sebastião; Senador Rui Palmeira; União dos Palmares; Viçosa); Barbacena-MG; Barueri-SP; Breu Branco-PA; Consórcio CONIAPE (Bezerros; Bom Jardim; Brejo da Madre de Deus; Casinhas; Frei Miguelinho; Jataúba; João Alfredo; Orobó; Riacho das Almas; Santa Cruz do Capibaribe; Santa Maria do Cambucá; São Caitano; São Joaquim do Monte; Surubim; Taquaritinga do Norte; Toritama; Vertente do Lério; Vertentes); Cascavel-PR; Caxias-MA; Santo André-SP; São Paulo-SP; Três Corações-MG
Total	185	

Source: Radar PPP (www.radarppp.com), October 3, 2016. Radar PPP updates its data daily.

As shown in Table 24, by October 2016, 185 Brazilian municipalities initiated processes or have demonstrated their intention to contract for public street lighting services under a PPP[68]. These include 101 municipalities (54.6% of the total) which initiated PPP procedures individually. These range from large regional capitals such as São Paulo and Belo Horizonte, and smaller cities such as Urânia in the interior of São Paulo state, which already has awarded the contract. The remaining 84 municipalities (45.4%) have joined together in two public consortia — CONIAPE (representing 18 municipalities in the State of Pernambuco) and CIGIP in the State of Alagoas (with 66 municipalities). However, more than half of these PPPs have either been cancelled or suspended, and only five have signed contracts. This demonstrates the immediate need for increased capacity building to help cities adequately prepare PPP tenders from the outset.

Model M2: Consortium of Municipalities Using PPP

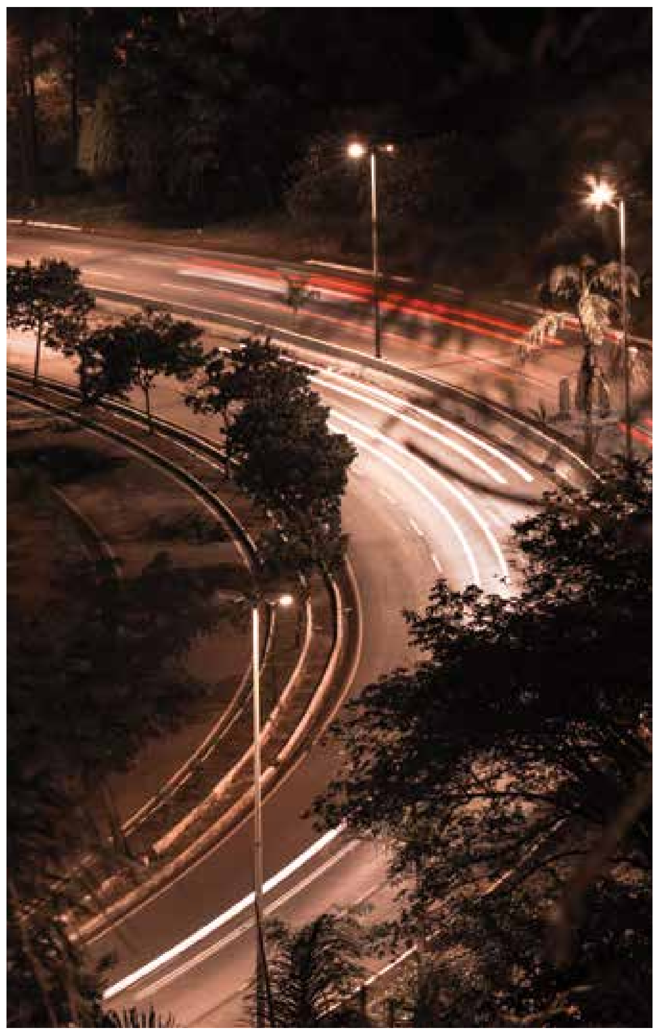
Description of the model and cash flow

Given that it will be challenging and not economically attractive for many small- and medium-size municipalities to individually grant concessions using the PPP model, municipal consortia are a possible solution to generate the scale necessary for the implementation of a PPP.[71] International experience shows that there are huge economies of scale involved in the procurement of luminaires by using this model.

Once established, the consortium of municipalities is able to contract a public-private partnership and the consortium itself functions as the grantor of operate street lighting services through a PPP.

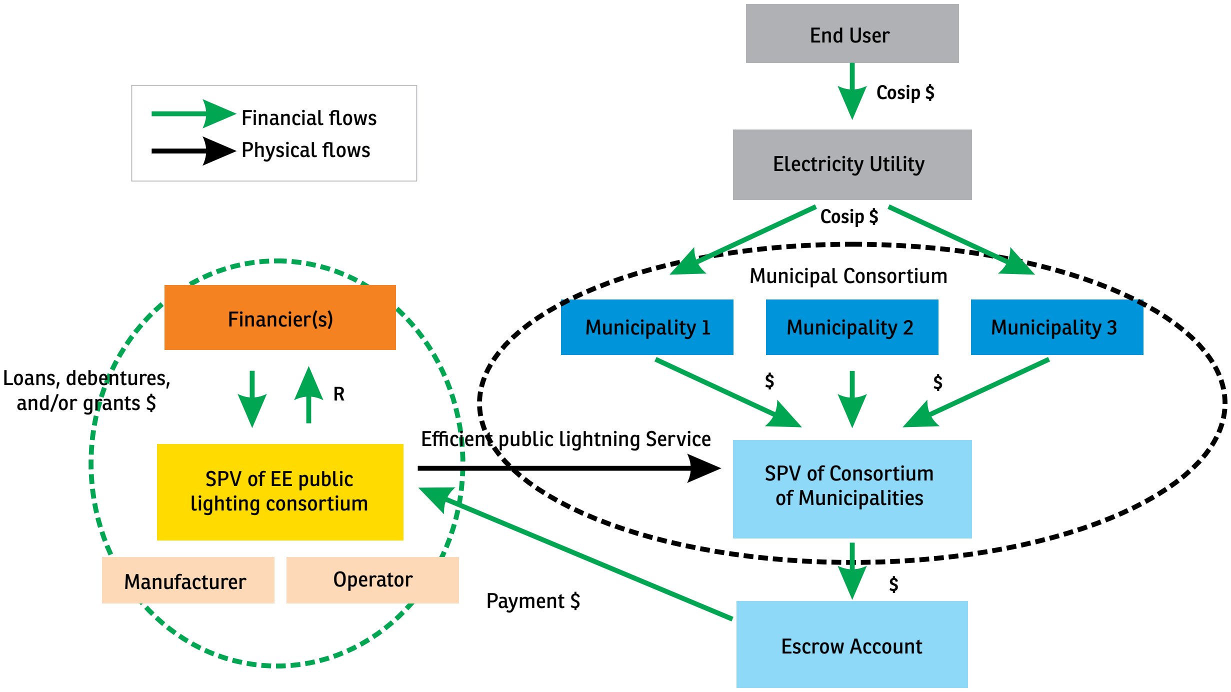
A PPP contracted by a consortium has the same general characteristics and *modus operandi* of a consortium contracted by an individual municipality.

Due to legal restrictions currently in force, the legal entity of the public consortium is not permitted to receive financing directly. However, the concessionaire involved in a PPP bid by a consortium can obtain financing in the capital market to undertake the necessary investments. Figure 16 summarizes the main actors involved and the cash flow of the PPP model contracted by a consortium of municipalities.



[70] Compiled from the RadarPPP database and data obtained by Pezco Consultoria.
[71] The public consortia concept applied to the federative entities was established by Law 11,107 of 2005.

Figure 16 - Example of the structure of a PPP with municipal consortium model



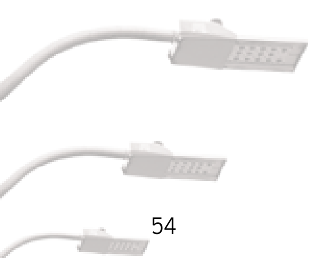
Main actors, risks and mitigating factors

Table 25 lists the main actors involved in the PPP model based on a consortium, indicates the main risks that could affect the project throughout the process, and contains recommendations for mitigating these risks.

Table 25 - Matrix of functions and actors in Model M2 — PPP consortia

M2 – Consortia for PPPs				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Municipalities	Formation of the consortium.	Lack of coordination between the municipalities in the consortium; insufficiently qualified personnel.	Clear governance rules in the consortium; capacity- building or standard manual.
	Consortia of municipalities	Prepare public notice and organize bidding process for contracting public lighting concessionaire.	Lack of coordination between the municipalities in the consortium; insufficiently qualified personnel.	Clear governance rules in the consortium; capacity- building or standard manual.
	Audit Court	Analyze and validate documents/comply with requirements published in the public tender notice.	Delay or suspend the process.	More involvement in preliminary consultations and at the initial stages of the process.
	Consortia of companies	Companies constituted to compete for the concession; submit project bid at a competitive price.	Lack of interested parties in the bidding competition.	Selection by the municipality of adequate ratio between risk and return in the public tender documents.

Obtaining finance	SPV of the consortium	Structure and leverage resources for the investment.	Complexity in the financial structuring due to the large number of participants; stakeholders; failure to reimburse the consortium can put all the members of the consortium at risk.	Provide mechanisms for guarantees and insurance against technical and credit risks, provide clear rules for the governance and treatment of default.
	Financiers	Provide funding at competitive rates.	Lack of investor interest; high interest rates.	Supply sufficient data to financeirs in order to facilitate understanding of the risks.
Procurement of lamps	Public street lighting concessionaire	Bidding for procurement of lamps.	Lack of capacity to cope with technical subjects; lack of adequate guarantees for the equipment.	The public notice to adhere to best national/international practices; bidding to include international competition; specialist advice
	Manufacturers	Production/importation of LEDs for the municipalities/SPV.	In the event of local production, the risks involved in financing the installation of the manufacturing plant; in the event of imported LED products, the exchange rate and import taxes on the equipment.	Overwhelming demand for LED lamps can provide an incentive for factories to be established in Brazil.
Implementation and installation	Public street lighting concessionaire	Manage the lamps installation process and related services (civil works, disposal of existing lamps etc.).	Lack of expertise about the public lighting network resulting in delays and/or cost increases.	Preparation of consistent technical studies; capacity-building.
Operation and maintenance	Public street lighting concessionaire	Provide efficient public street lighting services.	Failure to deliver expected energy savings, or failure to comply with the standard demanded by the municipality.	Technical and performance guarantees.
	Municipalities	Regulate and oversee the public street lighting services and those of the public lighting concessionaire.	Lack of qualified staff; political interference.	Regulatory and contractual training; provision of clear contract mechanisms to limit political interference.



Advantages and disadvantages

The PPP consortium approach has the advantage of allowing a wider range of municipalities to participate in a PPP scheme compared to the individual PPP model. Furthermore, a potential financier may be attracted to the scheme given the greater spread of political and credit risks of the various municipalities, e.g., subject to financial and governance arrangements, a single municipality default would not necessarily result in default by the consortium SPV.

However, if most municipalities´ profiles suggest high political and credit risk, the PPP consortium approach can generate risks for both financiers and consortium members. Transaction costs and risk perception may also be high in view of the more complex governance of a consortium, resulting in a lack of interest by both lenders and municipalities, as well as potentially incurring high financing costs.

Identification of groups to which the model would apply

Aggregation in a consortium is a more appropriate solution for Group C municipalities, which have low scale (less than 20,000 luminaires), but relatively good fiscal management. 329 municipalities are in this group, and some relatively small municipalities in Group B could also participate. By including only the Group C municipalities, the M2 model could be applicable to 6% of Brazilian municipalities that represent 7% of the total population and R$3.2 billion of investment (11% of the investment needed throughout Brazil).

Evolution of the model in Brazil

There is a trend towards forming public consortia in Brazil. The consortium to include the public street lighting sector was the Public Consortium for the Management of Electric Energy and Public Services (CIGIP)[72], consisting of 66 municipalities in the state of Alagoas. However, this consortium has not yet offered solutions for modernizing or operating the public lighting network, but rather has focused to date on boosting the municipality - utility relationship to ensure technical support, equipment, consulting services and training for running the street lighting network and the municipal public buildings of consortium members. Meanwhile, the state of Minas Gerais has deployed a strategy to encourage municipalities to form consortia based on initiatives between the state government, the State Audit Court, CEMIG (the state electricity distributor) and associations of municipalities. In Pernambuco, the Inter-Municipal Consortium of Pernambuco Hinterland and Borders (CONIAPE) initiated a public debate about the possibility of a PPP, but this has been suspended. Tendering procedures are currently being organized in the hope of obtaining comprehensive management and maintenance of the public street lighting systems of the 17 municipalities in the consortium.[73]

Although national interest in the consortium mechanism for running public services (including lighting networks) has increased, no consortium model has yet been used to create an SPV to secure financing to implement a street lighting project. More technical advice is essential to help interested municipalities to implement this model, particularly with regard to legal aspects involving the structuring of SPV financing and governance schemes.

Model M3: Municipal Financing

Description of the model and cash flow

The high level of upfront capital needed to implement LED technology is the main challenge to the conversion of the public lighting network.

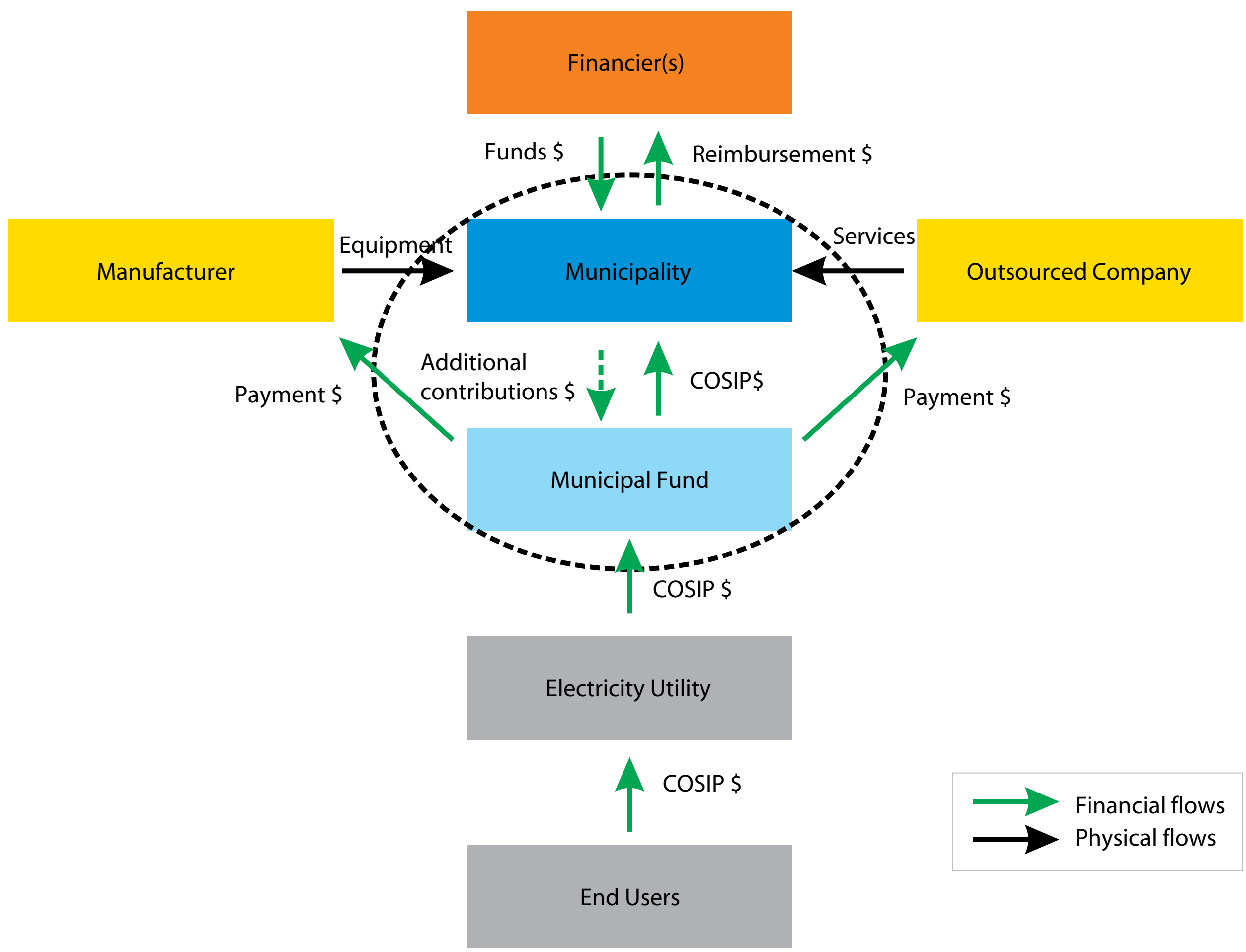
[72] CIGIP's public notice was special in that it provided for investments in various sectors, including public lighting, distributed generation, emissions mitigation and control of electricity consumption in public buildings, etc.

[73] Available at: <http://www.consorcioconiape.pe.gov.br>. Accessed in March 2016.

Leaving aside the concession model, the main responsibility for raising financing and undertaking the required investments will rest with the municipal administration, normally through loans or the issuance of bonds (debentures).

As with PPPs, municipal debt repayment could be financed by COSIP revenues (if available) and transferred to a municipal fund (or escrow account, if allowed under municipal legislation). If the municipality has not implemented COSIP, or if revenue from COSIP is insufficient to defray loan or other payments, the municipality would need to use funds from its general municipal budget to finance any outstanding amounts of debt payment. In this model, the municipality would be responsible for executing or outsourcing the implementation of the project, and for overseeing the operation and maintenance services. Figure 17 summarizes the main actors and the cash flow of the municipal financing model.

Figure 17 – Example of structure of the municipal financing model



Main actors, risks and mitigating factors

Table 26 lists the main actors involved in the PPP model based on a consortium, indicates main risks that could affect the project throughout the process and contains recommendations for mitigating them.

Table 26 - Matrix of functions and actors in the M3 model — municipal financing

M3 — Municipal Financing				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Municipality	Design and prepare the project; handle the bidding processes for equipment and services.	Lack of qualified staff.	Public notice to adhere to best national/international practices; competitive bidding; specialist advice.
Obtaining finance	Municipality	Structure and leverage resources for promoting investment.	Reaching upper limit of indebtedness capacity; market has credit risk perception; delays caused by lack of sufficient financing at the beginning of the project.	Provide guaranteed mechanisms against credit risks including robust legislation for COSIP (if it exists); Encourage market interest in the municipality´s credit status during the first stages of the project.
	Financiers	Provide financial resources at competitive rates for capital expenditure (CAPEX).	Lack of investor interest; high interest rates.	Provide data to facilitate understanding of the risks.
Procurement of lamps	Municipality	Organize bidding process for procurement of lamps.	Lack of capacity to cope with technical subjects; lack of adequate equipment guarantees.	Public notice to adhere to best national/international practices; competitive bidding; specialist advice.
Installation	Municipality	Manage the process or oversee the services of an outsourced company.	Lack of expertise about the public lighting system resulting in delays and/or cost increases, or lack of qualified oversight staff (in the event of supervision of an outsourced company).	Preparation of consistent technical studies; capacity-building.
Operation and maintenance	Municipality	Manage the process or oversee the services of an outsourced company.	Lack of qualified staff.	Technical and/or oversight capacity building.

Advantages and disadvantages

A key advantage of this business model is the low complexity involved in structuring the project due to the smaller number of actors and the possibility of procuring equipment using the routine bidding process provided for in Law 8,666/1993. This can result in lower transaction costs compared to the PPP models. This model therefore represents a possible way forward for municipalities with good fiscal management, but without sufficient scale to justify the transaction costs of a PPP.

However, as explained in Section 4.4 (Challenges for LEDs in the Brazilian Context), municipal indebtedness capacity is restricted under the Law of Fiscal Responsibility, and many municipalities are often unable to take on additional debt. Even when municipalities have adequate fiscal space, they may wish to use these resources on investments in other sectors for which it is more difficult to attract private sector investment (e.g., schools).

A further disadvantage of this model is that if the municipality outsources the operations and maintenance services, the performance guarantee will usually be limited to five years - the maximum period established by Law 8,666 / 1983. It follows that system operators will have no incentive to ensure technical performance over the lifespan of LEDs (10-15 years). In the less likely event of the municipality assuming the operations and maintenance services, there is a risk that the municipality may not possess the human and technical capacity to manage the process. Thus, this model could result in municipalities having to assume the majority of technical and operational performance risk.

Identification of groups to which the model would apply

This business model is most applicable to the smaller municipalities in Groups B (88 municipalities) and C (329 municipalities), since these have good fiscal management and good scale, but perhaps without sufficient scale to justify the transaction costs associated with structuring a PPP. This model could theoretically apply to 7% of Brazilian municipalities, representing 19% of the total population and R$7.4 billion of investment (26% of the investment needed throughout the country).

Evolution of the model in Brazil

While loans contracted by a subnational entity with a financial institution to finance capital investments is a traditional format in several countries, including Brazil, this model faces substantial fiscal and institutional constraints. Even in Europe, where bank financing for the public sector is the dominant model, lack of access to credit for local governments acts as a brake on public investment (AFD, FCH, IPEA, 2014, p. 95). Thus, credit for Brazilian municipalities generally involves loans from public banks supported by federal guarantees.

In the course of the research and interviews conducted for this study, no examples were identified in Brazil of municipal financing being used to raise capital for investment in the modernization with LEDs.

One way to catalyze this business model would be implementation of public policies that would provide exceptions to the indebtedness limits governed by the Fiscal Responsibility Law for investments in municipal energy efficiency. As explained previously, debts taken on by municipalities under the PROCEL-RELUZ program were not subject to the Fiscal Responsibility Law indebtedness restrictions, on the basis that the loans would reduce municipal energy costs, and thus improve the fiscal situation of the municipalities in the long term. However, cities are unable to benefit from this exception since the PROCEL-RELUZ program stopped disbursing resources for street lighting modernization (although PROCEL-RELUZ resources will increase due to the recent changes mentioned in Section 4.4.4, albeit at a relatively small scale). The federal government could consider further exceptions to assist municipal governments to obtain energy efficiency-related resources from other sources (i.e., capital markets), with a public body such as PROCEL acting as the supervisory authority to approve and guarantee the submission of high quality projects that meet energy-saving targets.

Model M4: Electric Utility Company Programs

Description of the model and cash flow

In the two national programs for the street lighting sector, PROCEL-Reluz and PEE, electricity utilities have a key role in the financing and/or facilitation of investments for large-scale public street lighting projects. However, these two programs currently have minimum potential for LED retrofit programs; the sole source of capitalization of PROCEL-Reluz has been discontinued (although the overall PROCEL program will receive new sources of funding from PEE), and PEE funds for public lighting have dwindled. Moreover, with the transfer of energy assets to the municipalities, the utility companies are no longer involved in the operational aspects of street lighting.

Regardless of the trend for energy utilities to be less involved in the public lighting sector, it is possible to envisage a scenario where they could play an important role in scaling up the roll out of LEDs throughout the network, as well as becoming involved in a wider range of energy efficiency projects. Given the current incentive structure, changes of a legal and regulatory nature are likely to be necessary to make this happen.

In some ways, this business model could be seen as a scaling up of the current PEE program. For this to happen, the electric utility would be given a broader mandate to invest in energy efficiency (e.g., higher than the 0.5% of the current annual net revenue - say up to 1.0%).[74] Part of this increase would be earmarked to the public lighting sector by way of loans to municipalities.

However, unlike under the current PEE program where utilities do not recover costs from the public beneficiaries of the energy efficiency investments, the electric distribution utility would lend to municipalities at a sustainable interest rate. If needed to make the investments viable, the interest rate could be below commercial rates, the utilities could recover part of their outlay via a slight increase in end-user tariffs (as is done under the current PEE program).

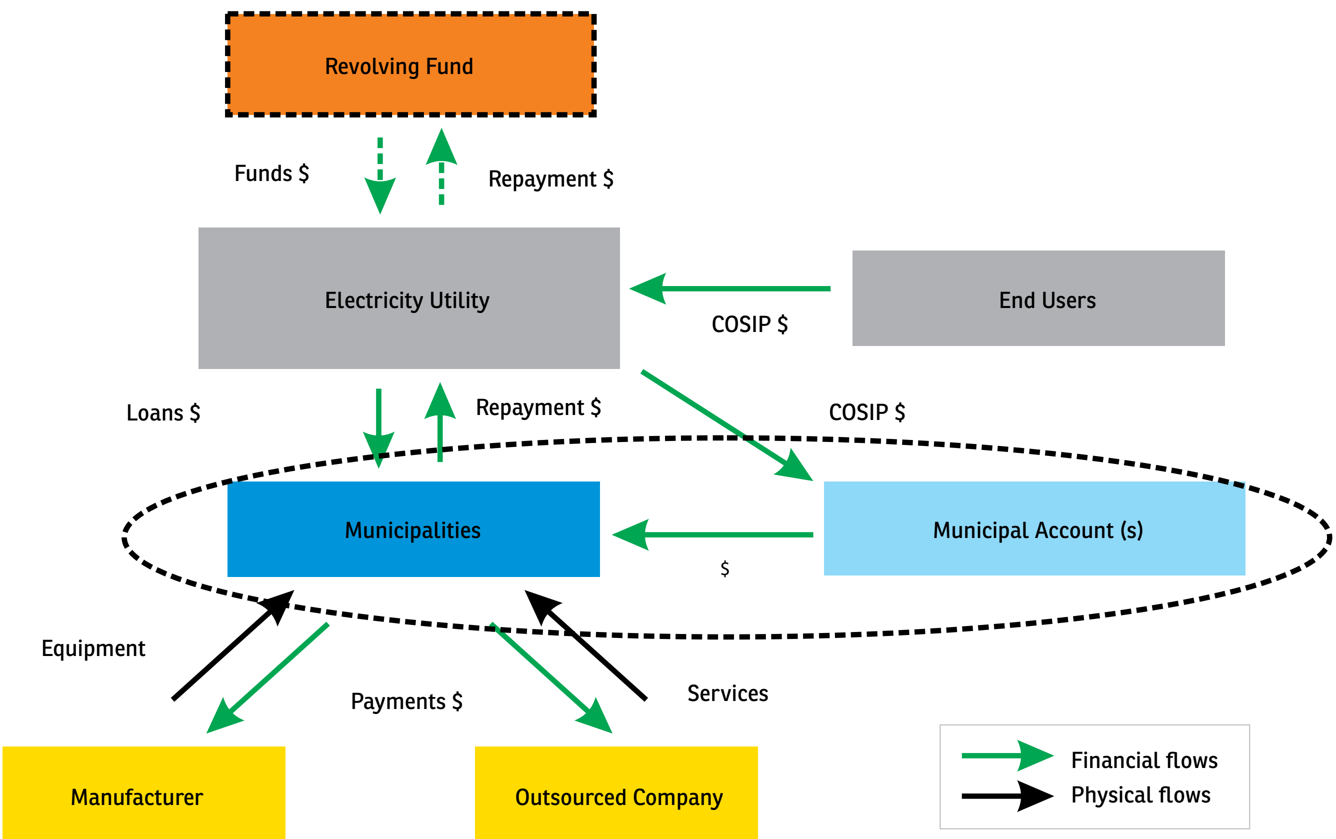
The profits from the program could capitalize a revolving fund that would be used to fund new investments in street lighting energy efficiency projects. The municipalities would use the loans, together with their own municipal contribution (funded by budgetary appropriation, COSIP or another municipal source), to purchase the LED equipment for the project. Municipalities would use savings generated by the program (i.e., surplus COSIP revenue due to reduced electricity bills) to repay their loans. The municipality would

[74]Some U.S. utilities invest a higher proportion in energy efficiency (e.g. 4%). The largest investments in EE in the United States are done by gas and energy concessionaires.

be responsible for managing the bidding process for equipment and for overseeing O & M (using the remaining COSIP resources or the municipal budget).

If program performance were adequate, the costs of an increasingly self-sustaining program would be reduced for all consumers.

Figure 18 - Example of structure of electricity utilities program model



Considering that this model would require regulatory changes, a short-term option would be for the energy utilities to earmark more PEE resources to the public street lighting sector. This may be possible for those with operations in areas with few low-income consumers or where these consumers already been serviced. The new legislation eliminating the minimum 60% investment in low-income households could provide further opportunities for investing in street lighting.

Main actors, risks and mitigating factors

Table 27 summarizes the main actors of each of the key stages of the electric utility programs model, and indicates main risks that could affect the project throughout the process and contains recommendations for mitigating them.

Table 27 – Matrix of the functions and actors in model M4 — electric utility companies' programs

M4 — Electric Utility Programs				
Functions	**Actors**	**Details**	**Project risks**	**Mitigating factors**
Planning and bidding	Municipality	Design and prepare the project; submit project proposal to electric utility for approval.	Lack of capacity to prepare a proposal or consistent project.	Hire expert advisors.
	Electric utility	Design investment and revolving program.	Lack of qualified personnel to oversee the program.	Confirmation that the program has sufficient resources for its management
	ANEEL	Agree to update the mechanism for using the PEE for engaging utility companies' financial interest in the sector.	Failure to approve project concept.	Clearly communicate the benefits of the program, including climate change targets and the possibility of future self-sustainability of the program
Obtaining finance	Electric utility	Make financing resources available for municipalities.	Municipal demand for funds exceeds supply.	Limiting the criteria for municipalities to receive resources from the program (e.g. small and medium-sized municipalities).
Lamp procurement	Municipality or ESCO	Organize bidding for lamp procurement.	Lack of technically qualified personnel; lack of appropriate equipment guarantees.	Public bidding notice to adhere to best Brazilian and international practices; bidding open to international competition; expert advisory.
Implementation and installation	Municipality or ESCO	Manage the process or oversee the services provided by ESCO.	Lack of knowledge of the public lighting system, resulting in delays and/or increased costs, or lack of oversight capacity.	Preparation of studies; ensure consistent technical approach; capacity-building.
Operation and maintenance	Municipality or ESCO	Manage the process or oversee the services provided by ESCO.	Lack of capacity.	Technical and/or oversight training.

Advantages and disadvantages

A financing program led by electricity utilities has several advantages: borrowing costs will be lower than those that municipalities could obtain in the capital market; centralizing the funds leveraging process would result in economies of scale, lower transaction costs and greater diversification, and possibly help reduce the cost of finance for municipalities; and, because the model involves lower costs, it could be useful for municipalities with limited possibilities of raising funds.

The main drawback of the model is that ANEEL would need to introduce regulatory changes to provide incentives for the energy utilities to allocate more investment for this sector. At present, this would likely be difficult given the recent regulatory trend towards reducing the involvement of energy utilities in the public street lighting sector.

Identification of groups to which the model would apply

This model could be applied mainly to the municipalities in Groups D and E, which represent more than 4,200 municipalities and around 75% of the Brazilian population, and for which investment totaling R$9.5 billion would be required. In certain cases, the model could also be applied to groups in addition to Groups C and F. The municipalities concerned are of relatively small size, with average fiscal management. To protect the utility as a lender, the municipality's credit risk could be mitigated with the use of an escrow account linked to COSIP revenues. Other types of credit risk mitigation could be considered for municipalities with more significant fiscal problems. The experience of PROCEL-RELUZ, which explicitly required municipalities to provide financial certification, could prove to be useful in this respect.

Evolution of the model in Brazil

As noted in Section 4.4.4, a recent bill of law proposed the allocation of 20% of PEE resources to PROCEL (approximately R$100 million annually), which would present an opportunity for increasing PROCEL's investments in public street lighting. This would be a first major step towards encouraging the electric utility companies to play a more prominent role in modernizing Brazil's public street lighting network.

Model M5: ESCO Model

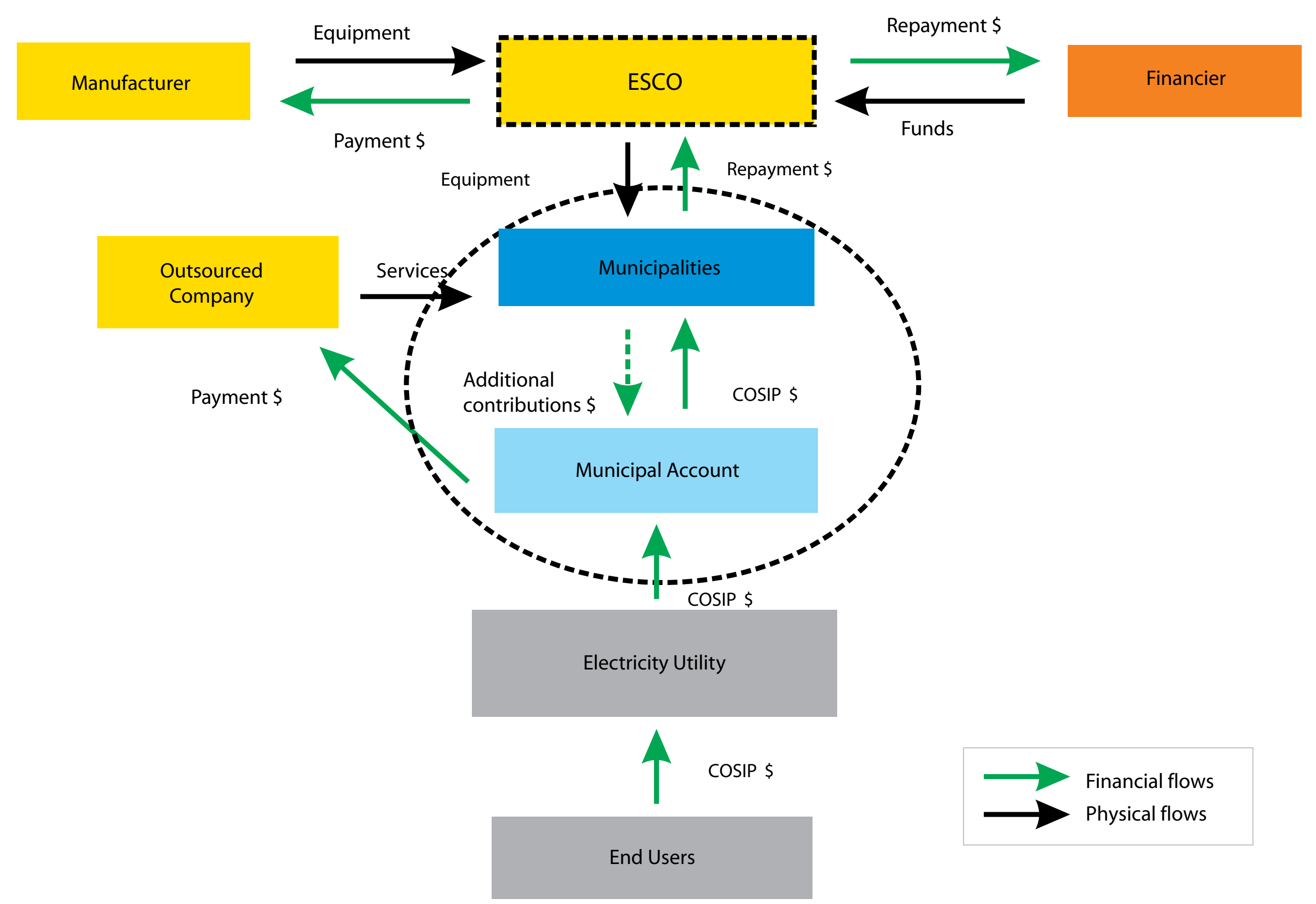
Description of the model and cash flow

This model involves municipal off-balance sheet financing, where the investment is made by a third party. In this way, the investments for modernizing the public street lighting network are not classified as municipal debt and do not affect a municipality's indebtedness limits. A company or a consortium of companies (SPV) raises funds, and purchases/installs LED luminaires in exchange for a fixed payment by the municipality. As in other models, the municipality would use COSIP and/or municipal budget resources to pay the ESCO. ESCOs are not normally involved in operation and maintenance, but they would guarantee the technical performance of the lamps they install.

ESCOs operate under one of two modalities: (i) a share of the efficiency gains; or (ii) a fixed payment for the investment made and for providing a product technical performance guarantee. Option (ii) has generally been preferred since it simplifies measuring and verification procedures and ensures a predictable cash flow, thus enhancing a project´s bankability.

Figure 19 shows the main actors and cash flow involved in an ESCO model sample.

Figure 19 – Example of structure of the ESCO model



Main actors, risks and mitigating factors

Table 28 summarizes the main actors in each of the key stages of the ESCO model, indicates the main risks that could affect the project throughout the process, and recommendations for mitigating these risks.

Table 28 – Matrix of functions and actors in model M5 — ESCOs

M5 – Electric Utility Companies (ESCOs)				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Municipality	Prepare public notice and carry out bidding process for contracting ESCO (equipment, installation and possibly operation and maintenance).	Lack of sufficiently qualified manpower to prepare the public notice and/or evaluate proposals; lack of competition to guarantee maximization of municipal resources.	Capacity building or standard manual; competitive bids.
	ESCOs	Submit substantive project at a competitive price.	Absence of interested parties in the bidding competition.	Selection by the municipality of an appropriate ratio between risk and return in the public notice documents.
	ESCOs	Structure and leverage resources for investment.	Lack of sufficient ESCO resources to ensure the scale of investments needed for the entire project.	Increased lines of financing available for ESCOs (with public/non-refundable grants if necessary); focus on the ESCOs that are subsidiary companies of electric utilities; focus on small-scale projects.
Obtaining finance	Financiers	Provide financial resources at competitive rates for capital expenditure.	Lack of investor interest; high interest rates.	Provide data to facilitate understanding of the risks.
Lamp procurement	ESCOs	Promote bidding for procurement of lamps.	Lack of capacity to cope with technical subjects; lack of adequate guarantees for the equipment.	The public follows best national/international practices; bidding to include international competition; specialist advice
Implementation and installation	ESCOs	Management of the process.	Lack of knowledge of public street lighting network, resulting in delays and/or cost increases.	Preparation of studies; use of consistent techniques; capacity building.
Operation and maintenance	Municipality or ESCO	Manage the process or oversee ESCO services.	Lack of qualified manpower.	Technical and/or oversight training.

Advantages and disadvantages

A key advantage of this model is that, as with the M4 model, it involves an off-balance sheet financing option for smaller municipalities. However, it does not require the same degree of involvement by the regulator, exposure to political fluctuations, etc., as would be required for the M4 model.

However, the scale and scope of this model are less than that of M4 since the financial capacity of ESCOs is much less robust than that of an electric utility, and because ESCOs would be more vulnerable to municipal credit risk (or less able to shield themselves from risk) since they have no direct access to municipal resources linked to revenues from end users (e.g., COSIP, electricity payments).

Identification of groups to which the model would apply

This model best applies to Group C, with a total of 329 municipalities characterized by relatively small-scale and good fiscal management. These municipalities contain 7% of the total population and require investments amounting to R$3.2 billion for modernizing their public street lighting network (11% of the investment needed throughout the country).

The evolution of the model in Brazil

A variant of the ESCO model is being proposed by the Regions 20 (R20) organization which has been instrumental in LED conversion programs in 13 Brazilian cities. The financing concept is based on "payment for the use of the asset," using a model that involves a municipal/private sector SPV for each municipality. In this scheme, the financial partner purchases the luminaires and supplies them to the municipality at a cost that takes into account the efficiency gains resulting from the conversion of the street lighting system.

The ESCO model and off-balance sheet financing has been considered by India, Mexico and several other countries. Box 7 illustrates the financing mechanism used by the city of Guadalajara in Mexico. The main points of interest are the leasing process and the level of coordination between government agencies for developing a comprehensive program of energy efficiency in the street lighting sector.

Box 7 - Guadalajara (Mexico): Lease-to-Own Model

The city of Guadalajara, with a population of approximately 1.5 million, is Mexico's fourth-largest city. It has approximately 80,000 installed luminaires, all of them of HPS, and plans to replace half of them with LEDs. Guadalajara began installing the new luminaires in 2013, benefiting from a federal energy efficiency program in the public street lighting sector. This program, mobilized by the Secretariat for Energy (SENER), the National Commission for Energy Efficiency (CONUEE), the Federal Electric utility (CFE) and the National Bank for Public Works (BANOBRAS), entails the provision of technical assistance for cities keen to develop LED projects. CONUEE also provides subsidies for municipalities to implement, verify and finance EE projects, a simulation model and a list of accredited products. Furthermore, the Secretariat is responsible for approving the technical aspects of projects as a prerequisite for obtaining Ministry of Finance authorization to employ public funds for street lighting projects. BANOBRAS also provides investment funds for projects through an energy efficiency incentives program.

The Guadalajara project is being financed by EE gains, which are expected to reach 50–55% over the baseline, representing a monthly saving of US$500,000. The financial instrument used is a US$19 million 10-year leasing contract for which the municipality pays an average of US$250,000 per month. At the end of the contract, ownership of the luminaires (with an estimated lifespan of 13 years) will be transferred to the municipality. The Mexican federal government guarantees coverage of certain operational costs in the event of the Guadalajara authorities' failing to make monthly payments. The existence of this guarantee has been a key incentive for attracting private capital to the venture.

Source: Adapted from "*Proven Delivery Models for LED Public Lighting.*" World Bank, 2016.

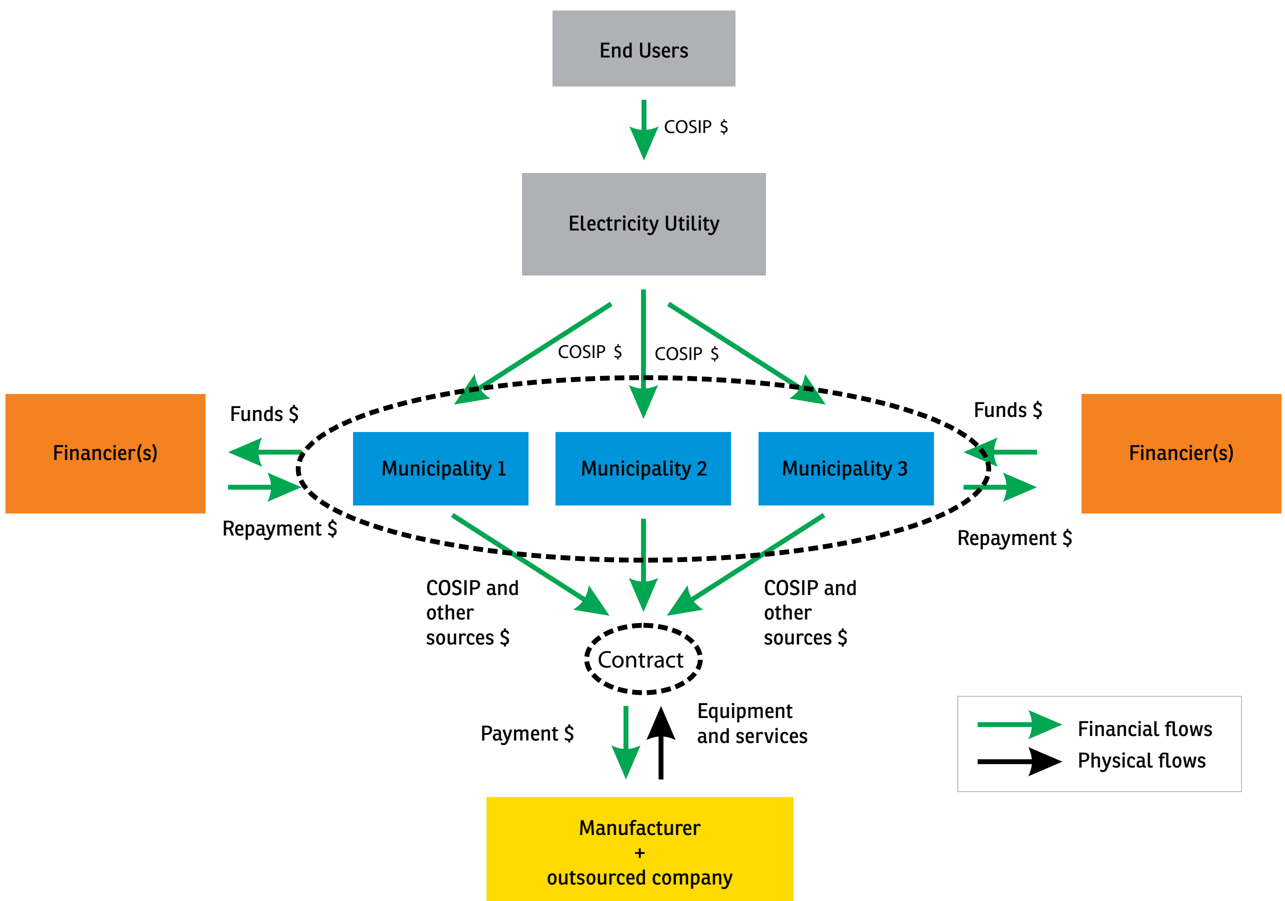
Model M6: Municipal Consortium or Central Purchasing Body

Description of the model and cash flows

This model seeks to capture economies of scale related to joint procurement of equipment (and possibly services) by multiple municipalities without joint municipal responsibility for raising finance. Although this model could involve an SPV, the main requirement is to establish a consortium-type mechanism, or a simpler arrangement, for the purpose of joint centralized procurement. The initial costs of purchasing new lamps would be borne by municipalities using COSIP resources and/or municipal budget funds.

Figure 20 summarizes the main actors and cash flows of a municipal consortium/central purchasing body, assuming a centralized procurement process involving a single contract with an equipment supplier.

Figure 20 – Example of structure of centralized procurement model



Main actors, risks and mitigating factors

Table 29 lists the main actors of each of the key steps of the municipal consortium/central purchasing body model, indicates the main risks that could affect the project throughout the process, and contains recommendations for mitigating these risks.

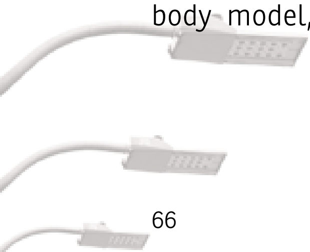


Table 29 - Matrix of functions and actors in model M6: municipal consortium or central procurement agent

M6 – Municipal Consortium or Central Procurement Agent				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Consortia of municipalities	Prepare public notice and organize bidding for equipment.	Lack of sufficient qualified manpower to prepare technical specifications.	Capacity-building or standard manual; competitive bids.
	Consortia of municipalities	Promote bidding for lamp procurement.	Lack of qualified manpower to cope with technical subjects; lack of adequate equipment guarantees.	Public notice follows best national/international practices; bidding to include international competition; specialist advice.
Obtaining finance	Municipalities	Structure and leverage resources to promote investment.	Inability of smaller municipalities to secure financing on their own.	Promotion of (public) credit lines for small- and medium-size municipalities.
	Financiers	Provide financial resources at competitive rates for capital expenditure (CAPEX).	Lack of investor interest; high interest rates.	Provide data to facilitate understanding of the risks.
Lamp procurement	Municipality or ESCO	Manage the process or supervise the services of an outsourced company.	Lack of knowledge of the public street lighting network resulting in delays and/or cost increases; lack of qualified manpower for supervision (in the case of an outsourced company).	Preparation of good quality technical studies; capacity- building.
Implementation and installation	Municipalities or consortia of municipalities	Manage the process or supervise the services of an outsourced company.	Lack of qualified personnel.	Technical and/or oversight training.

Advantages and disadvantages

An important advantage of this model compared to the M2 model (PPP consortia) is that it is not necessary to establish an SPV and it does not require joint financing arrangements. The individualized responsibility to raise funds makes the model substantially less complex, and there is no risk of a default by one municipality affecting the entire model. As a result, the municipalities benefit from economies of scale at lower transaction costs.

This model does not, however, resolve the difficulties faced by municipalities to obtain financing, which can be particularly difficult for medium-sized cities in view of the substantial upfront costs. In such cases, this model would need to be combined with a viable financing instrument. Moreover, the model would need the technical expertise of a leading municipality to coordinate the equipment-bidding process.

Identification of groups to which the model would apply

This model best applies to the municipalities in Groups C and D. These total 1,216 municipalities, with 21.8% of Brazil's population and represent R$ 6.5 billion of investment (23% of the investment needed throughout the country). This model could also be applicable to some cities in Groups E and F (4,219 municipalities).

Evolution of the model in Brazil

While it is likely that the model has already been implemented for non-LED technologies in Brazilian cities, we found no specific example of centralized procurement during our surveys and interviews. Nonetheless, the centralized procurement modality has proven to be successful in other parts of the world (economies of scale, etc.), as in the case of the province of Ontario, Canada, described in Box 8.

BOX 8 - Province of Ontario: Joint Management Model for Procurement

The Province of Ontario consists of 444 municipalities accounting for one third of Canada's population. Around two-thirds of them are small with populations of under 10,000 and less than 2,500 light points.

The Ontario Municipalities Association (OMA) has played a significant role in helping smaller cities modernize their public street lighting systems. The association also has a wholly-owned subsidiary company called LAS (Local Authority Services), which makes purchases of products and services – including LEDs - on behalf of member municipalities.

Several factors were instrumental in AMO's launching its LED-based public lighting program, including the high energy and operational costs of HPS lamps. The AMO/ LAS joint purchasing model basically aimed to: (i) ensure lower prices through large-scale purchasing; and (ii) reduce smaller municipalities' transaction costs involved in developing and managing complex specification processes associated with purchasing LED luminaires and maintenance services.

As of August 2015, 127 of the smaller municipalities had participated in the LAS joint LED-purchasing program (a total of 100,000 luminaires).

Many municipalities requested LAS technical assistance to select LED suppliers. RTE, the company chosen by LAS, implements and manages projects, promotes new products, and can provide financing and other services for the municipalities.

Canada's municipalities, especially in Ontario, are in good financial and credit shape due to the indebtedness limits imposed on them. Local authorities are obliged to meet strict transparency and competition requirements when conducting bids. However, many smaller municipalities suffer from the lack of experienced staff to prepare specifications and evaluate/ identify good quality suppliers and prefer to call upon AMO and LAS to bid for goods and services either centrally (which may involve the distribution of goods and services), or through straightforward centralized purchasing.

The combination of joint purchases by LAS, tax incentives, falling LED prices and the high-quality suppliers on the Canadian market has caused a rapid expansion of LEDs used in municipal street lighting in Ontario. In parallel, the number of municipalities that have adopted LED street lighting (contracted under LAS or independently acquired by larger municipalities) has grown rapidly. Joint bidding procedures that made it easier for smaller municipalities to adopt LED lighting appears to have encouraged larger municipalities to do the same.

Source: Adapted from "Proven Delivery Models for LED Public Lighting." World Bank Group, 2016.

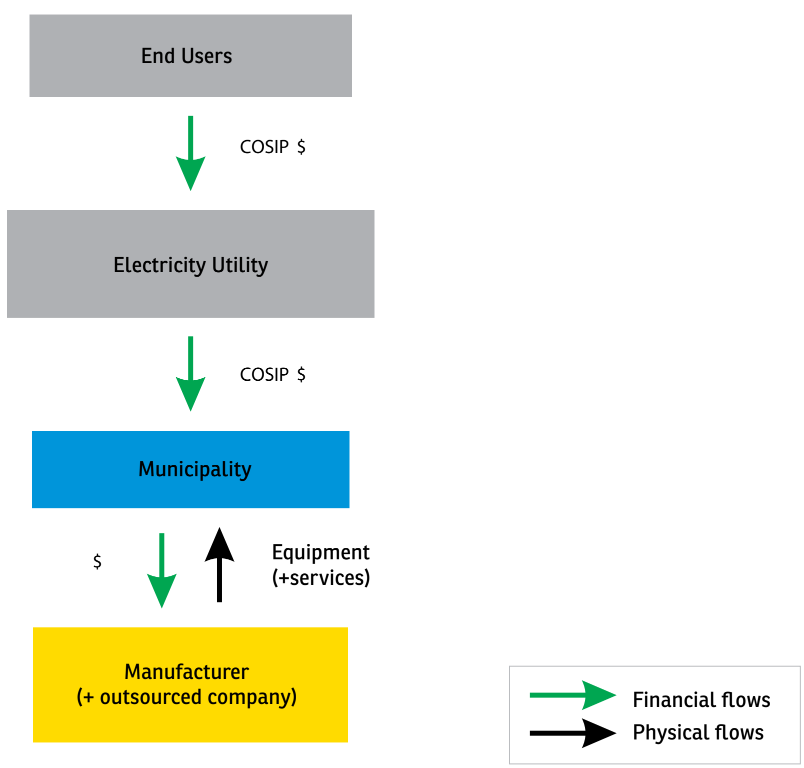
Model M7: Self-financing

Description of the model and cash flow

This model can be used by municipal governments to invest in modernizing their street lighting networks without third-party intervention. Municipalities undertake public lighting modernization investments using public lighting revenues *pari passu* with corresponding expenditures and investments, likely resulting in a relatively low value of annual investment, dependent on annual COSIP surpluses. The municipality could directly manage the O&M process, or it could be outsourced to a third party.

Figure 21 illustrates the main actors and cash flow involved in the self-financing model.

Figure 21 – Example of structure of self-funding model



Main actors, risks and mitigating factors

Table 30 lists the key actors in each of the main stages of the self-financing model, indicates the main risks that could affect the project throughout the process, and contains recommendations for mitigating these risks.

Table 30 – Matrix of functions and actors in model M7 – self-financing

M7 — Self-financing				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Municipality	Prepare public notice and organize bidding for equipment.	Lack of sufficiently qualified manpower to prepare technical specifications.	Capacity building or standard manual; competitive bids.
Obtaining finance	Municipality	Use surplus (if available) from annual budget for the public lighting sector and/or from COSIP.	Slow implementation of the project, causing lost opportunity for financial and energy-saving benefits for the municipality.	Maximize annual investment (e.g., robust structuring of COSIP, seeking opportunities to reduce costs on O&M, etc.), since the gains produced by the project will be greater than costs over the project lifetime.
Lamp procurement	Municipality	Prepare bidding for procurement of lamps.	Lack of qualified personnel to cope with technical subjects; lack of adequate equipment guarantees.	Public notice follows best national/international practices; bidding to include international competition; specialist advice.
Implementation and installation	Municipality	Manage the process or supervisor services of an outsourced company.	Lack of knowledge of the public street lighting network, resulting in delays and/or cost increases; lack of qualified manpower for supervision (in the case of an outsourced company for O&M).	Preparation of robust technical studies; capacity-building.
Operation and maintenance	Municipality	Manage the process or supervise the services provided by an outsourced company.	Lack of qualified manpower.	Technical and/or oversight training.

Advantages and disadvantages

The main advantage of this model is that its implementation does not require financial or institutional arrangements, thus reducing transaction costs. Moreover, the model may be the only way forward for smaller and fiscally fragile municipalities to carry out a LED street lighting project, unless they have federal government support in terms of capacity-building, financing, and/or financial guarantees.

Anticipating the use of COSIP funds or municipal budgets for upfront investments in street lighting projects may not be an option for many municipalities, given that self-financing requires surplus revenues to be available. Thus, municipalities with smaller scale and a shortage of qualified staff may find it difficult to increase COSIP revenues to a sufficient level for pursuing self-financing investment. A further problem is that such municipalities lack technical expertise, and risk purchasing expensive and lower-quality equipment.

One of the main disadvantages of this model is that it involves a slow street lighting modernization process given that it depends on surplus revenues and cannot count on outside financing. All this reduces the prospect of improving the financial situation of municipalities and improving the country´s energy efficiency overall.

Identification of groups to which the model would apply

This model may be the only option for many municipalities in Groups D, E and F, unless some type of public programs are available to assist them. These groups represent more than 90% of Brazil's 5,106 municipalities and require R$12.8 billion in investment (47% of the investment needed throughout the country). The self-financing model could also be applied to certain municipalities in Group C.

Evolution of the model in Brazil

Several large municipalities are already using the self-financing model for LED pilot projects—often an interim measure before implementing a larger PPP project using one of the alternative business models described here[75]. In view of the technical evolution and economic-financial benefits of LED technology, the full-scale conversion of street lighting to LED is almost inevitable. This reinforces the need for government involvement in municipal street lighting programs by providing technical assistance and concessionary funds for designing and implementing projects. One solution would be for public financing institutions, such as BNDES, Banco do Brasil and Caixa Econômica Federal (CEF) to provide subsidized credit lines.

Model M8: Transfer of Luminaires

Description of the model and cash flow

This model consists of the transfer of HPS, together with complete luminaires (housing, lens, ballast and mounting arm), from larger municipalities to others that still use less efficient lamps and do not have the resources to buy new LED lamps. This model focuses on inter-municipal (rather than intra-municipal) transfers of equipment that can be easily carried out by municipalities themselves without requiring purchasing or donation procedures.

The massive conversion in the future of HPS and mercury vapor lamps to new LED equipment[76] will leave a significant stock of secondhand HPS lamps which, after replacement, will be available for transfer to locations that still use other less efficient lighting technologies but that do not yet have the means to convert to LEDs[77].

A coordinating structure will be needed for this task. One of the possible candidates for this could be PROCEL, which could create an auction website (similar to *E-bay* or *Alibaba*, for example) to facilitate buying and selling in a transparent manner. The buyers could consist of municipalities or outsourced companies acting on their behalf, while the sellers would be municipalities with stocks of secondhand luminaires, or private actors who have purchased them from municipalities

[75]While preparing the public notice for its PPP project, the city of São Paulo used its own resources to install LED lamps on some of the city's major viaducts.
[76]In 2012 the installed network of HPS lamps amounted to 11.4 million units, far more than the 1.2 million light points currently existing in Group F municipalities. Metallic multivapor lamps totaled 201,000 and mercury vapor lamps (candidates for substitution) 3.8 million. There is also an operational public street lighting network using incandescent lamps (188,000), mixed lamps (283,000), fluorescents (160,000) and halogen lamps (10,900).
[77]The city of Los Angeles prepared a tender for the sale of the retired HPS luminaires, which produced around US$ 6.5 million.

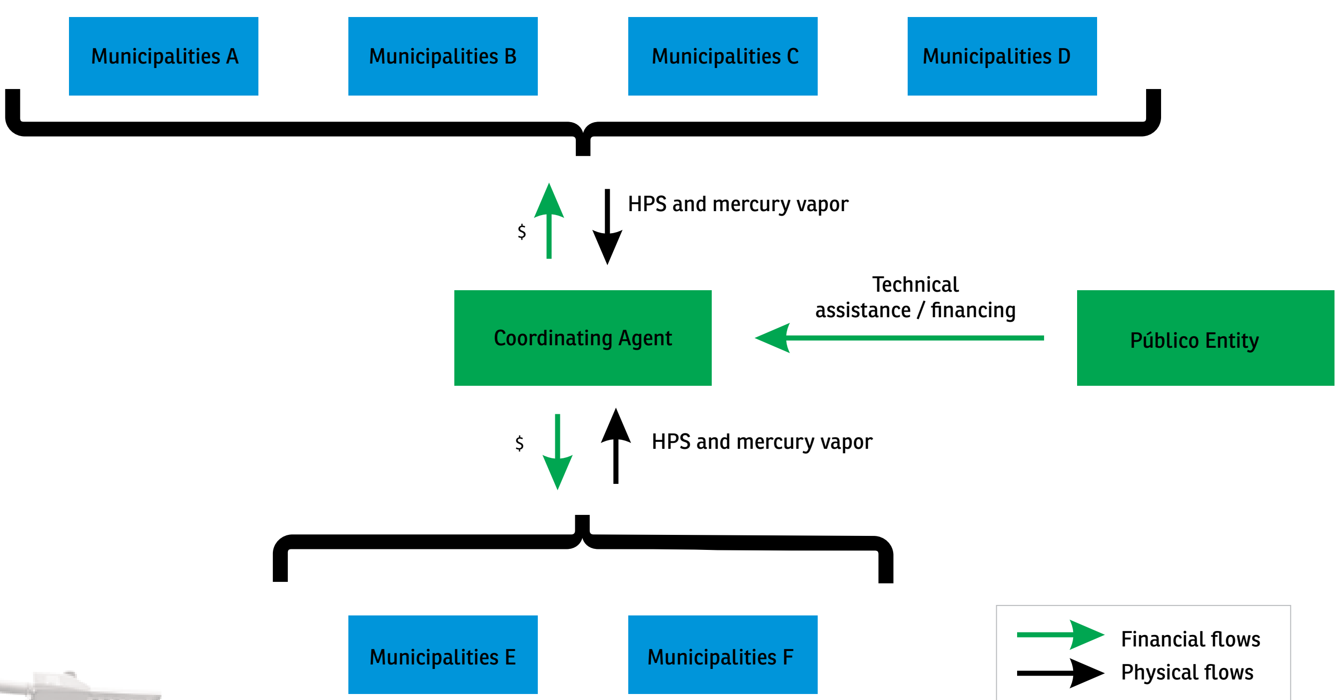
(or from dealers acting on their behalf) and are willing to sort them, fix them if necessary, and offer them for sale on the website. To do this, the products and quantities would need to be clearly described, including their technical specifications and residual life expectancy (with no guarantee of lifespan). The transactions could follow the upward bidding auction model as on E-bay. Note that these are simply ideas to encourage debate on how to make the most efficient use of the secondhand luminaires.

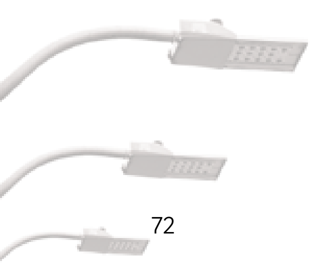
However, this model raises two important issues. The first concerns the transaction costs involved in transferring secondhand equipment. The receiving municipalities might also encounter problems in acquiring and testing the equipment, given the nature of the bidding processes needed, as well as problems involved in pricing and valuing the transferred items and paying for appropriate technical capacity-building to do this. It is worth noting that although transferring secondhand equipment would only be a temporary measure, the receiving municipalities would nevertheless gain short-term benefits while leaving the conversion to LED lighting until their financial positions improve.

The second issue concerns Brazil's national strategy for converting to LED technology. Transferring non-state-of-the-art equipment can represent energy efficiency gains in areas where the business models do not make LED deployment worthwhile, at least in the short and medium term. However, a more robust public policy strategy to replace the country's entire public street lighting system with LEDs would rule out the need for this model.

Figure 22 summarizes the main actors and cash flows of the luminaire transfer model.

Figure 22 - Example of structure of luminaire transfer model





Main actors, risks and mitigating factors

Table 31 summarizes the main actors in the key stages of the luminaire transfer model, indicates the main risks that could affect the project throughout the process, and contains recommendations for mitigating these risks.

Table 31 - Matrix of functions and actors in Model 8 — transfer of HPS luminaires

M8 – Transfer of HPS Luminaires				
Functions	Actors	Details	Project risks	Mitigating factors
Planning and bidding	Coordinating agent, municipalities or private companies	To create an online platform for the selling/buying municipalities to familiarize themselves with the products on sale	Complex coordination, possibly involving high transaction costs; lack of interest of public and/or private bodies in participating in the process.	Identify private sector actors who could provide coordination for logistical and financial aspects of the program; involvement of a public sector stakeholder to oversee the process.
	Municipality	Manage the process or supervise the services of an outsourced company.	Technology with a lower useful lifespan, or lack of qualified manpower for oversight (in the case. outsourced companies).	To offer lower prices to offset the technical risk; capacity-building.
	Coordinating agent, municipalities or private companies	Organize auctions for disposing of the HPS lamps.	Lack of qualified staff to manage the process; lack of controls possibly leading to financial risks.	Rely on private sector expertise.
Obtaining finance	Municipality	Use surplus (if available) from annual budget for the public lighting sector and/or from COSIP.	Lack of sufficient resources for purchasing LED lamps; complexity of organizing transactions between municipalities.	Robust implementation of COSIP to ensure surplus for public lighting modernization; involvement of the private sector in carrying out the transactions.
Lamp procurement	Municipality	Manage the process or supervise the services of an outsourced company.	Lack of qualified personnel; high cost resulting from rapid burnout of lamps acquired in this way.	Technical and/or oversight capacity-building.
Execution and installation	Municipality	Manage the exchange process or supervise the company outsourced to do this work.	Technology acquired with short remaining lifetimes, or lack of capacity to supervise outsourced company	Ensure prices of used equipment properly reflect the technical risk. Training.
O&M	Municipality	Manage the O&M process or supervise the company outsourced to do this work.	Lack of capacity; high failure rates of lamps, leading to high costs.	Ensure sufficient technical and/or supervisory skills.

Advantages and disadvantages

The main advantage of this model is that it offers an opportunity for smaller, lower-income municipalities to improve energy efficiency and service quality of their public lighting networks.

However, this model should be considered a temporary option, given the recommendation that the entire country should aim to convert its entire public street lighting network to LEDs in due course. Before proceeding with this option it is worth considering whether the short-term benefits can justify the possible transaction and coordination costs involved, if the secondhand HPS lamps are to be eventually replaced by LED technology. At the same time, given the financial limitations of smaller municipalities, this model may be their only short-term option.

Identification of groups applicable to the model

Transferring secondhand lamps could benefit the 4,219 municipalities in Groups E and F where fiscal and institutional difficulties rule out the conversion to LED-based street lighting in the short term. These groups represent 75% of all Brazilian municipalities and would require R$9.5 billion in investment (35% of the investment needed throughout the country).

Evolution of the model in Brazil

No similar model was identified as part of the research undertaken for this study. The need and/or attractiveness of this business model will be largely determined by whether the federal government develops a more robust public policy strategy to support and/or encourage the replacement of the country's entire public street lighting system with LEDs.

5.4 - Summary of Business Models and Mapping of Groups of Municipalities

This section seeks to identify business models that, considering the institutional environment and characteristics of the Brazilian market, would allow sufficient funds to be generated for implementing public street lighting modernization projects. Table 32 summarizes the eight models, indicating the main roles and key stakeholders involved in each key phase of the project.

Table 32 - Key stakeholders in each phase of the business models

Business model	M1 – Municipal PPP	M2 – Consortium for PPPs	M3 –Municipal Financing	M4 – Electric Utilities Programs	M5 – ESCOs	M6 – Municipal Central Procurement Agent	M7 –Self Financing	M8 –Transfer of Luminaires
Resource generation	Consumers	Consumers	Consumers	Consumers	Consumers	Consumers	Consumers	Consumers
Energy supply to light point	Electric utility company	Electric utility company	Electric utility company	Electric utility company	Electric utility company	Electric utility company	Electric utility company	Electric utility company
Supply of equipment	Manufacturers	Manufacturers	Manufacturers	Manufacturers	Manufacturers	Manufacturers	Manufacturers	Manufacturers
Planning and bidding	Municipality or Audit Court, consortia of companies	Municipalities, municipal consortia, Audit Court, consortia of companies	Municipality	Energy utility, municipalities; ANEEL	ESCOs, municipalities	Municipal consortium	Municipality	Coordination agent, municipalities
Obtaining financing	Public lighting concessionaire; financiers	Public lighting concessionaire; financiers	Municipality or financiers	Energy concessionaire	ESCOs; financiers	Municipal consortia or municipalities; financiers	Municipality	Municipality
Lamp procurement	Public lighting concessionaire; manufacturers	Public lighting concessionaire; manufacturers	Municipality	Municipality or ESCO	ESCOs	Municipal consortia	Municipality	Coordination agent; municipalities
Implementation and installation	Public lighting concessionaire	Public lighting concessionaire	Municipality	Municipality or ESCO	ESCOs	Municipality or ESCO	Municipality	Municipality
Operação e manutenção	Public lighting concessionaire; municipality.	Public lighting concessionaire; municipalities	Municipality	Municipality or ESCO	Municipality or ESCO	Municipal consortia or municipalities	Municipality	Municipality

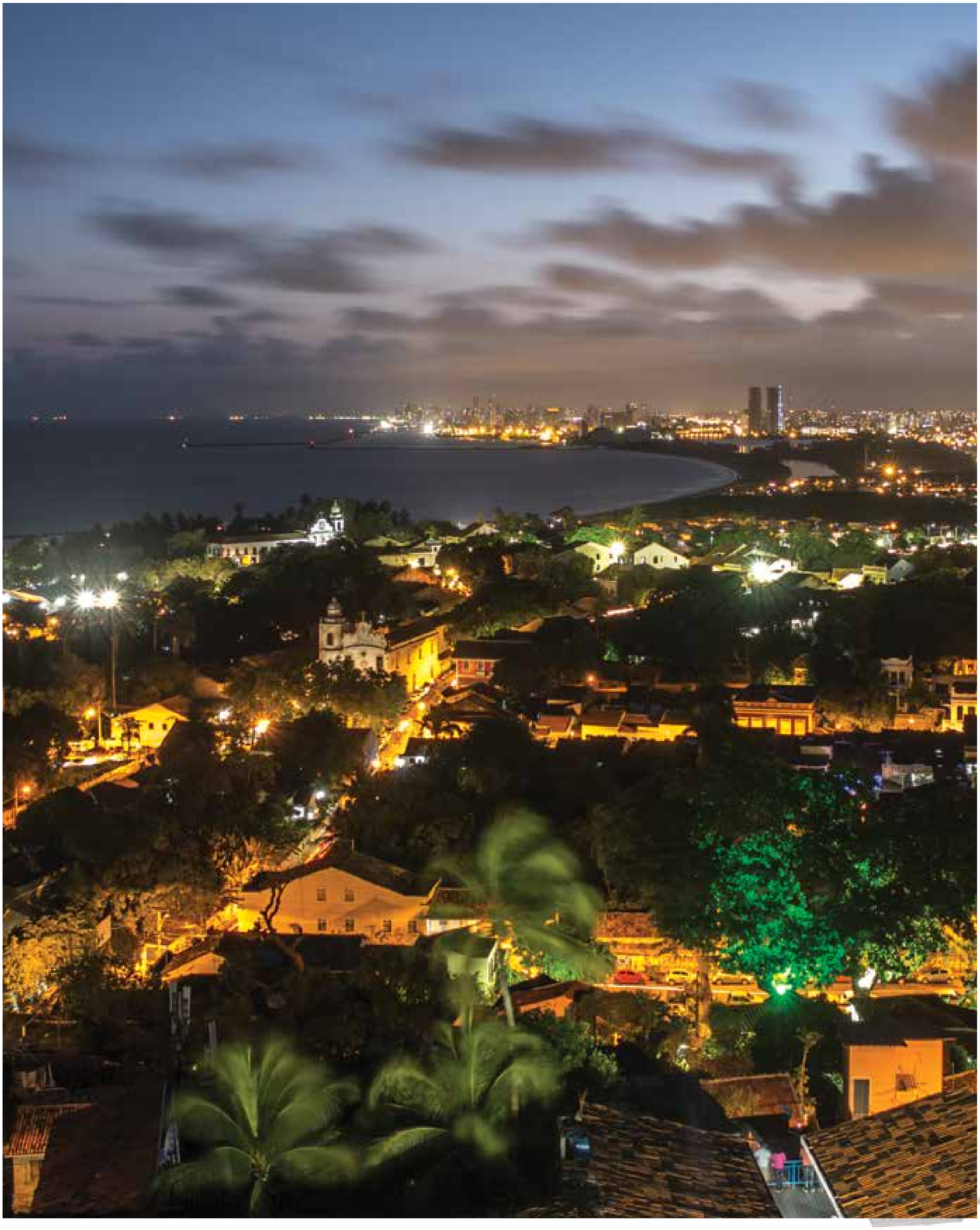
Given that, in many cases, the models apply to more than one group, it is important to map how the eight models can be applied to the six groups of municipalities. Table 33 shows the interface between the groups and the suggested business models. The municipalities themselves will be ultimately responsible for choosing the business model that is most appropriate to their circumstances or a combination of models that could produce the best solution in the short, medium and long term.

Table 33 - Business models for each group

Group	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
A	Suggested							
B	Suggested	Possible	Suggested					
C		Suggested	Suggested	Possible	Suggested	Suggested	Possible	
D				Suggested		Suggested	Suggested	
E				Suggested		Possible	Suggested	Suggested
F				Possible		Possible	Suggested	Suggested

Source: World Bank Group; Pezco Consultoria Key: = suggested; = possoble

The following section provides further details on the financing mechanisms that could be used for investing in the modernization of municipal street lighting networks under the various business models.



6 - Financing and Credit Enhancement Mechanisms

To take advantage of the benefits of converting to the new lighting technology, financing models are needed to facilitate the investments required for a city's chosen business model.

Each model contains specificities that require different financing options and models. While models such as M1 and M5 are more attractive to the private sector, others such as M3 depend heavily on the existence of lines of credit targeted at the public sector.

The major financial instruments are described below, together with their applicability to the different business models. At the end of the section, Table 35 summarizes application of the instruments to the various business models.

6.1 - Financing Mechanisms

1) COSIP is a charge or tax levied by the energy utilities on consumers and transferred to the municipality to cover the costs of running and expanding its public street lighting system. It is a ring-fenced (earmarked) fund - endorsed by the Constitution and created via municipal legislation - that cannot be used for other purposes. As such, the resources arising from this tax must be used for modernizing the public lighting sector. This ring-fenced and earmarked source of revenue is a differentiating factor that can attract private capital to the sector, given that its shielded status reduces municipal credit risk. As discussed in Section 4.3.3, most Brazilian municipalities charge COSIP, and others are preparing to do likewise. In the absence of COSIP, municipalities can resort to using municipal budget funds, although these are subject to other contingencies and compete with other social priorities. Given its benefits and widespread implementation, COSIP is a key source of financing in all the business models (M1 - M8).

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
COSIP or Minicipal Budget	●	●	●	◕	●	●	●	◕

Key: full circle = most applicable; empty circle = not applicable

2) Loans from public banks - Banco do Brasil (BB), Caixa Econômica Federal (CEF). Although these institutions do not provide specific financing lines for energy efficiency or public lighting projects, such lines could be created or projects could be tailored to their general lending requirements. Both institutions are extremely well-known to municipal governments, many of which are active clients in infrastructure and other areas. CEF possesses qualified and decentralized technical staff that could assist smaller municipalities with their public street lighting projects. Both BB and the CEF would be best placed to collaborate in M3 public sector projects and M6 municipal procurement consortia.

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Loans from Public Banks (BB, CEF)	◕	◕	◕	◑	◔	◕	○	◔

Key: full circle = most applicable; empty circle = not applicable

3) BNDES-Finem. This is a credit line dedicated to energy efficiency projects, replacing the previous BNDES PROESCO line, which completed 27 financing operations worth around R$510 million[78]. Market practitioners emphasize that this line was difficult to access because of the requirement for private guarantees or solid balance sheets. Its successor, BNDES-Finem[79], accepts operations equal to or greater than R$5 million and finances up to 70% of eligible items, at a cost equivalent to the TJLP (Long-Term Interest Rate) + 2.5% to 5.7% per annum. The portfolio of this new line has twenty projects already approved or being evaluated[80]. Subnational agencies can pass on financing. The BNDES-Finem line is likely to apply to smaller lighting projects where an ESCO is responsible for implementation (M5). Other possibilities might be projects carried out by municipalities, especially when they need counterpart funds for future concessionary programs (M4), or direct financing for equipment and services (M3 and M6).

[78] Revista Brasil Energia, Issue No. 423, February 2016, p. 16.
[79] BNDES credit line for project financing. In general, BNDES-Finem finances projects worth over R$20 million, covering 50% of the financeable items, but these parameters are more favorable (R$5 million and 70%) for EE efficiency projects.
[80] Revista Brasil Energia, Issue No. 423, February 2016, p.15.

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
BNDES - FINEM	◔	◔	◒	◒	●	◒	○	◔

Key: full circle = most applicable; empty circle = not applicable

4) Private Equity. This entails private capital investment as equity as a shareholder in a Special Purpose Vehicle (SPV) for financing a public street lighting modernization project. SPV involvement can range from an administrative concession granted by a municipality (M1) or PPP consortia (M2), to simpler structures where an ESCO is responsible for conversion to LED technology and receives payment to cover capital costs (M5).

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Private Equity	●	●	○	○	●	○	○	○

Key: full circle = most applicable; empty circle = not applicable

5) Mechanisms for improving credit risk. Forms of credit enhancement may be essential for financing public street lighting projects. Even when the COSIP tax is well-formulated and offers robust guarantees for lenders, there might be a perception of residual risk arising from insufficient COSIP resources and, thus, exposure of investors to municipal credit risk. To mitigate this risk, mechanisms (including forms of guarantee) may be required to ensure that these schemes effectively enhance financing capacity and generate the desired levels of investment.

Multilateral banks have products available for private partners to invest in public street lighting projects which could help to mitigate risks. One example is the World Bank's partial payment and partial loan guarantee schemes. Municipalities could also offer shares in municipal companies or guarantees to mitigate municipal credit risk. However, there are very few examples of these types of mechanisms being used as collateral, principally due to the limited availability of suitable assets even in larger municipalities.

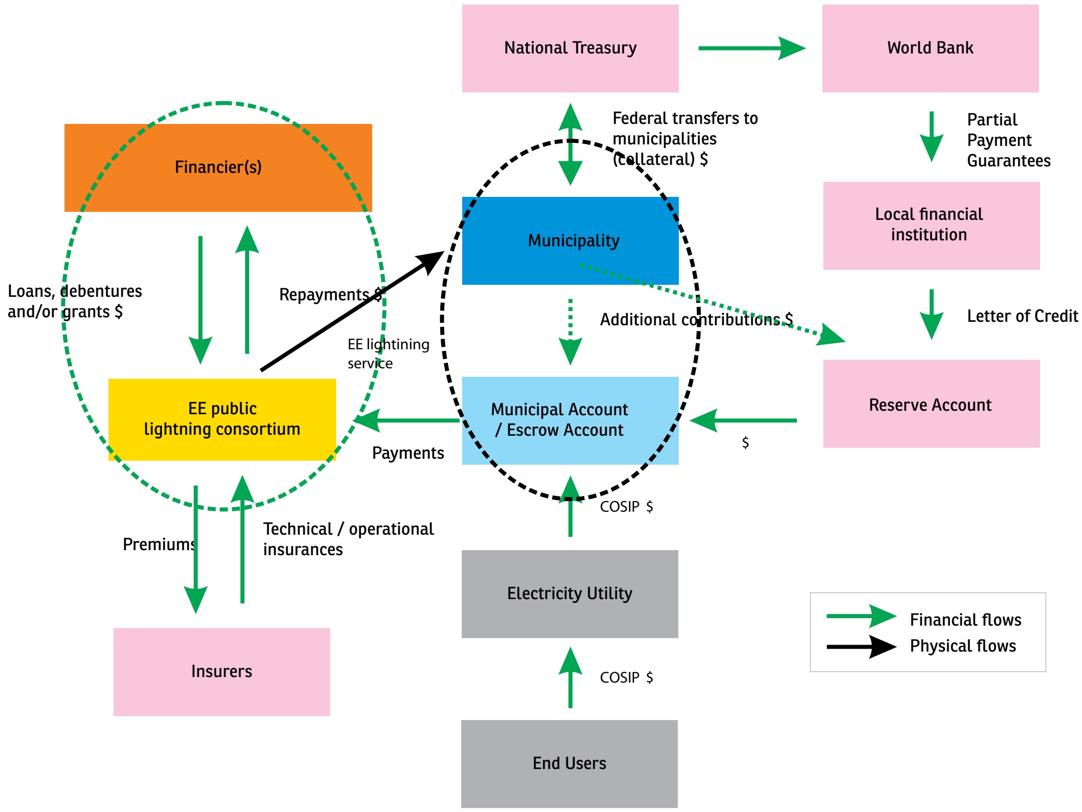
Credit guarantees apply to the business models with private sector investment, mainly M1–M3. They can also apply to the M4 and M5 models.

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Credit enhancements (i.e. World Bank)	◕	◕	◕	◔	◔	○	○	○

Key: full circle = most applicable; empty circle = not applicable

Figure 23 shows a potential scheme for the use of collateral in a PPP for street lighting, including a partial guarantee of payment of the municipality's payments in the consortium. It is important to note that the cost of such risk reduction mechanisms will ultimately be borne by the municipality through contracts with the consortium. Guarantees can be applied to other business models below (e.g., municipal funding, ESCOs), in addition to the PPP model. The role of the World Bank guarantees in this example is to ensure that the municipality's escrow account contains sufficient funds for remuneration of the public street lighting consortium (the concessionaire). A reserve account, backed by a letter of credit from a local financial institution and – ultimately – by the World Bank, is created to provide funds to the escrow account in the event of shortfalls. The amount to be allocated to the reserve account should be negotiated between the parties. This mechanism, with the sovereign guarantee of the National Treasury, is normally formulated to cover the liabilities of the account for a period of between three and six months.

Figure 23 - Example of the use of World Bank guarantees in the PPP model



6) Development banks (domestic and multilateral)

a) National development banks: These are federal, state or multilateral development institutions that provide financing instruments for energy efficiency projects, potentially including public street lighting projects. Examples of Brazilian development banks (BNDES, DesenvolveSP, AgeRio, BDMG, etc.) are listed in Table 34. The BNDES has shown interest in supporting specific PPP projects to modernize public lighting, such as those in São Paulo and Belo Horizonte. The Desenvolve-SP, AgeRio and BDMG agencies on-lend funds from BNDES or can offer their own specific financing lines for EE and street lighting, given that they have a mandate to invest primarily in infrastructure projects that have economic benefits, such as climate change mitigation projects. Many of the above-mentioned institutions have good access to smaller municipalities and to knowledge of local realities, and generally offer lower interest rates than the capital markets. Such sources of financing would be more appropriate for the M1, M2 and M3 models, and potentially for the M5 and M6 models.

b) International development banks: The World Bank, CAF and IDB and other multilateral banks can in principle finance projects for public entities, such as for larger municipalities using the M2 model. The private arms of these institutions, such as the World Bank Group IFC can finance PPP SPVs and ESCOs, and provide financing and technical assistance for certain public-private partnerships (M1, M2, M5), as well as possibly providing mechanisms to mitigate project risk.

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Development Banks (domestic, multilateral)	◕	◕	◒	○	◔	◔	○	○

Key: full circle = most applicable; empty circle = not applicable

Table 34 below provides examples of the financing lines already available in development banks.

Table 34-Details of financial instruments of development banks

Modality	Description	Cost[81]
BNDES – Climate Fund[82]	Credit line for projects that increase the sustainability of cities, including public street lighting.	Cost: 1.9% + credit risk (1% for public sector and 3.6% for remainder).
BNDES –support for specific projects.[83]	Credit lines available for specific PPPs (e.g. São Paulo and Belo Horizonte).	Cost: Terms and conditions set out in the Public Notices.
Desenvolve SP – Green Economy Line[84]	Credit line for financing EE projects.	Cost: from 6.55% per annum + IPCA.
Desenvolve SP –Public Street lighting[85]	Credit line for financing public street lighting services up to 100% of the value of the project.	Cost: 9.5% per annum.
AgeRio Pró-Urbano[86]	Credit line for urban infrastructure. Public street lighting is one of the items eligible for financing. This line can finance up to 100% of the project, with a ceiling of R$20 million.	Cost: Selic rate+ 4% per annum.
BDMG	Credit line with funding from the French Development Agency (AFD), for EE projects with budgets of R$50 million.	Cost: SELIC and interest rates of 5 6% per year.
Multilateral institutions (e.g., World Bank Group)	Loans for large municipalities. Loans for electric utility companies or ESCOs. Shareholder participation in SPVs. Technical assistance and support for structuring PPPs.	On a case-by-case basis.

7) Sectorial financing (PEE, Reluz, PROCEL). While sectorial funds have played an important role in the modernization of public street lighting systems, legal changes have reduced the amount of funding available to this sector. Although the funds for the public street lighting sector in Brazil will depend on the implementatioan of the new legislation to transfer resources from PEE to PROCEL or any other new policies and regulation emerge, it is expected that the utilities will facilitate or coordinate energy efficiency-related resources (M5). Sectorial funding for small- or medium-sized public or private projects is also a possibility, depending on the rules to be established for managing the PEE funds.

[81]Figures from April 2016.
[82]Available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Programas_e_Fundos/Fundo_Clima/cidades_sustentaveis_mudanca_clima.htm>
[83]Available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Ferramentas_e_Normas/Credenciamento_de_Equipamentos/credenciamento_equip_iluminacao.html>
[84]Available at: <http://www.desenvolvesp.com.br/empresas/opcoes-credito/projetos-sustentaveis/linha_economia_verde>
[85]Available at: <http://www.desenvolvesp.com.br/municipios/opcoes-credito-municipios/linha-iluminacao-pública>
[86]Available at: <http://www.agerio.com.br/index.php/br/component/content/article?id=107:pro-urbano>

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Sector Financing Lines (PEE, Reluz, PROCEL)	○	○	◕	●	◔	◔	○	◔

Key: full circle = most applicable; empty circle = not applicable

8) Loans from private banks. This involves Brazilian or foreign, private commercial banks lending directly to municipal governments (M3, M6) or agents acting on their behalf (M1, M2 and M5) for street lighting modernization. The terms and conditions of such loans in principle reflect market conditions and take into account the project and credit risks of the municipalities. Loans by private banks to the public sector must also take into account the fact that municipalities are subject to indebtedness limits.

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Loan from Private Banks	◕	◕	◔	○	◕	◔	○	○

Key: full circle = most applicable; empty circle = not applicable

9) Debentures, FDIC, FIP, Green Bonds. These are mechanisms that allow larger and more cost-competitive funds to be obtained in the Brazilian or international financial market for large-scale projects. They are mentioned here because they involve "securitization" of the revenues of projects that receive investment. These instruments are briefly described as follows:

a) Debentures are debt instruments (bonds) issued by an SPV (M1, M2) or by a municipality (M3). Bonds are nowadays the most readily-accepted securitization instrument in Brazil's capital markets. Infrastructure debentures can be acquired by private investors or development banks (e.g., BNDES) and are particularly attractive because they can also offer substantial tax relief.

b) FIDCs are mutual funds that invest at least 50% of their net assets in debt securities. They are a suitable tool to securitize the future cash flows from infrastructure projects, such as COSIP or even debentures. FIDCs can acquire debentures issued by SPVs (M1, M2 and M5) or municipalities (M3), thus diversifying the risks for investors. As with debentures, FIDCs also offer considerable tax advantages.

c) FIPs (Private Equity Investment Funds) are closed funds that invest in stocks, debentures and convertible debt instruments of any publicly or privately held Brazilian company providing it is a corporation. This is most applicable to M1 and M2 models. Financial institutions, insurance companies and pension funds are among the possible investors for these funds, which can also be tax exempt in certain cases. FIPs could be used in public street lighting projects requiring funding by institutional investors, and are most applicable to the M1 and M2 models.

d) Green Bonds are credit instruments similar to debentures in the Brazilian market, which can be issued by private, public or multilateral institutions. The primary purpose is to invest in projects of environmental interest, mainly focused on climate change mitigation. In principle, energy efficiency projects like LEDs for public street lighting systems would qualify for Green Bonds, since such projects reduce the GHG emissions linked to electricity production. Due to the high transaction costs (including because investors may require verifiable benefits), the Green Bond instrument would be most suitable for large-scale projects by the private sector (M1, M2, or M5) or large municipalities (M3).

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
Debentures, FIDC, FIP, Green Bonds	◕	◒	◔	○	◔	○	○	○

Key: full circle = most applicable; empty circle = not applicable

10) FI-FGTS. Although FGTS resources have been used to support certain urban infrastructure projects, few have been in the street lighting area unless they form part of a broader urbanization project. While the electricity sector has historically been the main manager and financier of public street lighting projects, a sensible initiative would be to treat public street lighting modernization projects as part of the urban infrastructure, given that all municipalities now must take ownership of these assets. The allocation of FI-FGTS funds requires the intervention of the Ministry of Cities and approval by the FGTS Board of Trustees.

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
FI-FGTS	○	○	◔	○	○	○	○	○

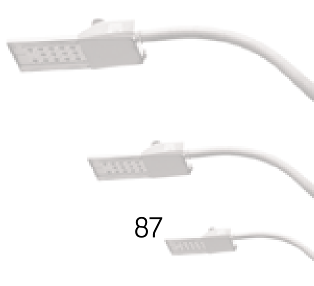
Key: full circle = most applicable; empty circle = not applicable

Table 35 summarizes applicability of each financial instrument to each business model.

Table 35 - Financial instruments suitable for use in the different business models

Financial Instrument / Business Model	M1 PPP Municipal	M2 Municipal Consortium with PPP	M3 Municipal Funding	M4 Electric Utility Programs	M5 ESCO (s)	M6 Centralized Procurement	M7 Self-Funding	M8 Transfer of Luminaires
COSIP ou Municipal Budget	●	●	●	◕	●	●	●	◕
Loans from Public Banks (BB, CEF)	◕	◕	◕	◑	◔	◕	○	◔
BNDES - FINEM	◔	◔	◑	◑	●	◑	○	◔
Private Equity	●	●	○	○	●	○	○	○
Credit enhancements (i.e. World Bank)	◕	◕	◕	◔	◔	○	○	○
Development Banks (domestic, multilateral)	◕	◕	◑	○	◔	◔	○	○
Sector Financing Lines (PEE, RELUZ, PROCEL)	○	○	◕	●	◔	◔	○	◔
Loans Private Banks	◕	◕	◔	○	◕	◔	○	○
Bonds, FIDC, FIP, Green Bonds	◕	◑	◔	○	◔	○	○	○
FI-FGTS	○	○	◔	○	○	○	○	○

Key: full circle = most applicable; empty circle = not applicable



6.2 - Risks and Mitigation Mechanisms

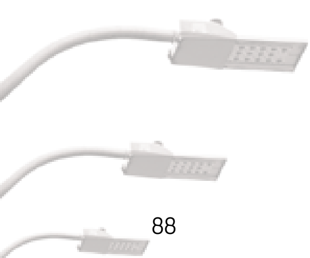
In addition to the credit risks mitigated by the mechanisms discussed in the above section, other key risks need to be considered and mitigated in public street lighting projects. These include: the risk of technical and/or operational performance, political risk and non-manageable risks. These are summarized in Table 36.

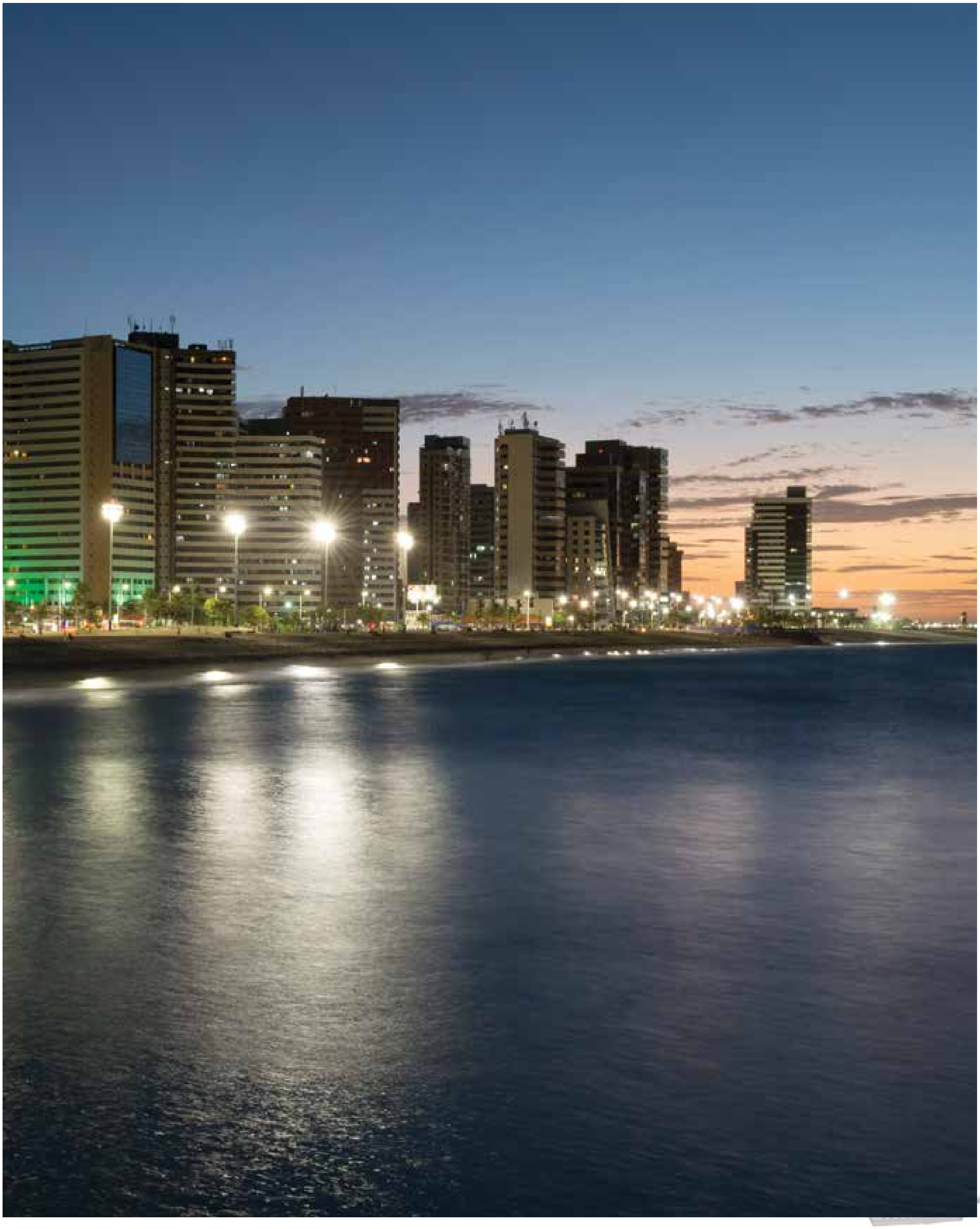
Table 36 – Other risk mitigation mechanisms

Risks	Mitigation mechanisms	Examples of mitigation products
Technical performance risk	Manufacturer´s or factory guarantee	Guarantees supplied by large manufacturers (cost embedded in the price of LED lamps)
Technical and/or operational performance risk	Insurance guarantee	Reassurance company (e.g., MunichRe) products, notwithstanding the fact that these still lack market maturity
Political risk	Multilateral financial institution insurance	MIGA (World Bank)
Non-manageable risks	Federal Government guarantee for infrastructure (ABGF)	Infrastructure Guarantee Fund (FGIE), tends to focus on larger projects, and is not applicable to the majority of municipalities.

Source: Compiled by Pezco Consultoria based on stakeholder consultations and public sources.

Many of these mechanisms will be needed to support projects in which the private sector is involved as a concessionaire, an ESCO or a private financial institution (i.e., applicable to models M1 to M5).





7 - Other Considerations in the Design of a LED Project

Although this report has covered options for business models and financing instruments that municipalities and other key stakeholders need to take into account when designing a modern public lighting project with LED technology, many other details and decisions are involved. It is out of the scope of this report to detail many of these other factors; nonetheless, this section provides a brief overview of possible options that need to be considered, such as: (i) the level of automation of the public street lighting system; and (ii) other civil works that are included within the scope of a project to improve the infrastructure of a public lighting system and of other related sectors.

7.1 - Automation, Remote Management and Ancillary Services

Public street lighting modernization projects can enable cities to take advantage of the structure related to the installation of LED luminaires to benefit a city in terms of automation and remote maintenance and provide complementary services to benefit the population. One possibility is to rent out the available infrastructure for the private sector to increase the range of telecommunications and other services for the public. The layout of poles, access to reliable power supplies, granularity, and "on-board" communication electronics can facilitate the delivery of these services at a relatively low incremental cost. Various levels of automation and service delivery are described in Table 37.

Table 37 – Automation levels of public street lighting projects

Level of automation	Description
Low automation	No control over the status of lamps (burnt out, off at night, on in daylight hours). No individualized measurement of electric energy and savings are based on estimates (*deemed*). Quality control is done by ad-hoc maintenance crews, and the model includes a customer call center.
Operational automation	The model includes control over the status of the lamps, and energy inputs are measured at some points. This information is sent remotely to a control center, which may also possess two-way communication to operate shutdowns, dimming and other features. The communication structure only serves operational requirements.
Automation to support a public good	In addition to the above-mentioned control facilities, the model may also contain a system of sensors for transmitting key data for managing different urban facilities such as traffic control, signals, security cameras, electric vehicle recharging points, etc. This structure can also support Wi-Fi points for the convenience of the population. These services are of a public nature and most of them are difficult to monitor. The cost of the services are borne by the municipality.
Automation to support new businesses	New private businesses can also use the public lighting system´s granularity and " "footprint" for data sending and control. This can include data on parking management, vehicle sharing, etc. The most promising and viable application could be the use of public lighting points for improving 4G cellphone reception.

While increased automation can benefit a municipality's street lighting and other key sectors such as transportation and security, it also involves higher costs due to project design delays and complex contract negotiations with the private sector. Municipalities are therefore well-advised at the project planning phase to carefully evaluate the costs and benefits of automation and develop a step-by-step strategy, possibly by designing a simpler project to begin with that is "future proofed," i.e., sufficiently flexible to accommodate more complex automation in due course. Box 9 contains ideas of how to incorporate this concept in a PPP concession for public street lighting.

Box 9 - Future-Proofing a PPP Concession Contract

Although LED technology is advancing rapidly in terms of luminous efficiency (lumens per watt) and cost per watt (i.e., a significant reduction of US$ per lumen), some obsolescence of equipment can be expected during the term of a concession agreement. While the equipment is unlikely to become dysfunctional or fail to generate the expected benefits during its lifetime, the expansion of a public street lighting system will in the future benefit from cheaper and even more efficient technologies. It may even be feasible, on energy-saving grounds, to justify replacement of LED lamps before the end of their useful life, in which case it may even be possible to replace the chip in the luminaire, retaining the electronic and optical components.

Concession contracts will need to be sufficiently flexible to accommodate these technological innovations. Contracts will also need to contain provisions for reviewing the economic/financial balance of projects if future technological developments justify modifications to the existing street lighting system. A review could, for example, be held in anticipation of the end of the lamps´ useful life, when they will need to be replaced. In this case, concession contracts should include generic clauses governing how the additional future efficiency gains due to technological innovation will be shared between the municipality and the concessionaire.

It is likely that major changes in the value of a concession will be due to the incorporation of new private services that can be monetized by the city or concessionaire. One example would be the installation of a 4G cellular network benefiting from public street lighting infrastructure (posts, energy supply, control systems, etc.). This technology is not yet widely used but has already been laboratory tested, with trials in cities such as Berlin, Germany. According to experts, this technology is promising; however, other options may exist that do not depend on the public lighting network.

Given these uncertainties and the high added value they could involve, the ideal way to "future-proof" would be to exclude from the public lighting concession any reference to future services that may be developed, leaving these for the local authorities to handle under a future regime. At present municipalities such as São Paulo and Belo Horizonte have concession contracts that set conditions for sharing revenues from future technological innovations and the ancillary services that may be developed by the current utility companies. Other municipalities may find it worthwhile to compare the advantages and disadvantages of this approach. Given the uncertainties and risks of future ancillary services, bidders for the project may be heavily discounting their potential value to the detriment of municipalities. For the time being, clearer information is needed on technological innovations before granting rights to use public lighting networks for undefined ancillary services.

7.2 - Modernization of the Public Street Lighting System in a City Infrastructure

The modernization of public lighting systems can involve a wide range of different activities in addition to converting to LEDs, such as other civil infrastructure works in other sectors linked to public lighting (electrical energy distribution, transport, security, telecommunications, etc.). Cities will need to carefully consider the level and scope of their street lighting modernization projects: fiscal savings, improved service quality, compliance with technical regulations, aesthetic/commercial improvements, etc. Table 38 summarizes some of the different approaches to modernizing the public street lighting infrastructure.

Table 38 – Levels of modernization of the public street lighting infrastructure

Modernization level	Goals	Description
Simple modernization	• Improve energy efficiency, using the simplest and most economical design possible. • Offer positive effect on service quality given that: (i) burned-out lamps are replaced; (ii) some LED luminaires would help to partially light darker areas between poles.	• Substitute existing lamps with more efficient models to improve compatibility of the system with the quality standards established by national norms. • Continue to use the points to which luminaires are fixed (poles, buildings) with no need to provide extra points.
Intermediate modernization	• All of the above, plus: • Ensure basic compatibility of the system with quality standards established by national norms.	• All of the above, plus: • Change existing points and/or installation of extra points in order to comply with national public lighting norms. • Inspect cabling (including grounding) to ensure functioning of the lamps including in stress situations, e.g., frequent lightning episodes.
Complete modernization	• All of the above, plus: • Ensure the compatibility of the system with quality standards established by national norms. • Implement other improvements for aesthetic reasons and/or to benefit other city facilities (including infrastructure for private sector initiatives).	• All of the above, plus: • Inspect cabling (including grounding) throughout most of the city. • Install remote management systems to support other public service areas (security, transport, etc.) and/or for creating new private sector businesses (WiFi, 4G, etc.) as described in Table 37.

There is no single or perfect model for cities. Selecting one will depend on the strategic goals of each modernization scheme, the initial quality of the public lighting services, available resources and the option of joining forces with utility companies to install an underground cabling network.

8 - Gaps in the Market and Recommendations

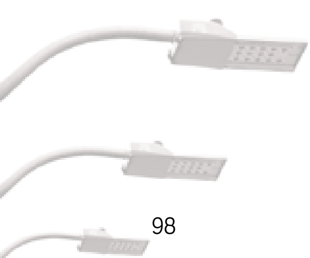
Most of the business models and financial instruments presented above require some form of institutional support to ensure countrywide speedy implementation.

This study shows that, without some kind of government intervention in the public street lighting market, the most probable scenario will be for 90% of the cities to use the self-financing business model (M7) representing 50% of the light points (i.e., Groups D, E and F). This would imply a very slow retrofit of Brazil's public street lighting sector reducing the economic and social benefits that LED technology can provide (e.g., energy savings, public safety, improvement of services rendered to the community, etc.).

It is therefore vital to identify gaps and seek solutions to include the largest number of Brazilian cities in this technological revolution. Table 39 lists the gaps and barriers that impede the overall development of the sector in six areas: (1) the regulatory framework; (2) the legal framework (3) public policies; (4) financing; (5) capacity-building; and (6) technology. The table also includes a number of recommendations to overcome the various gaps and barriers and suggests various key stakeholders who could play a leading role in the respective areas.

Table 39 - Gaps, barriers, and recommendations

Gaps/barriers		Recommendations	Key players
Legal and regulatory framework	Lack of a regulator and regulatory capacity for the public lighting sector	1) Identify possible actors with regulatory knowledge to fill regulator gap, or at least to provide regulatory advice to municipal governments when necessary	State regulatory agencies; Ministry of Cities; Brazilian Associations of Municipalities; consortia formed between municipalities for this purpose
	Lack of clarity in the legal interpretation of COSIP	2) The federal government interpret and clarify what are the legal uses of COSIP (e.g., for expenditures electricity, O&M, expansion, modernization). 3) Standardization of the legal framework cities can use to earmark COSIP funds	National Audit Court (TCU); public ministry; legal departments of the justice courts (TJ); specific rulings by the Supreme Court (STF)
	Gaps in the legislative framework to enable public consortia to be a viable mechanism for aggregation	4) Revise the legislative framework for public consortia to allow direct financing of the public consortium´s legal entity	Ministry of Cities; Brazilian Associations of Municipalities; PPI
	Lack of clarity in the application of Law 8.666 and the PPP law and their possible inconsistencies	5) Establish a uniform approach for oversight agencies verifying the legal provisions applied to different procurement bidding modalities.	Congress, via specific legislation; PPI
Public Policies	Lack of national leadership for efficient public street lighting	6) Identify and designate federal, state, and/or municipal leaders to be responsible for leading coordination of EE street lighting initiatives and for helping municipalities to overcome barriers	Ministry of Mines and Energy; Ministry of Cities; ELETROBRAS; public banks; PPI Executive Secretary
	Absence of a national strategy/policy	7) Federal government should design a national strategy for EE street lighting, including targets for converting the national public street lighting network to LEDs	Ministry of Mines and Energy; Ministry of Cities



Financing	Insufficiency of public or sectorial lines of subsidized credit	8) Create new credit lines and/or instruments for municipalities unable to attract (sufficient) private investment.	ELETROBRAS; energy distributors via current PEE; FGTS Board of Trustees
	Lack of standardized EE investments to attract large scale, private sector financing	9) Design investment funds offering new, standardized EE asset class to attract a variety of investors at scale	Public banks, multilateral development agencies, bilateral development agencies, DFIs, private sector
	Fiscal Responsibility Law limits municipal financing (to 16% of Net Current Revenue).	10) Pass new legislation that allows exceptions to be made in municipal debt thresholds in order to enable greater investments in EE public lighting (similar to exceptions that were provided to debt under PROCEL program).	Federal government
	Municipal credit risk discourages private investment	11) Create instruments for mitigating municipal credit risk.	Federal government; multilateral agencies
	Lack of incentives for energy distributors to invest in energy efficiency in the public lighting sector	12) Provide electric utilities different incentives to promote EE street lighting by altering the form of compensation for energy distributors, namely through decoupling sales (and MWh) and revenues	ANEEL, energy distributors
	Currency exchange risks	13) Explore new instruments that may reduce FX risk that are affordable and available over the longer term (e.g., partial indexation in US$)	Federal government; multilateral agencies; financial sector
Training	Insufficiency at municipal level of technical and/or managerial capacities for managing public lighting	14) Create national or state technical assistance programs 15) Create standardized project evaluation tools 16) Introduce standard templates for EE public street lighting contracts 17) Create guidelines for implementing or adjusting COSIP 18) Standardize business models 19) Standardize financial contracts/instruments	ELETROBRAS; development banks; public banks; SENAI; Brazilian Association of Municipal Administration; private sector; Associations of Brazilian Municipalities
	Lack of common understanding of the sector by the different Audit Courts (TCs)	20) Ensure efficient and effective flow of information between the municipal audit courts to promote consistency 21) Arrange seminars for exchanging ideas between the audit counts on the most controversial subjects affecting public lighting contracts	Ministry of Cities; Brazilian Associations of Municipalities; Brazilian Institute of Municipal Administration; municipalities engaging with TCs from the start of the process
	Lack of clear information about the sector	22) Introduce new databases for providing key data related to EE street lighting projects for cities and potential investors (city street lighting inventories, COSIP collection information, etc.)	FNP (to increase the data available in www.comparabrasil.com); ELETROBRAS; energy distributors; cities

Technology	Lack of information about product quality to allow valid comparisons to be made	23) Standardization/certification of LED equipment	Brazilian Association of Technical Norms; INMETRO; certification companies
	Perception of technological performance risks of LED luminaires by municipalities	24) Standardize equipment guarantees provided by suppliers 25) Increase use of other technology risk mitigants available in the market (e.g., insurance)	Brazilian Association of Technical Norms; INMETRO; insurance companies; Ministry of Industry and Commerce
	High cost of LEDs resulting from low level of national production	26) Create an industrial policy for national production of LEDs (review import taxes, etc.) 27) Increase national production by creating credit lines for the national production of LEDs	Minister of Industry and Commerce; Ministry of Finance; BNDES

Source: World Bank.

As shown in Table 39, the vast majority of gaps and barriers require public sector involvement. The different levels of government will play an important role in filling gaps such as: the lack of a national strategy and/or policy, lack of clarity in the legal interpretation of COSIP, the lack of mechanisms to mitigate municipal credit risk, municipal capacity-building, etc. Leadership at the national level will also be indispensable to prioritize and coordinate the aforementioned actions to ensure the efficient use of resources and avoid duplication.

Not all of the above recommendations can realistically be completed in the short term, and some are more critical to the development of the LED street lighting market than others are. In order to facilitate stakeholder uptake and implementation of the above recommendations, this report also categorizes the recommended actions in terms of their indicative timeframe for implementation and their level of priority, as shown in Table 40 below. The numbers at the end of the recommendation correspond to the list in Table 39 above.

This analysis shows that there are a handful of high-priority activities that could be implemented in the short-term to help catalyze the LED street lighting market in Brazil. These include (i) identifying and designating national leaders for leading coordination of EE street lighting initiatives, (ii) creating new public credit lines, (iii) design investment funds offering standardized EE asset class to attract private-sector investors at scale, (iv) creating instruments for mitigating municipal credit risk, and (v) finalizing the standardization/certification of LED equipment. Other important steps will need to be taken in the medium and long term to expand the market, such as standardization of business models and contracts, establishment of new industrial policies to promote domestic LED production, and revision of the legislative framework for public consortia to increase their feasibility (e.g., allow them to take on financing obligations directly).

Table 40 – Prioritization of recommendations and indicative implementation timeframe

Short-term (<1 year)	
Highest priority recommendations	**Important recommendations**
Identify and designate federal, state, and/or municipal leaders to be responsible for leading coordination of EE street lighting initiatives and for helping municipalities to overcome barriers (#6)	Create standardized project evaluation tools (#15)
Create new credit lines and/or instruments for municipalities unable to attract (sufficient) private investment. (#8)	Create guidelines for implementing or adjusting COSIP (#17)
Design investment funds offering new, standardized EE asset class to attract a variety of investors at scale (#9)	Arrange seminars for exchanging ideas between the audit counts on the most controversial subjects affecting public lighting contracts (#21)
Create instruments for mitigating municipal credit risk (#11)	Introduce new databases for providing key data related to EE street lighting projects for cities and potential investors (city street lighting inventories, COSIP collection information, etc.) (#22)
Standardization/certification of LED equipment (#23)	
Medium-term (1–3 years)	
Highest priority recommendations	**Important recommendations**
Identify possible actors with regulatory knowledge to fill regulator gap, or at least to provide regulatory advice to municipal governments when necessary (#1)	Standardization of the legal framework cities can use to earmark COSIP funds (#3)
The federal government interpret and clarify what are the legal uses of COSIP (e.g., for expenditures electricity, O&M, expansion, modernization). (#2)	Establish a uniform approach for oversight agencies verifying the legal provisions applied to different procurement bidding modalities. (#5)
Standardize business models (#18)	Federal government should design a national strategy for EE street lighting, including targets for converting the national public street lighting network to LEDs (#7)
Standardize financial contracts/instruments (#19)	Explore new instruments that may reduce FX risk that are affordable and available over the longer term (e.g., partial indexation in US$) (#13)
Create an industrial policy for national production of LEDs (review import taxes, etc.) (#26)	Create national or state technical assistance programs (#14)
	Introduce standard templates for EE public street lighting contracts (#16)
	Ensure efficient and effective flow of information between the municipal audit courts to promote consistency (#20)
	Standardize equipment guarantees provided by suppliers (#24)
	Increase use of other technology risk mitigants available in the market (e.g., insurance) (#25)
	Increase national production by creating credit lines for the national production of LEDs (#27)

Long-term (>3 years)	
Highest priority recommendations	**Important recommendations**
Revise the legislative framework for public consortia to allow direct financing of the public consortium´s legal entity (#4)	Provide electric utilities different incentives to promote EE street lighting by altering the form of compensation for energy distributors, namely through decoupling sales (and MWh) and revenues (#12)
Pass new legislation that allows exceptions to be made in municipal debt thresholds in order to enable greater investments in EE public lighting (similar to exceptions that were provided to debt under PROCEL program) (#10)	

9 - Conclusions

In an increasingly urbanized world, global solutions largely depend on locally designed public policies and projects. Energy efficiency projects in cities, which now account for more than two-thirds of energy consumption and more than 70% of emissions, can have a substantial positive impact at the global level.

In the case of public street lighting in Brazil, there is huge potential for increasing energy efficiency with projects that can significantly reduce energy consumption and also meet the country's climate change mitigation goals. However, implementing this kind of project is not a simple task, and there is no single recipe applicable to all cities. Solutions such as adopting PPPs could benefit groups with the appropriate scale and minimum financial/ institutional capacity, while other groups will need the support of specific public policies. It is clear that within these groups each municipality´s needs can vary. The complex nature of the public street lighting services in Brazilian cities presents many challenges and opportunities that need to be faced in the quest for more efficient technologies.

The new LED lighting technologies are now widely accepted throughout the world as a great opportunity for cities to reduce the operational and maintenance costs of public street lighting. These technologies are also important on account of the benefits associated to better lighting quality such as reduced crime and the increased perception of security by residents of communities. They also herald the integration in the lighting services network infrastructure of "smart city" services. Meanwhile, cities such as New York and London, and even entire countries such as India, are making significant progress in implementing large-scale LED projects, thus helping to reduce further the costs of this technology.

Brazilian cities, although aware of the benefits, are still on the threshold of this technological change and are faced with a series of economic, financial and regulatory barriers to developing their public street lighting projects. This is the case not only at the local level, with the imbalance between the amount of investment needed (CAPEX) and the restrictions imposed by the Fiscal Responsibility Law or the lack of access to credit, but also at the macroeconomic level where extremely high interest rates prevail and where deprecation of the national currency is an ever-present concern.

At the same time, Brazilian municipalities are in a relatively favorable position to make investments in the sector, given the mounting costs of energy, the declining costs of LED technology and, in most municipalities, the existence of ring-fenced funds that are available through the COSIP mechanism.

Moreover, the 40%+ municipalities that only recently became owners of their public lighting assets now have incentives to invest in energy efficiency and may wish to identify alternatives to paying electricity utilities to operate and maintain their street lighting networks.

With this initial survey of Brazilian municipalities (in terms of size, fiscal management and public lighting characteristics), it has been possible to identify groups with different capacities and needs. The classification of Brazil´s 5,570 municipalities in six groups is a first step towards finding solutions tailored to their needs. We are aware that there is room for improvement in the proposed classification by, for example, incorporating other relevant data that we have been unable to confirm, such as accurate data on the COSIP revenues or the level of municipalities´ technical and institutional capacities.

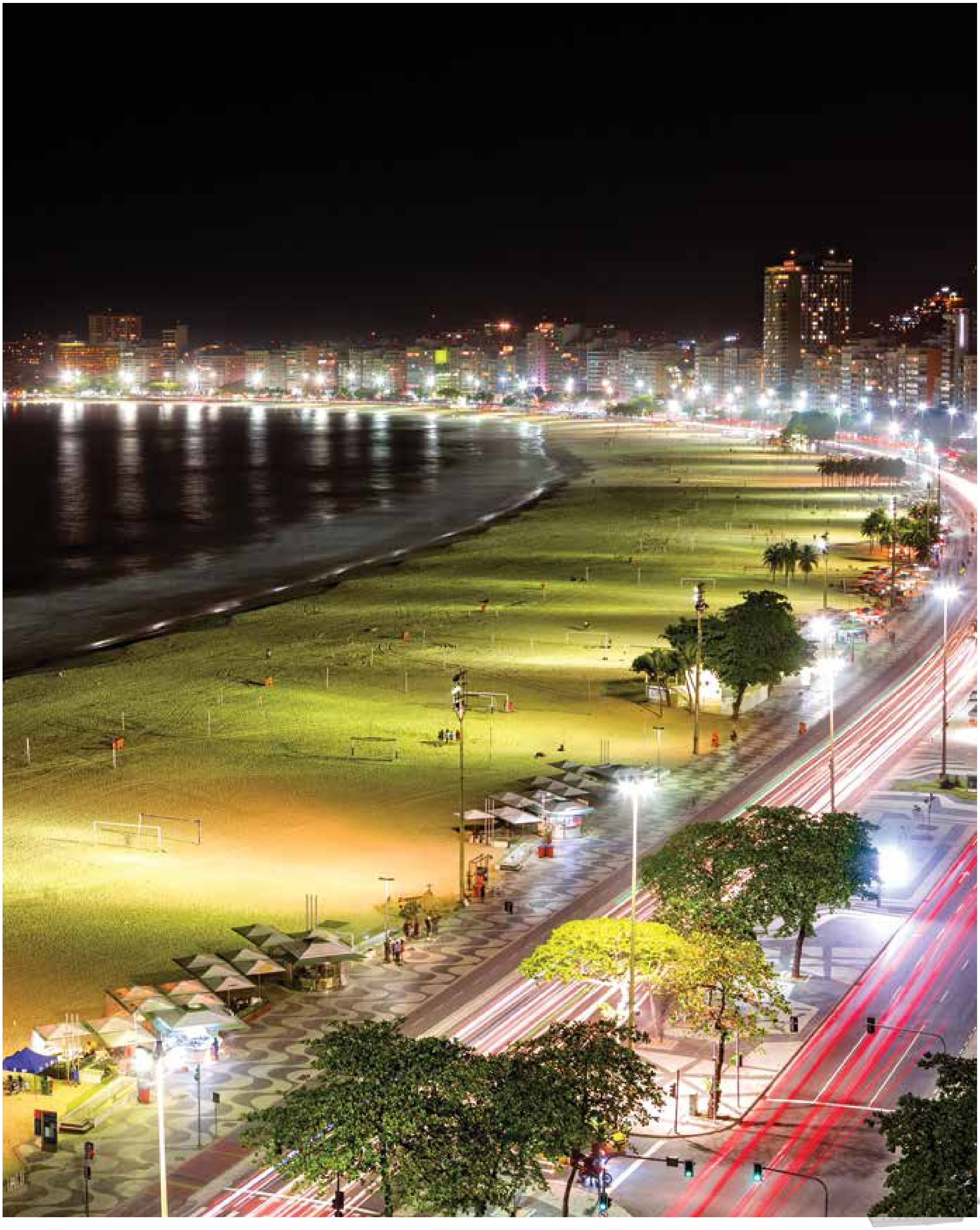
The eight business models presented above take account of the characteristics of the groups of municipalities identified, and propose structures and sources of financing to enable the entire public street lighting system to be scaled up. These models contain a complete range of financing sources - from models that are operated and financed directly by the private sector through to national development programs or operations financed with municipalities´ own revenues.

Before selecting a particular business model, it is important for municipalities to carry out a critical assessment of their own needs and capacity for designing and/or managing each business model. Once the business model has been chosen, the next step is to identify the best sources of finance to take the project forward, including, whenever necessary, additional risk mitigation mechanisms, such as guarantees for mitigating municipal credit risk. This report outlined 10 potential financing and credit enhancement instruments, and showed how these instruments can be tailored to the business models.

The report also identified several challenges and opportunities related to energy efficient investments in the public lighting sector in Brazil, which have been discussed and validated with public and private stakeholders. The report has also served to trigger dialogue among the interested parties, providing material for decision makers to focus on concrete agenda to modernize the public street lighting sector.

In order to speed up the implementation of energy efficiency projects in public street lighting, the report has identified gaps and barriers in the current market, and proposed a series of "next steps" to fill the gaps and overcome barriers. Given that most of these recommendations require governmental intervention, it is important that a national level entity begins to exercise leadership in the sector. The changes that have occurred at the federal government level over the past few months, including the creation of an Executive Secretariat in the Investment Partnerships Program (PPI) and the introduction of Law 13,280/2016, which enhances the role of ELETROBRÁS (PROCEL) in the area of energy efficiency, could well provide opportunities for federal agencies to take a leadership role in promoting the energy efficient public street lighting agenda.

The World Bank Group stands ready to support the Brazilian government and other key stakeholders to accelerate investments in modernizing the public lighting sector and increasing energy efficiency.



ANNEXES

ANNEX 1 – Summary of Business Models

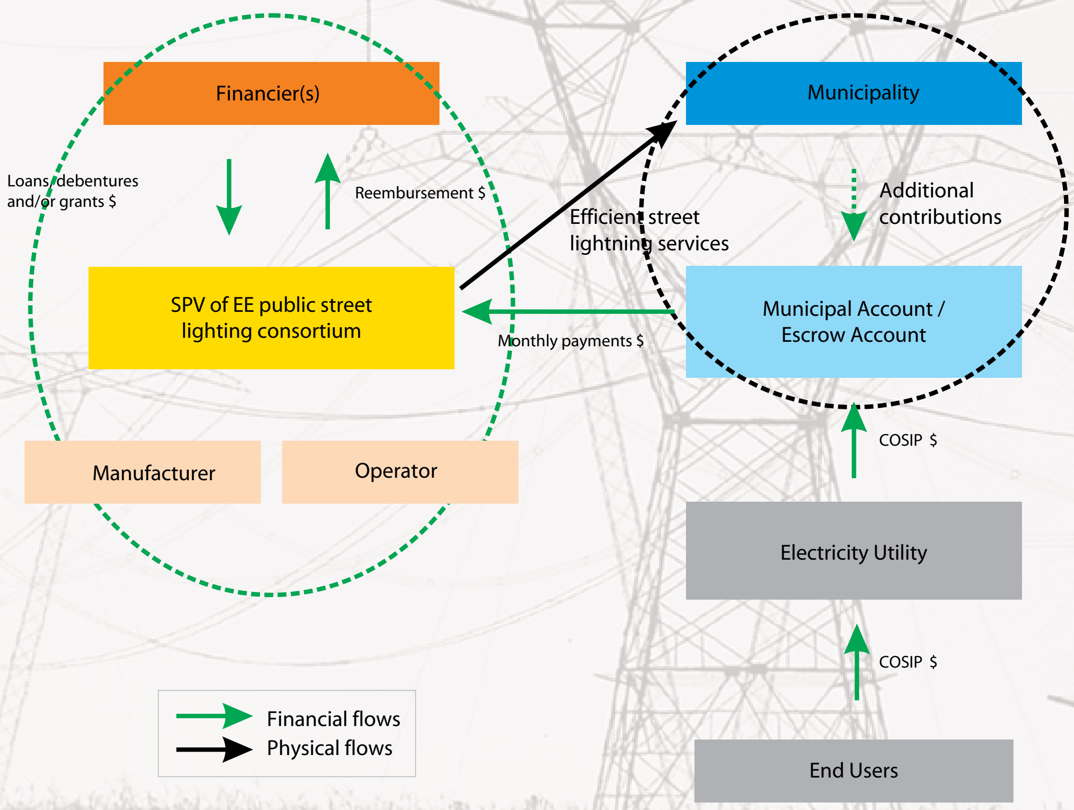
Model M1: Public-Private Partnership (PPP)

Some public lighting projects in Brazil are able to attract private capital through a PPP. This applies especially for large cities with good credit standing. The following is an outline of the PPP model.

Main Characteristics

- The existence of a concessionaire. The municipality awards a concession involving compliance with a range of responsibilities (installation, O&M) related to the system over the PPP contract life.
- SPV is formed by the winning consortium (for example, an operator, lender and manufacturer), to be responsible for raising finance for the project.
- The city remunerates the concessionaire through monthly payments using COSIP (or, if insufficient or nonexistent, the municipal budget).
- COSIP is collected by the electric utility and transferred to a municipal or escrow account.

Figure 24 - Example of the structure of the PPP model



Groups

- Groups A and B represent a total of 135 municipalities (2.4% of Brazil's municipalities)
- These municipalities contain 40.9% of the total population and R$10.1 billion of investment (42.4% of the required investment for the entire country).

Advantages

- The public sector transfers most of the performance risk to the private sector, which has better ability to manage this risk.

Disadvantages

- Transaction costs involved in a PPP preparation can be significant.

Risks

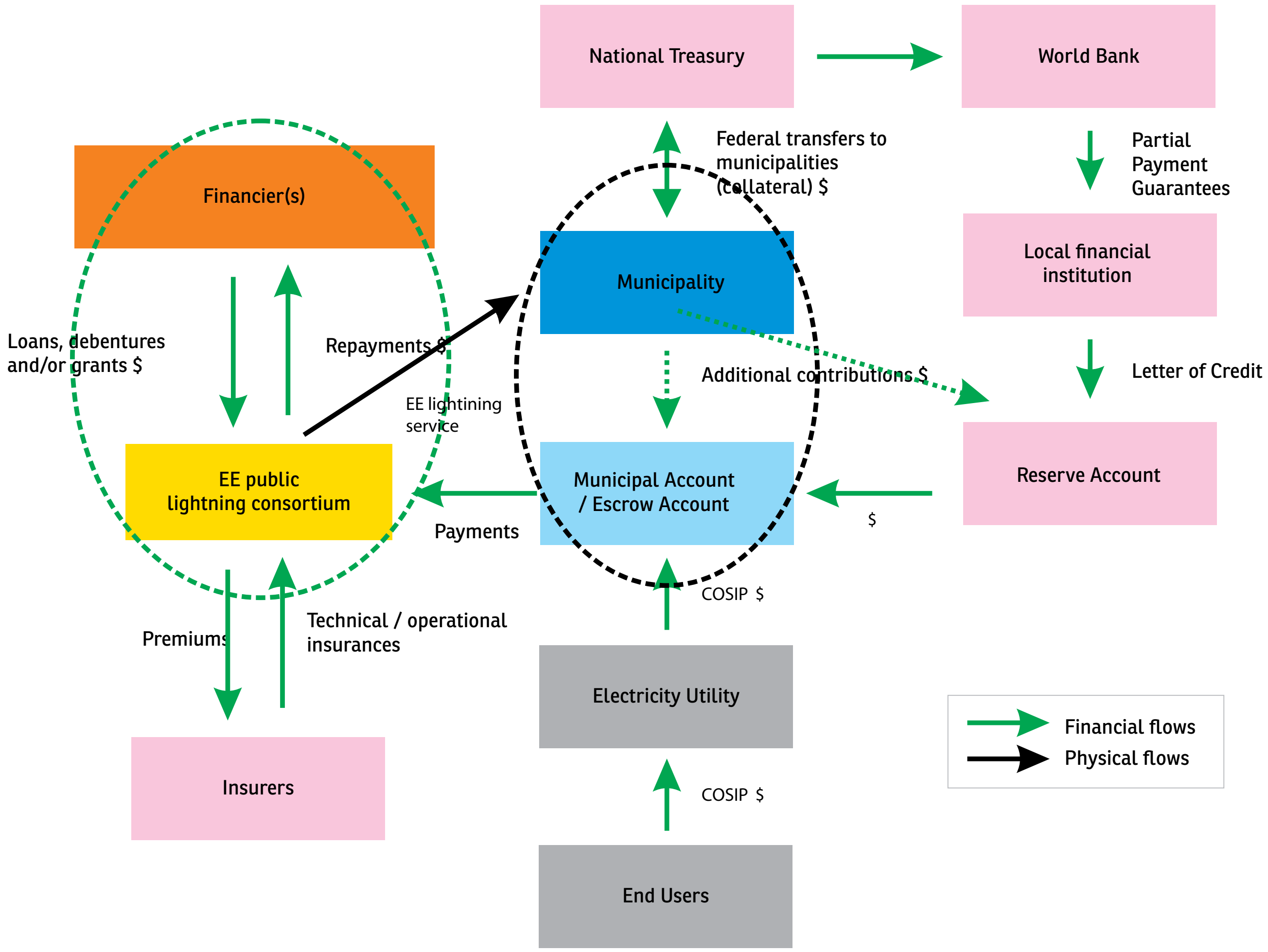
- Lack of qualified municipal personnel.
- Municipal credit risk, lack of funding.
- Lack of regulatory framework.

Mitigating Factors

- Capacity-building for municipalities, standardization of contracts.
- Implementation of COSIP and provision of credit guarantees.
- Public Audit Court (TC) involvement in the initial phases of the project.
- Performance guarantees provided by the manufacturer and/or concessionaire.

Figure 25 shows a potential scheme for the use of guarantees in a public lighting PPP to mitigate the above-mentioned risks. This scheme includes the creation of a reserve account as a partial guarantee of payment by the municipality to the public lighting consortium of the PPP. This mechanism is usually formulated to cover obligations from the Escrow Account during a term of three to six months. The mechanism includes a sovereign guarantee by the National Treasury.

Figure 25 – Example of use of guarantees in the PPP model



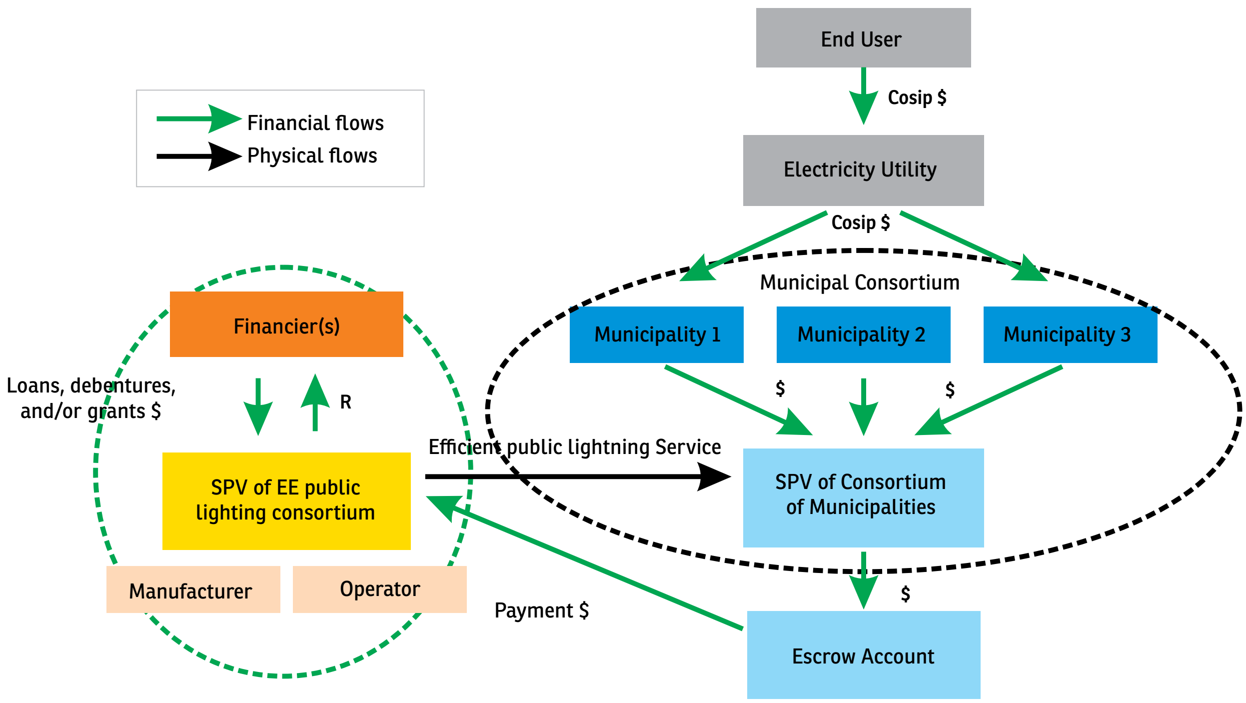
Model M2: PPP with Municipal Consortium

Given that it is not feasible for a large number of municipalities to individually grant concessions using the PPP model, municipal consortia are a possible solution to generate the scale necessary for the implementation of a PPP. International experience shows that there are huge economies of scale to be derived from the procurement of luminaires. This model is summarized below.

Main Characteristics

- Municipal consortium formed by small- or medium-sized municipalities, with the creation of a SPV.
- Very similar to M1, although a municipal consortium can be the granting authority.
- SPV of the municipal consortium reimburses the concessionaire via monthly payments from COSIP (or, if insufficient or nonexistent, from the municipal budget).
- COSIP is collected by the electric utility and transferred to a municipal or escrow account.

Figure 26 - Example of the structure of the PPP/Municipal Consortium model



Groups

- Most suitable for municipalities in Group C, due to small scale, typically less than 20,000 luminaires.

Advantages

- Increases the feasibility of the PPP model to a larger number of municipalities.
- Diversification of municipal credit and political risk.

Disadvantages

- Consortium governance is more complex; transaction costs and perception of risk can be high.

Risks

- Lack of municipal consortium qualified personnel.
- Lack of clear governance of the municipal consortium.
- Municipal credit risk, lack of funding.
- Lack of regulatory framework.

Mitigating Factors

- Training for municipalities and the consortium; standardization of contracts.
- Implementation of COSIP and provision of credit guarantees.
- Audit Court involvement in the initial phases of the project.
- Performance guarantees provided by the manufacturer and/or concessionaire.

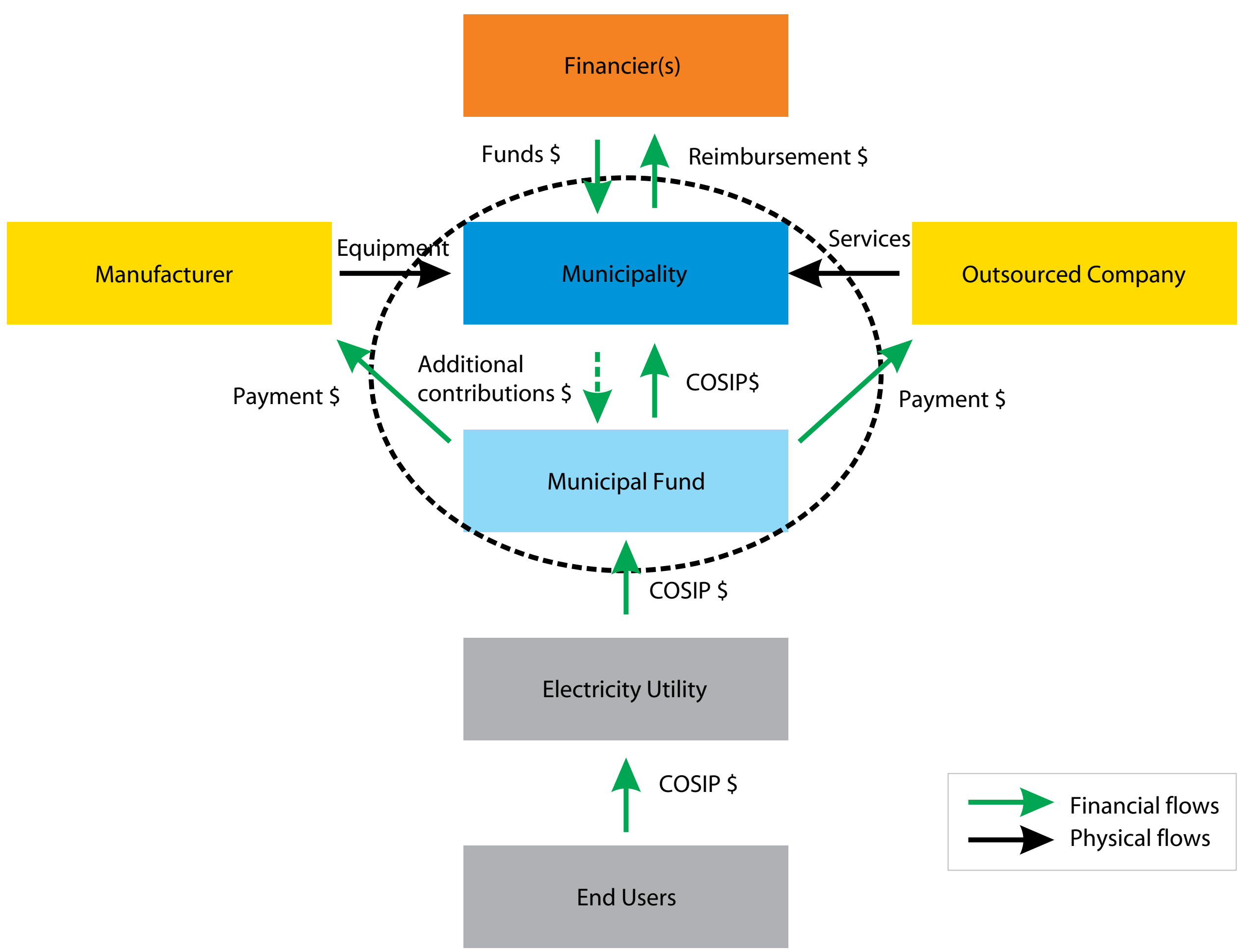
Model M3: Municipal Finance

The large amount of capital needed to implement LED technology is the main challenge to the conversion of the public lighting network, considering the relatively high upfront outlay. In Model M3, the municipality itself is responsible for raising finance and making investments. Below is a summary of the model.

Main Characteristics

- The municipality takes on loans or issues bonds.
- The municipality reimburses the lender through monthly payments using COSIP (or, if insufficient or nonexistent, from the municipal budget), collected by the electric utility and transferred to a municipal or trustee account.
- The municipality is responsible for undertaking O&M services either on its own, or outsourcing and overseeing them.

Figure 27 – Example of the structure of municipal financing model



Groups

- The relatively small municipalities in Group B (88 total) and Group C (329 total), have good fiscal management and scale, but perhaps this scale is not sufficient to justify the transaction costs associated with structuring a PPP.

Advantages

- Project structuring less complex (fewer players, routine bidding process already set forth in Law 8.666/1993).

Disadvantages

- Restricted ceilings of municipal indebtedness disqualify many municipalities
- Municipalities could use their available tax resources for investments in other areas that could not be undertaken by the private sector (opportunity cost).
- The public sector assumes most of the responsibility for project performance.

Risks

- Lack of technical and human know-how to manage the process.
- Municipal credit risk, investors´ lack of interest

Mitigating Factors

- Training in best national/international practices; competitive biddings; adequate technical performance guarantees; specialized advisory services for the municipalities.
- Consortia experience in the solid waste treatment sector is an advantage.
- Implementation of COSIP, credit guarantees.

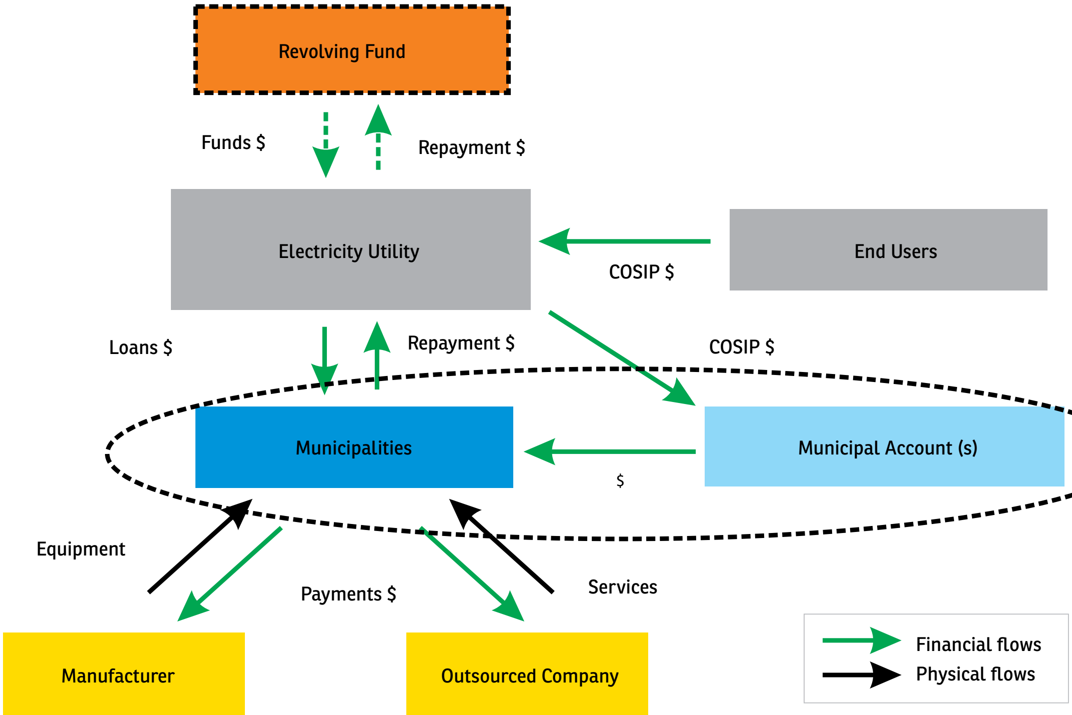
Model M4: Electric Utility Programs

As previously described, in both the national programs dedicated to the public lighting sector (PROCEL-Reluz and PEE), electricity utilities have an important role in the financing and/or facilitation of investments for large-scale public street lighting projects. Given their lack of resources, these two programs currently have little potential for increasing the volume of investments, but it is possible to envisage a scenario where utilities could play a major role in modernizing Brazil's public lighting network, as well as being involved in a wider range of energy efficiency projects. Below is a description of the model.

Main Characteristics

- Represents an expansion of the PEE program, with some design changes.
- The electric utility grants loans to municipalities; these are recovered from two sources: from the municipality (COSIP or municipal budget) and from increased electricity tariffs for end users (as already occurs under the PEE program).
- Net receipts from the program would be transferred to a Revolving Fund for financing public lighting projects.
- The municipality is responsible for O&M services (on its own or outsourced).

Figure 28 - Example of structure of electricity utilities program model



Groups

- Municipalities in Groups D and E (>4.200 municipalities; 75% the population); in certain cases, some municipalities from Groups C and F. (represent R$9.4 billion in investment).
- Relatively small-scale, with relatively good fiscal management

Advantages

- Loan costs below capital market levels.
- Benefits from funding centralization and better risk diversification
- Option for municipalities with few options to raise funds

Disadvantages

- Requires regulatory change by ANEEL in an environment where the trend is to reduce involvement in the sector by electricity utilities.

Risks

- Lack of interest by electricity utilities, or non-approval by ANEEL of the project concept.
- Municipal demand for funds exceeds supply.
- Municipalities lack qualified personnel to implement the project.

Mitigating Factors

- Strong engagement with ANEEL over the benefits of the program; or, in the short term, the utilities would earmark more PEE resources for the public lighting sector[87].
- To restrict number of eligible municipalities (e.g., small–medium size) and provide capacity-building for municipalities.

[87]This may be possible for concessionaires operating in areas with few low-income consumers. There is a regulatory obligation to invest 60% of the PEE funds in this group of consumers, but in some concession areas the market is already saturated and there is not sufficient demand in this sector for concessionaires to invest. A recent legal change (Law No. 13.280/2016) establishes a maximum of 80% of PEE investments in low-income areas, with no minimum limit.

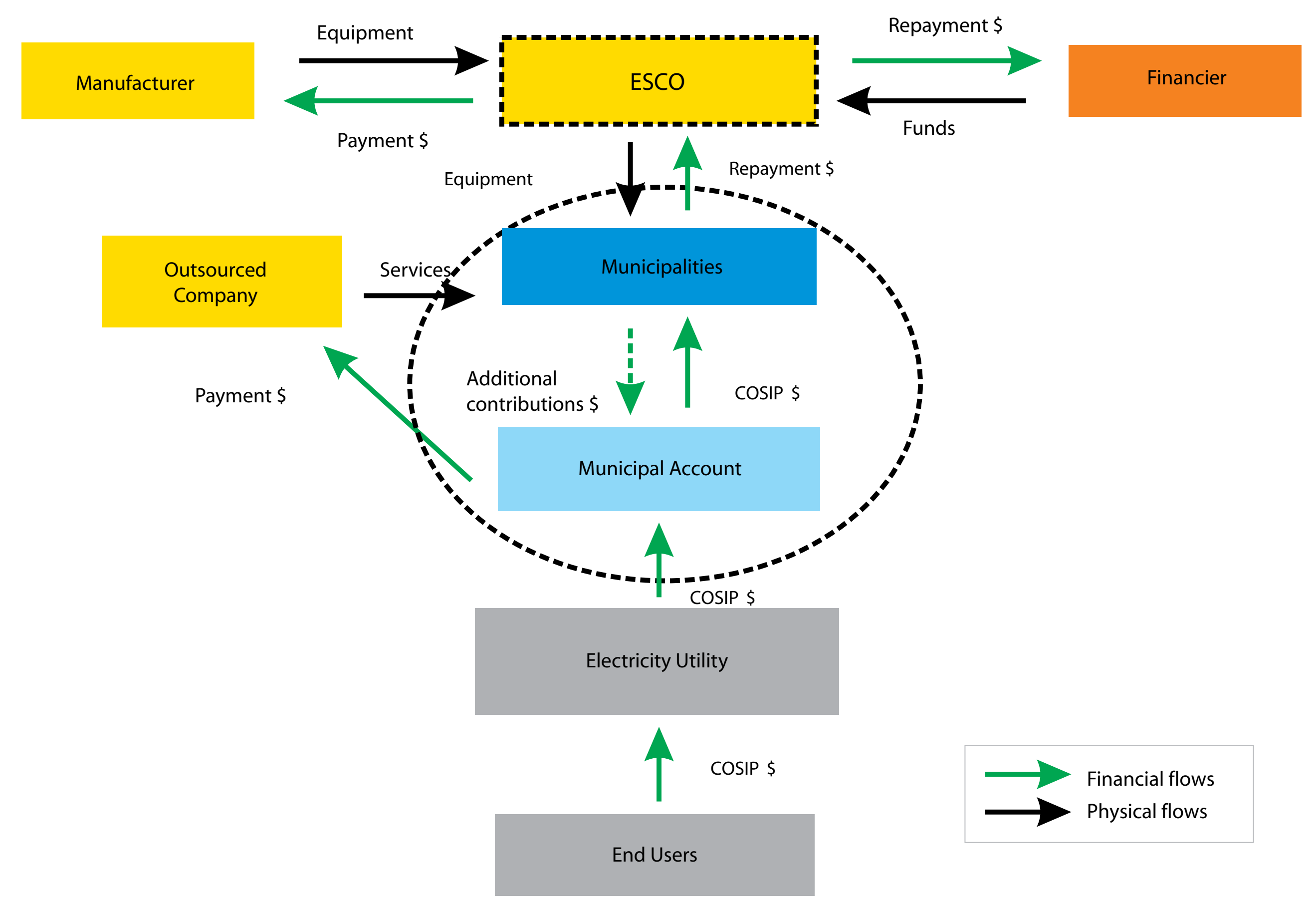
Model M5: The ESCO Model

This model involves off-balance sheet financing for the municipality, where the investment is made by a third party ("*third-party financing*"). In this way the investments for modernizing the public lighting network do not affect municipal indebtedness limits. Below is a summary of the ESCO model.

Main Characteristics

- The company or consortium of companies (SPV) raises funds, purchases and installs LED luminaires in exchange for regular payment by the municipality using COSIP and/or the municipal budget.
- The municipality is responsible for O&M services (on its own or outsourced).
- Two modalities: (1) the ESCOs share the efficiency gains; or (2) the ESCOs receive a fixed payment for the investment made and present a product performance technical guarantee.

Figure 29 – Example of structure with ESCO model



Group

- This model is applicable to Group C, which totals 329 municipalities, characterized by relatively small-scale, but with good fiscal management.

Advantages

- Provides an off-balance sheet financing option for smaller municipalities, without requiring the same level of involvement by the regulator or political changes as model M4.

Disadvantages

- Smaller coverage compared to M4.
- Higher costs for municipalities given that ESCOs have less access to the municipal resources directly linked to consumer electricity payments.

Risks

- Lack of qualified municipal personnel to manage the project.
- Lack of ESCOs´ financial capacity to ensure financing, thus reducing the scope and scale of the project.
- Municipal credit risk.

Mitigating Factors

- Capacity-building for municipalities.
- Increase financing lines for ESCOs; focus on ESCOs that are subsidiary companies of electricity utilities; concentrate on small-scale projects.
- Implement COSIP, credit guarantees.

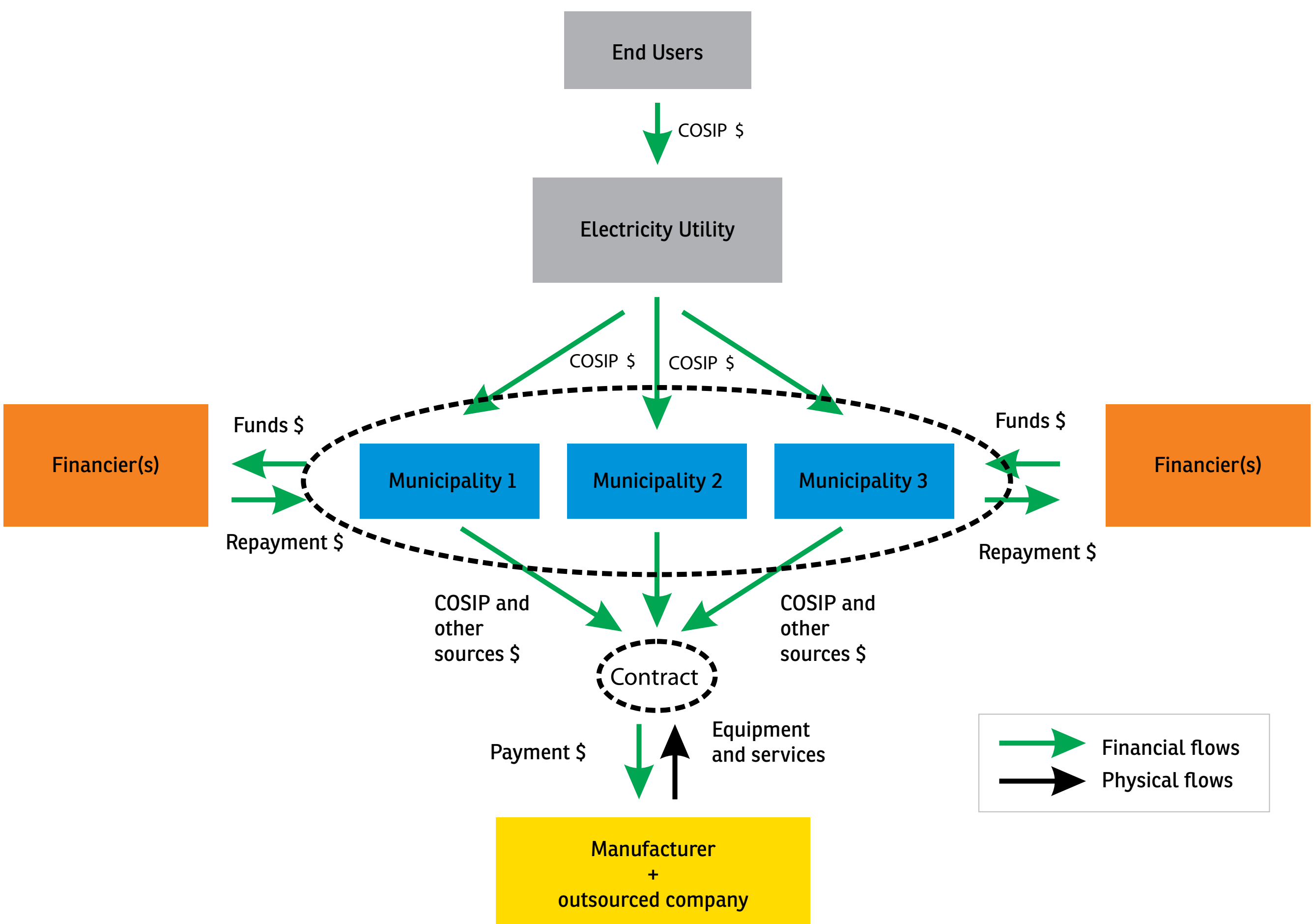
Model M6: Centralized Procurement

This model seeks to capture economies of scale related to joint equipment (and possibly services) procurement by multiple municipalities without the responsibility for raising finance. Below is a summary of this model.

Main Characteristics

- Establishment of a consortium or other mechanism (or process) to undertake centralized procurement.
- If an SPV is established this would raise funds for the municipality; if not, municipalities are responsible for raising financing themselves.
- The municipality is responsible for O&M services (on its own or outsourced).

Figure 30 – Example of structure of centralized contracting model



Groups

- This model is applicable to municipalities in Groups C and D (1.216 municipalities; 21.8% of the population).
- In some cases it could also apply to Groups E and F.

Advantages

- Potential for lower transaction costs compared to model M2, if SPV not established.

Disadvantages

- If a SPV is not established, municipalities' difficulty to raise financing is not resolved.

Risks

- Municipalities' lack of qualified personnel to prepare technical specifications.
- Complex coordination involved in raising finance for several municipalities.
- Municipal credit risk; investors' lack of interest.

Mitigating Factors

- Capacity-building for municipalities.
- Standards covering legal and financial issues for municipality consortia.
- Implementation of COSIP, credit guarantees.

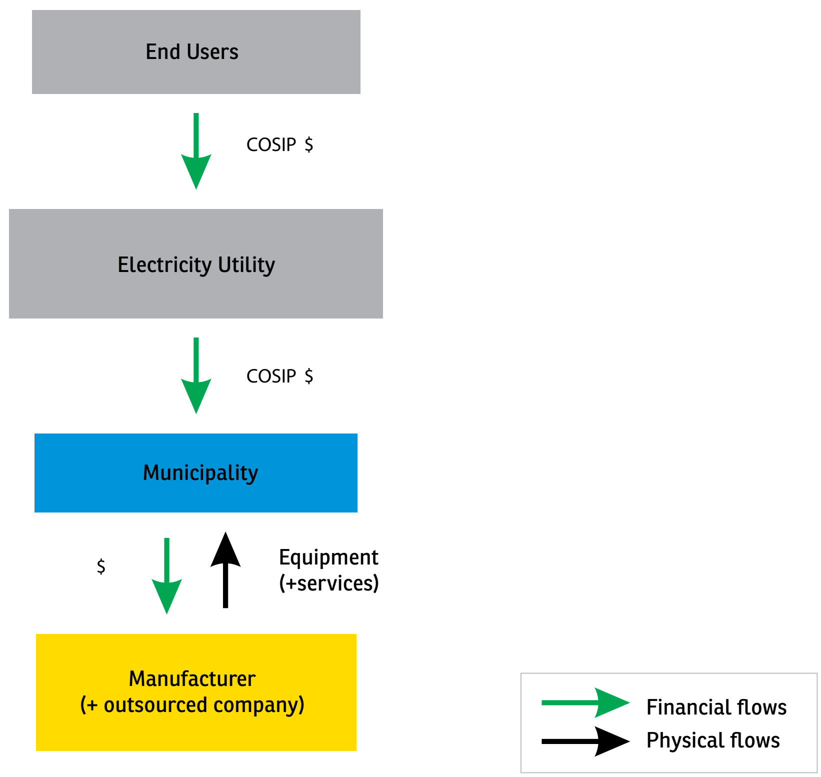
Model M7: Self-Funding

When municipalities have no other options to raise funds for their projects, one alternative is to self-fund projects over a longer timescale reflecting the municipality´s financing availability. A summary of this model is below.

Main Characteristics

- Municipalities undertake public lighting modernization investments using public lighting revenues *pari passu* with corresponding expenditures and investments.
- Involves slow pace of investment (and a longer period of lighting retrofit), basically depending on whether COSIP revenues are subsidized or not with funds from the municipal budget.

Figure 31 – Example of structure of self-funding model



Groups

- This model is applicable to municipalities in Groups C and D (1.216 municipalities; 21.8% of the population).
- In some cases the model could apply to Groups E and F.

Advantages

- Low transaction costs due to not requiring financial or institutional arrangements.
- This could be one of the few viable options for some cities unable to obtain government support.

Disadvantages

- In municipalities with small scale and low staff qualification there is less space for creating a COSIP that would produce enough revenue to finance investments.
- Greater performance risk for municipalities.

Risks

- Lack of municipal qualified personnel to prepare the technical specifications.
- High cost per lamp due to small-scale purchasing; lack of resources to implement the project.

Mitigating Factors

- Capacity-building for municipalities.
- Robust COSIP implementation to produce surplus funds for the retrofit project.

Model M8: Transfer of Luminaires

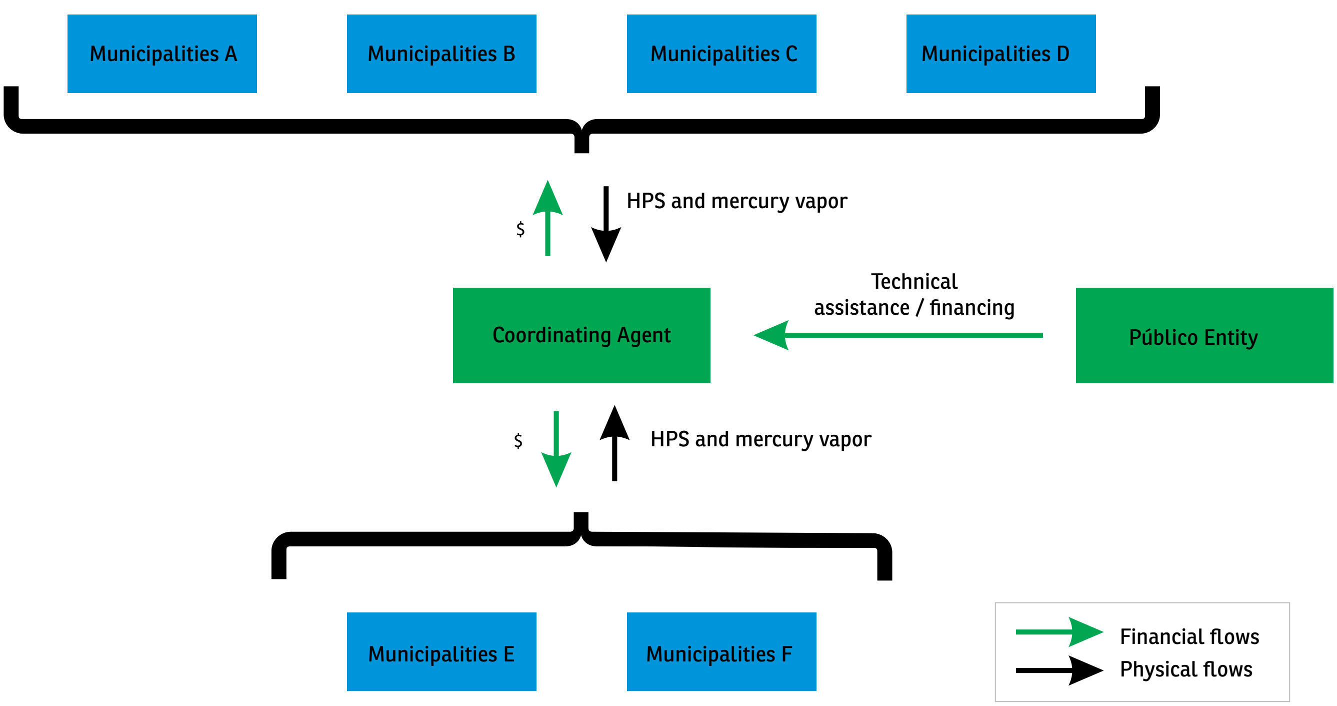
This model involves the transfer of HPS (or mercury vapor) lamps, together with complete luminaires, from cities that have been LED-retrofitted, to other cities that use less efficient lamps but which are at present unable to modernize their public lighting networks with LAD due to lack of finance, etc.

The model presupposes a massive conversion in the next few years of HPS and mercury vapor lamps to LEDs[88]. This would result in a large stock of secondhand HPS lamps that will be available for transferring to locations that cannot yet afford to invest in LED lighting and which still use other less efficient technologies.

Main Characteristics

- Interim transfer system of stocks of HPS from municipalities that have been retrofitted with LEDs to municipalities unable to afford LED lighting in the short or medium term.
- Creation of a coordinating structure to handle bilateral transactions using transparent auctions organized by public or private agents.
- The buyers would be municipalities or outsourced companies; the sellers would be municipalities or private entities that have acquired the materials from the municipalities.

Figure 32 – Example of structure of luminaire transfer model



[88]In 2012 the installed network of HPS lamps amounted to 11.4 million units, far more than the 1.2 million light points currently existing in the Group F municipalities. Metallic multivapor lamps totaled 201,000, and mercury vapor lamps (candidates for substitution) 3.8 million. There is also an operational public street lighting network using incandescent lamps (188,000), mixed lamps (283,000), fluorescents (160,000) and halogen lamps (10,900).

Groups

- Groups E and F, with 4.219 municipalities (approximately R$1.6 billion)

Advantages

- Provides an opportunity to improve energy efficiency and lighting services in municipalities with low buying power or financial/institutional difficulties.

Disadvantages

- The implementation of a sale/exchange/ donation system may be operationally complex.
- Possible shorter service life of the re-located equipment.

Risks

- Complex coordination resulting in high transaction costs.
- Lack of interest or capacity of public and/or private agents in the scheme.
- Lack of municipal resources or qualified personnel.

Mitigating Factors

- Involvement of public sector agency to supervise the process and of private sector actors interested in providing services.
- Prices charged to municipalities must adequately reflect the technical risks.
- COSIP implementation consistent with creating a surplus to finance lighting modernization.

ANNEX 2 - S / P Correction between Scotopic Vision (S) and Photopic Vision (P)

Table 41 - S / P correction factor between scotopic vision (S) and photopic vision (P)

Low pressure sodium	0.25
High pressure sodium (HPS) 250 W clear	0.63
HPS 400 W clear	0.66
HPS 400 W coated	0.66
Mercury vapor (MV) 175 W coated	1.08
MV 400 W clear	1.33
Incandescent	1.36
Halogen headlamp	1.43
Fluorescent Cool White	1.48
Meetal halide (MH) 400 W coated	1.49
MH 175 W clear	1.51
MH 400 W clear	1.57
MH headlamp	1.61
Fluorescent 5000 K	1.97
White LED 4300 K	2.04
Fluorescent 6500	2.19

Source: Outdoor Lighting: Visual Efficacy. Volume 6, Issue 2. January 2009. Alliance for Solid-State Illumination Systems and Technologies. Lighting Research Center. Rensselear Polytechnic Institute

ANNEX 3 - Methodology for Generating Clusters and Grouping of Municipalities

Brazil has 5,570 highly heterogeneous municipalities. Designing financing models for the public street lighting of these requires the prior grouping of municipalities with similar characteristics in order to facilitate the segmentation of the modeling task and tailor the distinctive features of each group to a different model.

This section presents the approach and procedures employed in the construction of a taxonomy of Brazilian cities. The study involved: database construction; cluster analysis; regrouping; and a representative analysis of the groupings thus obtained.

3.1 - Summary of Approach and Methodology

The overall goal of the project was to identify business models for public street lighting projects in Brazilian municipalities. The municipalities are highly heterogeneous, both in terms of socioeconomic characteristics (size, income levels and development), and in their physical and demographic features, all of which are relevant to the modernization of the public lighting network in terms of demographic density, degree of verticalization of the urban mesh, etc. This degree of heterogeneity makes it impossible to design a general model to apply to all Brazil´s municipalities.

The first challenge of the project is therefore to identify groups of municipalities with similar features, prior to suggesting the business models best suited to different local circumstances. In short, it is necessary to form substantial groups of municipalities to develop effective solutions for public lighting projects.

The approach was based on three principles:

i. For the analysis input, a set of variables needed to be considered to mirror the underlying fiscal and socioeconomic features of the municipalities while respecting data quality and availability constraints.

ii. The methodology of the analysis was based on accepted scientific models.

iii. Regarding analysis outcomes, the number of resulting groups needed to be small, so that business models could be effectively applied based on the instruments and actors available in the Brazilian market.

Note that two grouping procedures were performed — a *statistical cluster analysis*, followed by the identification of homogeneous clusters — for two main reasons:

- The *cluster* model allowed the insertion of a set of key elements in the analysis such as the physical configuration and density of the network, as well as fiscal aspects, thereby producing a model far superior to a simple visual stratification with only two or three variables;
- Large cities, especially São Paulo and Rio de Janeiro, tend to form clusters with a single municipality, which could lead to a very heterogeneous grouping. In these cases the cluster analysis needed to allow for the formation of more homogeneous groups.

After the *clusters* were identified, and in order to include in the analysis other aspects relevant to the development of the public lighting network, clusters of municipalities were grouped according to the variables *network size* and *fiscal management*.

The two-step strategy allowed for consideration of multiple key factors to be considered (size, development, fiscal situation, network density, sectorial indicators) while maintaining a small number of clusters. Without these two steps it would have been necessary to initially include a specific number of clusters in the statistical analysis, or to choose a type of stratification based on few indicators. In the event we were able to obtain a small number of groupings that met the key requirements of the study.

3.2 - Database and Selection of Variables

The dataset for the study is formed by Brazil's existing 5,570 municipalities. In the selection of variables, we considered those that could potentially be used in the financing models but which had not been considered previously, since the grouping and modeling needs to address different characteristics, although related to the common goal (public lighting modernization). There was a simple reason for this: to use a variable in the statistical model that had already been used for the initial segmentation would have weakened its predictive power, since the segments had already become homogeneous in relation to this particular characteristic.

It is not possible to design a generalized business model for public lighting projects. The primary challenge was therefore to group the municipalities in terms of their similarities to develop solutions that could be adapted to each type of municipality.

The first data source consisted of a research survey carried out in over 300 Brazilian municipalities with different demographic and economic profiles for us to gain a better understanding of the overall context of the country's public street lighting sector.

After tabulation and revision, the data obtained from this exercise were consolidated and calculated for each of the states, for the geographic regions, and for Brazil as a whole, with weightings based on the number of municipalities per state. The precision index for the survey results are shown in Table 42, by region.

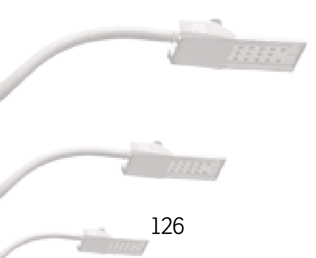


Table 42 - Precision index by region

Region	Precision index (%)
North	86.3
Northeast	90.3
Center-West	81.3
Southeast	89.7
South	85.7
BRAZIL	94.5

Source: World Bank; Castagnari Consultoria Ltda.

With this research data and a quantity of socioeconomic information obtained on all the Brazilian municipalities, the team was able to group the municipalities according to their capacity to develop different business models to enable investments targeted at lighting sector modernization.

The set of socioeconomic characteristics included the economic status of the municipalities, their physical size, the size and density of the lighting network, levels of socioeconomic development and their fiscal situation. Other sectorial indicators such as type of lighting technology and existing network coverage were drawn directly from the aforementioned sample survey.

Table 43 summarizes the characteristics considered most relevant for selecting well-delineated groups — obtained from public data sources and which were intuitively related in some way to a potential financing outcome (default). The variables were derived from public sources (IBGE, Firjan, National Treasury, Ministry of Cities), with the exception of data on the public street lighting situation in Brazilian municipalities, provided by the World Bank Group sample survey of 300 municipalities.

Table 43 - Database characteristics

Variable	Definition	Objective/logic for using	Unit	Year of data
GDP per capita	GDP divided by number of inhabitants of municipality	Proxy of the municipality´s level of development	R$	2012
Consumer units per water supply connection	Measurement of the water supply network density. A connection consists of the consumer unit/units linked via a single extension to the distribution network.[89]	Proxy of the level of "verticalization" of the municipality, thus of the public street lighting network density. The public water supply system often covers the same area as the public lighting network.	Ratio	2013
IFGF	Index for measuring how taxes paid by community residents are administered by the municipal authorities. Composed of five indicators: Own Revenue, Personnel Costs, Investments, Liquidity, and Debt Cost.	Proxy of the level of the municipality´s fiscal management.	Index	2013
NCD/NCR	Ratio between NCD (Net Consolidated Debt) and Net Current Revenue (NCR).[90]	To measure municipality´s indebtedness level.	Ratio	2015
Number of light points	Estimate of the number of light points in the public street lighting system. [91]	Proxy of the size of municipalities, and to estimate the size of the public street lighting system - also a proxy for assessing the level of investment needed for a public lighting retrofit project.	Number	2014
More than 20% mercury vapor lamps used in the public street lighting network[92]	Indicator (yes/no) to estimate whether the municipality uses more than 20% of inefficient mercury vapor lamps in its public street lighting network[93]	Efficiency level of the current network in order to gauge the possible level of energy savings via a modernization program	Indicator	2014
Percentage of the municipality not covered by public street lighting	Percentage of the municipality not covered by public street lighting.[94]	Proxy for the amount of investment needed to modernize the existing network versus extension of the network to unserved areas.	Percentage	2014

Source: IBGE; FIRJAN; National Treasury; Ministry of Cities, World Bank Group

Note: The population was not considered, in view of the high correlation with GDP (95.6%).

The size of municipalities was calculated on the basis of the total number of existing light points in use. Meanwhile, a municipality's development level was assessed by its per capita GDP measured in monetary units.

The database included aspects of the configuration of the public lighting network of each municipality. To assess the extension and density of public lighting networks, we researched the public water supply service, which essentially covered the same

[89]For example, a building with ten apartments can have a single connection serving ten consumer units, therefore for this building the ratio consumer units/per connection = ten.
[90] There are cases where the municipality may have negative NCD (i.e., cash availability exceeding financial liabilities). In this case a negative NCD/NCR index indicates how much cash the municipality has in relation to its Net Current Revenue.
[91]Using current available data and estimates using a regression model when data unavailable.
[92]Technology used in the network estimated from the use of a proportion of more than 20% mercury vapor lamps.
[93]Using current data when available and estimates using a regression model when they are not available.
[94]In these variables, we used data from a sample survey done by the World Bank Group with Brazilian municipalities, with no data available for the entire universe of municipalities.

geographic area as that of the public street lighting service. We observed, for example, the density (consumer unit per connection)[95] of the water supply network, which also gave an idea of the 'verticalization' of the urban space (i.e., a greater density of population per light point can make a public lighting project more feasible).

The following two variables were used to show the characteristics of the municipalities from the standpoint of their fiscal (tax) management and indebtedness:

- Firjan Index of Fiscal Management (IFGF), which aims to measure how a population' s taxes are handled by the municipal governments. This index comprises five indicators: own revenue, personnel expenses, investments, liquidity and debt cost.
- Ratio of Net Current Debt (NCD), which is the amount of the Consolidated Debt of the municipality deducted from the balance of financial assets, and Net Current Revenue (NCR - the total of tax revenues accruing from property, agricultural, industrial, service-provision activities as well as other current transfers and receipts). There are cases where the municipality may have negative Net Debt, i.e., with cash availability exceeding its financial liabilities. In this case, a negative NCD/NCR index indicates how much cash the municipality possesses in relation to Net Current Income (NCI).

To calculate the size of the public street lighting network, the number of light points were counted directly or estimated for each municipality[96]. The obsolescence of the network was assessed on the basis of the use of 20% or more mercury vapor lamps in the municipal system. Network coverage was determined by the percentage of the municipality not covered by public lighting. For these variables, we used data from the above-mentioned World Bank survey.

We sought to include other data such as the value of the COSIP that might have been relevant to business models, but the databases consulted, such as FINBRA, provided little information in this respect. We decided therefore not to take this variable into account in the grouping.

The matrix of the cross-correlations of the selected variables is shown in Table 44. It can be seen that the level of correlation between pairs of variables is relatively low, which indicates that all of them have a key explanatory power for the selection of the groups (i.e. the "redundancy" level is low)[95].

Table 44 – Matrix of cross-correlations of selected variables

Correlations	a) GDP per cap	b) Cons. Units	c) IFGF	d) NCD/NCR	e) No. Light Points	f) MV > 20%	g) % w/out PL
a) GDP per cap	1.000	0.124	0.323	–0.152	0.305	–0.087	–0.237
b) Consumer Units	0.124	1.000	0.163	–0.015	0.401	–0.077	–0.139
c) IFGF	0.323	0.163	1.000	–0.349	0.316	–0.132	–0.143
d) NCD/NCR	–0.152	–0.015	–0.349	1.000	0.524	–0.028	–0.019
e) No. Light points	0.305	0.401	0.316	0.524	1.000	–0.088	–0.098
f) MV > 20%	–0.087	–0.077	–0.132	–0.028	–0.088	1.000	0.024
g) % without public lighting	–0.237	–0.139	–0.143	–0.019	–0.098	0.024	1.000

[95] A connection is an extension connected to the distribution network. For example, a building with ten apartments can have a single connection serving ten consumer units, therefore for this building the ratio consumer units/per connection = ten.

[96] The model used for the estimated calculation of light points was derived from the data obtained from the sample survey of the socioeconomic characteristics of Brazilian municipalities.

[97] The GDP variable was considered, but given the fact that it had a high correlation with the number of light points in the municipality (0.912) it was not used in the analysis.

3.3 - Generation of Clusters

The purpose of cluster analysis is to group sample units of interest (i.e., individuals, companies, cities, countries, etc.) into categories, so that the components have a high degree of affinity or homogeneity while maintaining a clear distinction between classification groups. The cluster analysis technique is used when the classification category structure is not known in advance and when there is little or no information about it. A single list of observations has unknown grouping categories, and the core objective is to discover a classificatory structure that fits the available data.

The number of possibilities for grouping a small sample of observations into a small number of groups can be very substantial. Most of these possibilities are irrelevant or are simply variations that rival other possibilities of greater interest. Complex cluster analysis algorithms enable structures and relationships to be found between observed data that are not evident from a quick visual inspection. The method allows these possibilities to be reduced to the relevant choices for analysis of the problem.

The 18 clusters (homogeneous groups) obtained in the analysis are randomly described below as follows[98]:

• **Cluster 1 (number of municipalities = 110):** The municipalities of this group have prominent verticality (1.54 consumer units per connection) among non-high income municipalities (average GDP per capita R$ 19,500). They also have, on average, fewer light points (7,300), but with reasonable to good fiscal management (average IFGF of 0.59) and an average cash flow of 7% of Net Current Revenue. Of the municipalities with available data, there is no public lighting in 7.45% of their territories.

• **Cluster 2 (number of municipalities = 887):** Comprises municipalities with an average per capita GDP of R$16,000. These possess a average of 2,400 light points. While these municipalities have fairly low economic standing, they are nevertheless well-managed (average IFGF of 0.63), with have an average cash flow of 11.5% of net revenues. All the municipalities with available data use more than 20% mercury vapor lamps and on average 6.45% of their territories have no public lighting.

• **Cluster 3 (number of municipalities = 73):** The municipalities in this cluster are also not high-income (average per capita GDP of approximately R$16,000) and an average of only 2,000 light points. Moreover , a common feature is that they have no information on the number of units per extension. However, their fiscal management is reasonable (IFGF average of 0.55), although this cluster includes one of the leaders in this respect: Alvorada de Minas (MG), with an IFGF of 0.91, and an average cash flow of 6.4% of Net Current Income. The only municipality with appropriate data available has 80% of its territory with no public lighting.

• **Cluster 4 (number of municipalities = 1):** An exclusive group of the city of Rio de Janeiro (RJ) on account of its unique characteristics compared to the rest of Brazil. Its development is reflected in its income indicators (per capita GDP of R$34,000) and high verticality (2.31 units per extension — one of the highest in Brazil) and a large-scale public lighting network (426,000 light points).

• **Cluster 5 (number of municipalities = 872):** These municipalities are characterized by their small size (average of 2,700 light points) and average income

[98]The data presented here should be considered at the aggregate level.

(per capita GDP of R$20,000). Fiscal management is low (average IFGF of 0.48), and the average cash flow represents 3.6% of NCR.

- **Cluster 6 (number of municipalities = 97):** The municipalities in this group are characterized by their considerable size (an average of around 37,000), reasonable income (average per capita GDP of R$27,700), some verticality (average of 1.3 units per extension) and good fiscal management (an average IFGF of 0.61).

- **Cluster 7 (number of municipalities = 832):** This group comprises the municipalities with the worst indexes (an average of less than 1,000 light points), income (average per capita GDP of R$6,800) and poor fiscal management (average IFGF of 0.23), as well as having average debts corresponding to 6% of NCR. All municipalities for which data is available use more than 20% mercury vapor lamps and on average 13.8% of the territories are not covered by public lighting.

- **Cluster 8 (number of municipalities = 7):** Although these municipalities have a modest scale of public lighting (average of 21,000 light points), they nevertheless have Brazil's highest per capita GDP - average of R$262,000. In general, they have good fiscal management (average IFGF of 0.65) and an average cash flow (negative NCD) of 1.5% of NCR.

- **Cluster 9 (number of municipalities = 1,169):** This group covers municipalities that are more developed than those in group 7 but with small-scale public lighting (average of 1,000 light points), income (GDP per capita of R$8,100) and management (average IFGF of 0.43). Most of them have no debt (average cash flow of 0.78% of net revenue) and, among the municipalities with available data, 4% use more than 20% mercury vapor lamps. An average of 47% of their territories is not covered by public lighting.

- **Cluster 10 (number of municipalities = 4):** This group comprises the municipalities of Fortaleza (CE), Salvador (BA), Belo Horizonte (MG) and Brasília (DF)—with some of the highest verticality in Brazil (an average of 1.59 units per extension and an average IFGF of 0.66), although average income in these municipalities does not significantly exceed that of the rest of Brazil (per capita GDP of R$28,500).

- **Cluster 11 (number of municipalities = 7):** The municipalities in this cluster are characterized by the highest verticality indexes in the country (average of 2.93 units per branch). In general, they have a considerable public lighting structure (average of 29,300 light points) and relatively low incomes (per capita GDP between R$4000 and R$87,000), good fiscal management (with an average IFGF of 0.67) and an average cash flow of 5.4% of net revenue.

- **Cluster 12 (number of municipalities = 1):** This cluster contains only the city of São Paulo (SP), Brazil's largest and richest city with more light points than any others: 600,000. GDP per capita is also high (R$41,000), and considerable (1.59 units per extension).

- **Cluster 13 (number of municipalities = 92):** As with cluster 3, the municipalities in this group have no data on consumer units per extension. Their development indexes are similar to clusters 7 and 9, with average per capita GDP of approximately R$10,000, around 1,700 light points on average and critical fiscal management situation (average IFGF of 0.34). Furthermore their debts correspond on average to 12% of revenue.

- **Cluster 14 (number of municipalities = 17):** This cluster contains a concentration of large

municipalities with an average of 103,000 light points), average per capita GDP of R$41,800 and high verticalization (an average of 1.42 units per extension). In general they possess good fiscal management (average IFGF of 0.64) but with average debt levels of 12% of Net Current Revenue.

• **Cluster 15 (number of municipalities = 460):** This group consists of municipalities with low incomes and a low scale of public street lighting (1,200 light points) and average per capita GDP of R$10,000. However, they are somewhat better-managed (average IFGF of 0.54) than the municipalities in other low development clusters. The municipalities with NCD / NCR data possess a considerable cash reserve - an average of 109% of net revenue.

• **Cluster 16 (number of municipalities = 721):** The municipalities in this group are characterized, similar to clusters 7, 9 and 13, by low development indices: average of 1,500 light points, per capita GDP of R$8,100 and critical fiscal management status (0.33 of IFGF). Unlike the municipalities in clusters 7, 9 and 13 this group has debts corresponding on average to 59.6% of net revenue.

• **Cluster 17 (number of municipalities = 181):** This cluster contains small-scale municipalities (less than 5,000 light points on average), but with a relatively high per capita GDP (average of R$44,500). They possess reasonable fiscal management (average IFGF of 0.55) and a cash flow of 2.6% of revenues. Of the municipalities with data available, they use more than 20% mercury vapor lamps in their public street lighting networks.

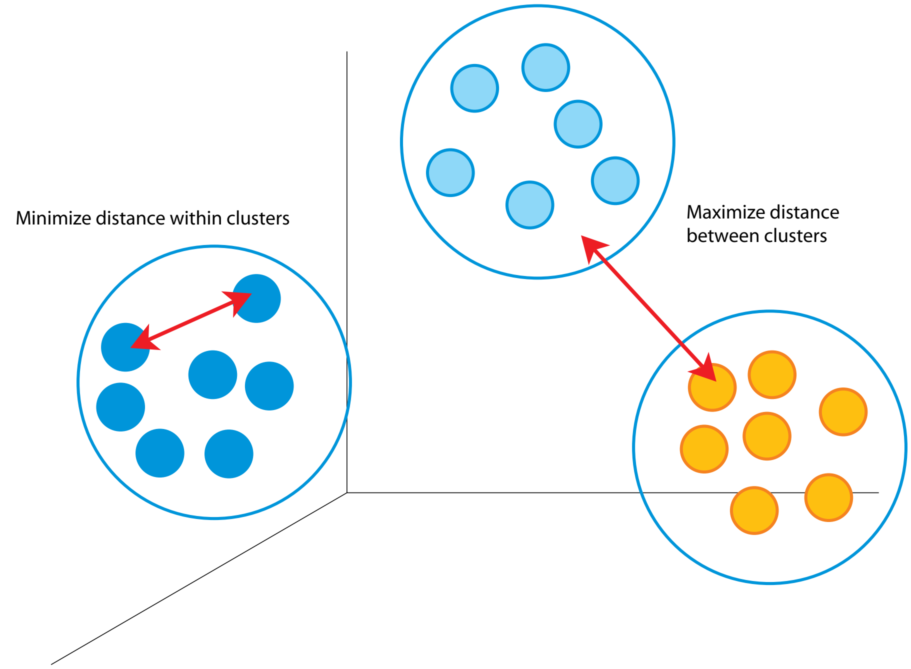
• **Cluster 18 (number of municipalities = 39):** The municipalities in this group have a high per capita GDP (average of R$100,000) and a fairly large public lighting network (an average of 17,000 light points). They also have good fiscal management, with an average IFGF of 0.60 and average cash flow of 7.8% of revenues.

3.4 - Technical Details of Cluster Analysis[99]

In practice, we compare individuals according to observable characteristics, and each characteristic of interest defines a variable of the process. Through the observed variables of each individual *cluster*, analysis determines the closeness or distance that separates individuals, so that nearby individuals are placed in the same cluster (small distance within the groups), and distant individuals (large distance between groups) in different clusters.

[99]This section presents a more technical approach to cluster analysis. For readers interested in a less technical approach this section can be avoided without loss of understanding of the context of the analysis.

Figure 33 – Schematic diagram of cluster analysis



By analyzing a set of p dimensions or attributes of a particular individual (with real values), we can see the individual as a point in a p-dimensional space. Thus it is possible to define the proximity between two points with real value characteristics when using a metric of the distance between both points (in this case the Euclidian metric):

$$d(X,Y) = \sqrt{\sum_{i=1}^{p} (x_i - y_i)^2}$$

where X and Y represent two different points as p-dimensional vectors.

We used the k-means algorithm (MACQUEEN, 1967), which is initialized with the desired number of groups (i.e., the number of clusters must have been previously established). For k clusters, k initial points known as seeds are defined in the p-dimensional space of the data that will function as the centroids of the k groups. The distance between each point and the centroid of the groups is then calculated and the observation is allocated to the nearest centroid group.

Once all the observations have been allocated and the groups formed, the algorithm recalculates the centroids of these and restarts the algorithm, calculating the distances between the observations and the centroids. The algorithm ceases to be used when there is no further group change between the observations.

Grouping largely depends on the initial seed choice — two different choices can lead to completely different groupings (MILLIGAN, 1980). Fortunately there are seed selection techniques that ensure that the resulting groups will be well-discriminated. For more details on such methods see Pavan et al. (2011).

Although there are no totally satisfactory methods for determining the optimum number of groups (EVERITT, 1980; Harkan, 1985; BOCK, 1985), the decision criterion used in this analysis is based on two metrics known in the scope of the cluster analysis. The first is the pseudo-F statistic (CALINSKI; HARABASZ, 1974), which is a ratio between the sum of squares between groups and within groups, weighted by their respective levels of freedom (which are functions of sample size and the number of clusters).

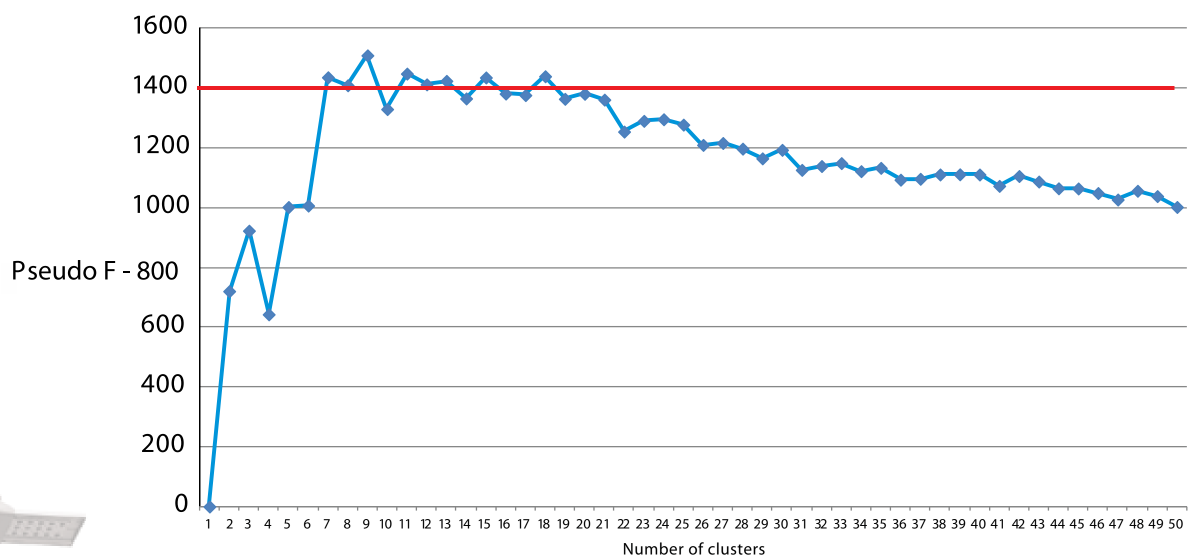
The idea of using pseudo-F statistics is to evaluate whether the groups formed have very concentrated elements (i.e., low variance in the group) while, as groups, remaining distant from each other (i.e., high variance between groups). We can analyze the evolution of pseudo-F statistics as the number of clusters gradually increases, and we have to consider the extent to which the pseudo-F statistic increases in relation to the previous number of clusters (MILLIGAN, COOPER, 1985).

The second metric is the Cubic Clustering Criterion (CCC), created by the SAS software (SARLE, 1983). This is a statistic that compares the variance between the groups obtained with the variance of these groups in the hypothetical case of the observations being distributed uniformly (plus making cluster analysis impracticable). The positive values of this statistic indicate that the variance between the groups formed is greater than it would be if the data had a uniform distribution, thus indicating in this case that Cluster Analysis is necessary. The author also indicates the statistic as a criterion for choosing the number of clusters as well as the pseudo-F (high CCC values = good groupings).

50 independent cluster analyses were performed, each with a number of clusters ranging from 1 to 50. The pseudo-F and CCC statistics were computed for each cluster, and the former led to the graph in Figure 34. Since there are several peaks in a region where the pseudo-F is high (between 6 and 18 groups), the approach was to establish a threshold value for the statistic and treat all clusters above the threshold as potential candidates. These indicate the quantities of groups in which the discrimination of the municipalities (in terms of reduction of group variance) is optimal. In this study a Harper value of 1,400 was chosen (Figure 34), and the 8, 15 and 18 groups stood out as potential candidates.

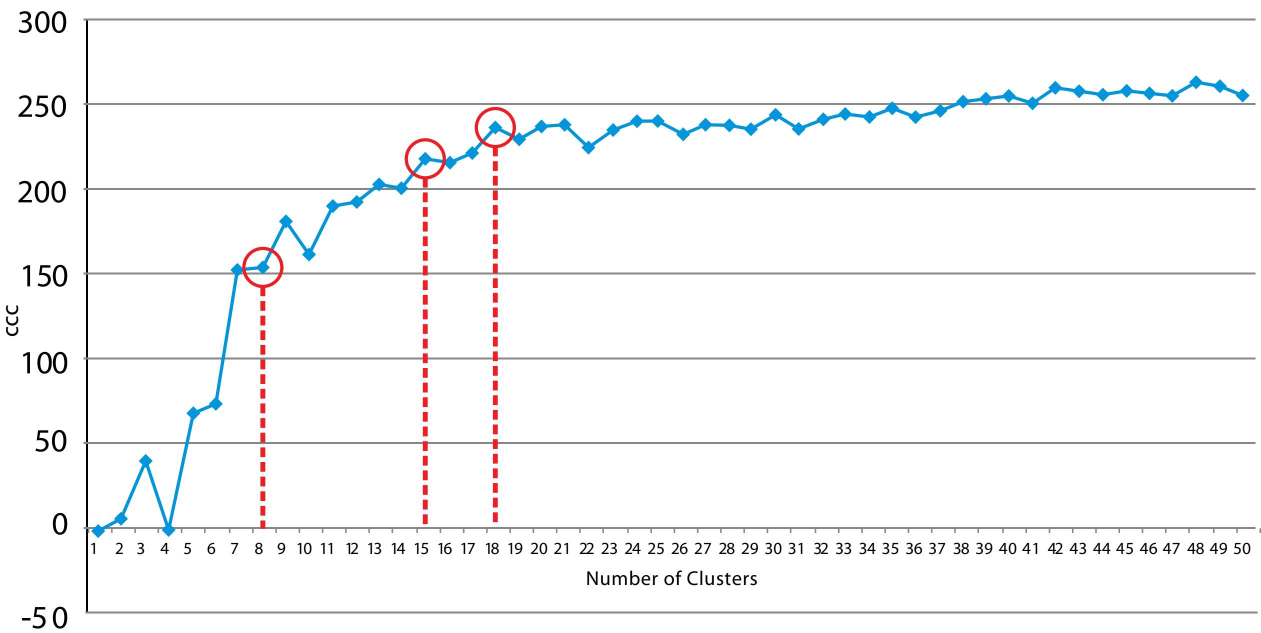
In order to make the final decision on the number of groups, the CCC statistic (Figure 35) was compared for the numbers of groups exceeding the specified ceiling, where it is possible to observe that the group of 18 clusters has an advantage, with a much greater CCC than the analyses with the 8 and 15 clusters. Given the criteria outlined above, and also to enhance the granularity of the groups, 18 groups were considered.

Figure 34 - Evolution of pseudo-F statistics for different amounts of groups



Source: World Bank Group; Pezco Consultoria

Figure 35 - Evolution of CCC statistic for different amounts of groups



Source: World Bank Group; Pezco Consultoria

After forming the 18 groups, Table 45 shows for each of the variables a comparison between the variances within and outside the groups, resulting in an index that determines how well the variable is broken down by the *clusters*. The index also reveals the relevance of the variable in the formation of groups (different from statistical significance insofar as no hypothesis test is performed).

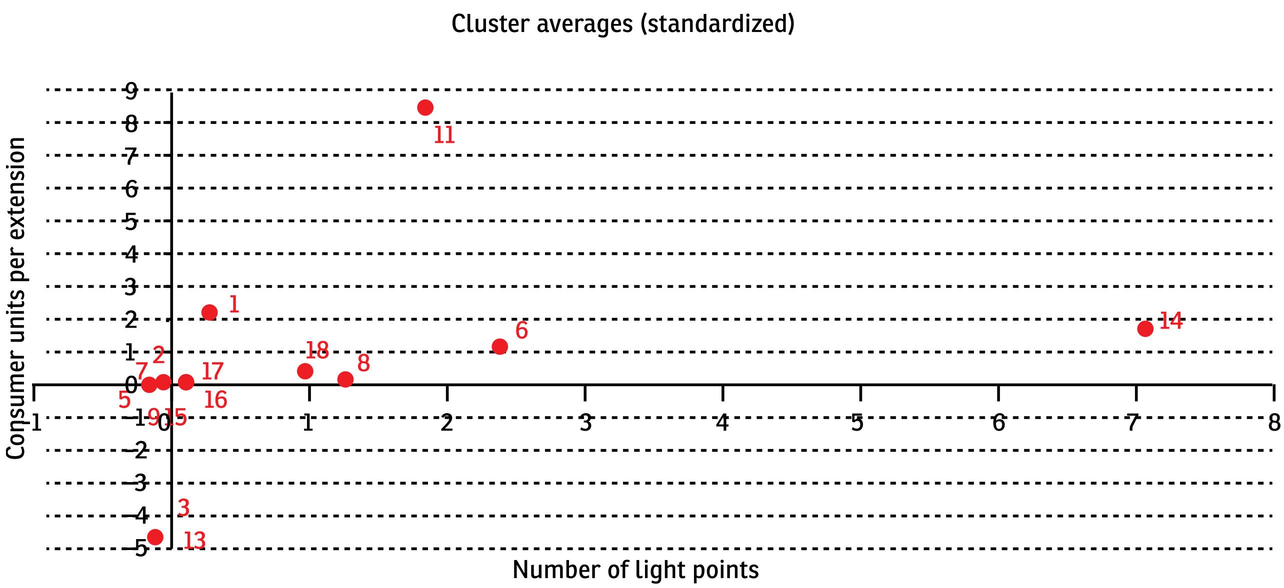
Table 45 - Relevance of variables in the formation of groups

Correlations	$R^2/(1 - R^2)$
Per capita GDP	3.80
Extensions/consumer unit	7.26
IFGF	3.57
NCD/NCR	1.57
No. light points	10.53
MV > 20%	8.80
% with no public lighting	2.29

It can be seen that the variables reflecting the number of light points, the utilization of mercury vapor lamps and the consumer units per per connection are the most outstanding features of the groups, while the NCD / NCR ratios and the percentage of territories not covered by public lighting are lower in the ranking. This means that although there are clearly distinct groups (e.g., in terms of the number of light points) the proportion of non-coverage by public street lighting differs very little between the groups.

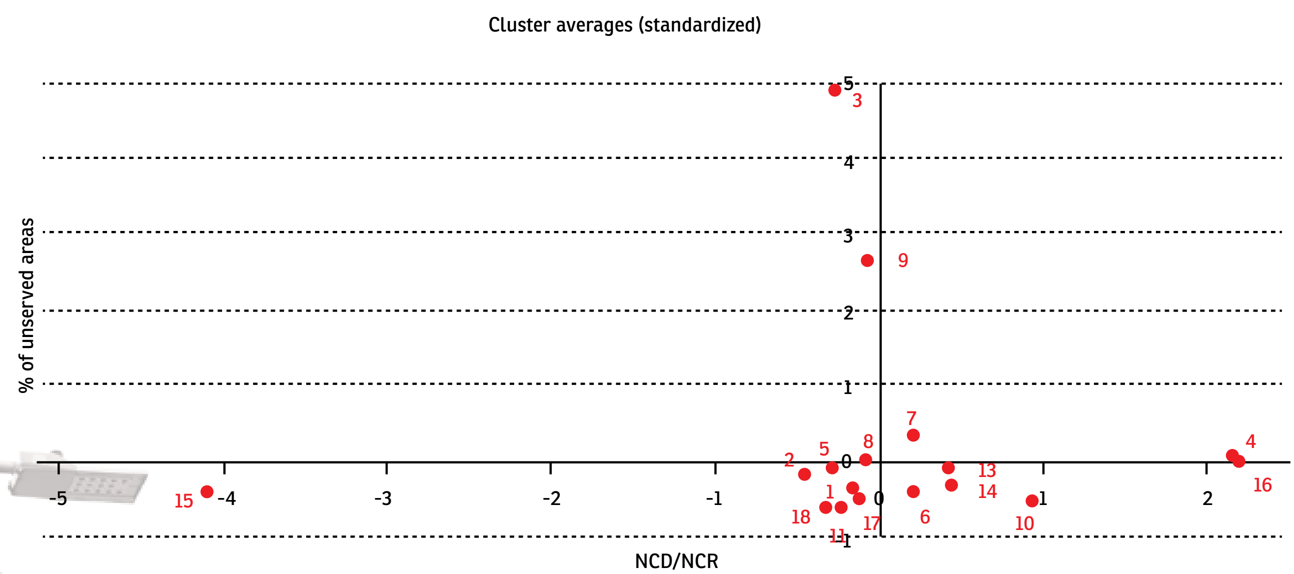
The dispersion diagrams (Figures 35 and 36) show the standardized averages of the clusters obtained and therefore give an idea of their location. Note that the graph in Figure 35, involving two key variables for the cluster, shows groups that are distant from each other. This graph, however, does not show groups 4, 10 and 12 due to the scale of the graph (they have standardized average light points of 30, 14 and 42 respectively). The distance between the averages of the groups shows that the two variables show clear divisions n the data (hence the need for a breakdown). Figure 36 shows two less relevant variables and does not clearly show where the data should be divided to form the groups — the distance between the averages of the clusters here is considerably smaller (note the scale of the graph). It is also worth considering that the two graphs are comparable because the variables observed have been reduced to the same scale. In this way they possess an average of 0 and a variance of 1.

Figure 35 - Dispersion diagram of the clusters averages of the variables GDP and consumer units per connection



Source: World Bank Group; Pezco Consultoria

Figure 36 - Diagram of dispersion of the averages of the clusters relative to the NCD / NCR variables and % of non-coverage of public lighting



Source: World Bank Group; Pezco Consultoria

Table 46 shows, for each of the 18 groups, the averages of the variables considered in the study, while Table 47 lists the groups within each variable (from best to worst average). For example, a municipality with a high use of mercury vapor lamps is interesting from the standpoint of the need for it to invest in public street lighting. Using this criterion, the *higher* the number, the *worse* the group is in relation to the specific variable. If two or more groups have the same average, the group with the lowest standard deviation is favored.

Table 46 - Average variables in each group

Cluster	No. of municipalities	Number of light points	Per capita GDP (Brazilian R$)	Econ/Lig	IFGF	NCD/NCR	No. of light points	MV > 20%
1	110	7,297	19.476,50	1,54	0,59	–7,07	0,00	7.45
2	887	2,442	16.090,86	1,07	0,63	–11,52	1,00	6.45
3	73	1,953	15.889,60	0,00	0,55	–6,43	0,00	80.00
4	1	426,609	34.232,33	2,31	0,82	58,69	0,00	10.00
5	872	2,755	20.109,47	1,06	0,48	–3,57	0,00	3.97
6	97	36,876	27.785,22	1,30	0,61	6,39	0,07	3.07
7	832	907	6.866,14	1,02	0,23	6,31	1,00	13.83
8	7	21,249	262.525,95	1,08	0,65	–1,55	–	–
9	1,169	1,053	8.100,13	1,03	0,43	–0,78	0,04	47.25
10	4	206,000	28.518,58	1,59	0,66	25,65	0,00	1.33
11	7	29,388	35.982,75	2,93	0,67	–5,43	0,00	0.00
12	1	600,000	41.978,81	1,59	0,77	185,74	0,00	7.00
13	92	1,763	9.985,46	0,00	0,34	12,00	0,00	7.80
14	17	103,018	41.797,52	1,42	0,64	12,61	0,00	4.22
15	460	1,224	10.096,27	1,03	0,54	–109,00	0,00	3.45
16	721	1,504	8.177,45	1,04	0,33	59,57	0,00	9.02
17	181	4,978	44.574,25	1,06	0,55	–2,60	1,00	1.67
18	39	16,925	100.173,63	1,12	0,60	–7,79	0,00	0.00

Source: World Bank Group; Pezco Consultoria

It is important to note, among other things, that groups 4, 10 and 12 are prominent from the standpoint of scale (number of light points) and fiscal management (IFGF), groups 8 and 18 by income (GDP per capita), groups 4 and 11 by verticalization (consumer units per extension), and groups 2 and 7 by the number of municipalities using mercury vapor lamps. Groups 7, 9, 13 and 16 have a negative profile in terms of development (number of light points, GDP per capita) and fiscal management. Table 48 assigns A, B, C and D ratings to the groups by considering the averages of each variable, while respecting some of the thresholds suggested in Table 48.

Table 47 - Classification of clusters in each variable

Cluster	No. munic.	Per capita GDP (Brazilian R$)	Econ/Lig	IFGF	NCD/NCR	No. light points	MV > 20%	% without IP
1	110	R$ 19,476.50	1.54	0.59	–7.07	7297	0.00	7.45
2	887	R$ 16,090.86	1.07	0.63	–11.52	2442	1.00	6.45
3	73	R$ 15,889.60	0.00	0.55	–6.43	1953	0.00	80.00
4	1	R$ 34,232.33	2.31	0.82	58.69	426609	0.00	10.00
5	872	R$ 20,109.47	1.06	0.48	–3.57	2755	0.00	3.97
6	97	R$ 27,785.22	1.30	0.61	6.39	36876	0.07	3.07
7	832	R$ 6,866.14	1.02	0.23	6.31	907	1.00	13.83
8	7	R$ 262,525.95	1.08	0.65	–1.55	21249	.	.
9	1169	R$ 8,100.13	1.03	0.43	–0.78	1053	0.04	47.25
10	4	R$ 28,518.58	1.59	0.66	25.65	206000	0.00	1.33
11	7	R$ 35,982.75	2.93	0.67	–5.43	29388	0.00	0.00
12	1	R$ 41,978.81	1.59	0.77	185.74	600000	0.00	7.00
13	92	R$ 9,985.46	0.00	0.34	12.00	1763	0.00	7.80
14	17	R$ 41,797.52	1.42	0.64	12.61	103018	0.00	4.22
15	460	R$ 10,096.27	1.03	0.54	–109.00	1224	0.00	3.45
16	721	R$ 8,177.45	1.04	0.33	59.57	1504	0.00	9.02
17	181	R$ 44,574.25	1.06	0.55	–2.60	4978	1.00	1.67
18	39	R$ 100,173.63	1.12	0.60	–7.79	16925	0.00	0.00

Table 48 - Criteria for assigning score for each variable

Score	Per capita GDP (in R$1000s)	Econ/Lig	IFGF	NCD/NCR	No. light points (thousands)	MV > 20%	% without IP
D	< R$ 15	N/D	< 0.4	> 100	< 2	—	> 15
C	[R$ 15 ; R$ 30)	< 1.2	[0.4; 0.6)	(10; 100]	[2 ; 20)	< 1 ou.	(8; 15] ou.
B	[R$ 30 ; R$ 60)	[1.2; 1.8)	[0.6; 0.8)	(–10; 10]	[20 ; 100)	[1;50)	(4; 8]
A	>= R$ 60	>= 1.8	>= 0.8	<= –10	>= 100	>= 50	<= 4

3.5 - Regrouping

The clusters analysis method produced a number of clusters that cannot be easily identified with business models (i.e., nonoperational). In principle, the analysis should result in a small number of clusters, so that business models can be effectively applied based on a set of instruments and actors currently available in Brazil

Reducing the number of clusters involved carrying out a new procedure consisting of grouping 18 clusters into a total of six larger groups by making a qualitative evaluation of characteristics that had similar prospects for the implementation of appropriate business models. The regrouping mainly took into account scale and fiscal management, as can be seen in Table 49.

Table 49 - Regrouping of clusters according to main characteristics

Group	No. of municipalities	Clusters incorporated	Size of municipality[100](number of light points)	Fiscal management (IFGF average; NCD/NCR)
A	47	4, 10, 12, 14*	Very large >50.000	Relatively well-managed IFGF average >0.6 NCD/NCR average > 0
B	88	6, 8, 11, 18	Large 20.000–50.000	Relatively well-managed IFGF average >0.6 NCD/NCR average > 0
C	329	1, 17**	Medium-sized <20.000	Relatively well-managed IFGF average = 0.6 NCD/RC average L < 0
D	887	2	Small Average< 5,000	Relatively well-managed IFGF average >0.6 Average NCD/NCR < 0
E	3.406	3, 5, 7, 9, 15	Very small Average < 2,000	Moderately managed IFGF average >0.4 NCD/NCR average < 0
F	813	13, 16	Very small Average < 2,000	Limited management IFGF average <0.3 NCD/NCR average > 50

*Includes municipalities in Group B with more than 50,000 light points
** Includes municipalities in Group B with less than 20,000 light points

Source: World Bank Group; Pezco Consultoria

[100] Thresholds of 20,000 and 50,000 light points were identified through consultations with market agents.

3.6 - Relevance of Clusters

The relevance of groups formed by clustering is shown in Table 50—in absolute numbers of municipalities, size of resident population, number of light points and the amount of capital expenditure (CAPEX) required to convert the public lighting network to LED technology.

Table 50 - Relevance of groups of municipalities, absolute numbers

Groups	No. of municipalities	Population	Light points (estimated)	Capex (estimated), in R$
A	47	59.878.706	5.052.440	6.547.962.240,00
B	88	23.763.643	2.771.156	3.591.418.176,00
C	329	14.706.648	2.073.597	2.687.381.712,00
D	887	23.033.096	2.161.580	2.801.407.680,00
E	3.406	64.445.770	5.085.685	6.591.047.760,00
F	813	18.613.109	1.246.586	1.615.575.456,00
BRASIL	5.570	204.440.972	18.391.044	23.834.793.024,00

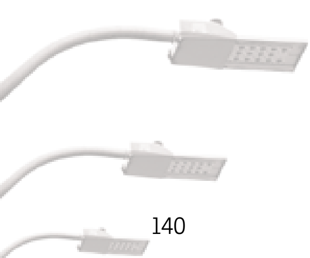
Source: World Bank Group; Pezco Consultoria

Table 51 presents the relative importance of the clusters in the Brazilian context. (in percentage terms over national aggregates).

Table 51 - Relevance of groups of municipalities,%

Groups	No. of municipalities	Population	Light points (estimated)	Capex (estimated), in R$
A	0,84%	29,29%	27,47%	27,47%
B	1,58%	11,62%	15,07%	15,07%
C	5,91%	7,19%	11,28%	11,28%
D	15,92%	11,27%	11,75%	11,75%
E	61,15%	31,52%	27,65%	27,65%
F	14,60%	9,10%	6,78%	6,78%
BRASIL	100,00%	100,00%	100,00%	100,00%

Source: World Bank Group; Pezco Consultoria



ANNEX 4 - International Standards and Specifications for High Performance Luminaires

The Global Lighting Challenge (GLC), a Clean Energy Ministerial (CEM) initiative, aims to install 10 billion high-efficiency lights such as LEDs, and make them available to a large part of the population. One of the basic principles of the initiative is to use products that have high standards of efficiency, performance and durability.

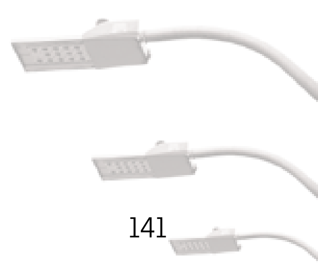
The GLC's Super-Efficient Equipment and Appliance Deployment (SEAD)[101] initiative has established quality standards for industrial and street lights that represent typical standards for the top 2–3% of the best products on the market. These products are eligible for the "Global Efficiency Medal".

By way of example, the following table lists some of the standards required for high quality external luminaires used in public street lighting networks.

Features	Standard recommended for external luminaires
1) Minimum efficiency of luminaire at ground level	• 120 lumens per watt
2) Color Reproduction Index (CRI)	• 70
3) Power factor	• 0.90
4) Total harmonic distortion	<20%
5) Operating temperature	From –30 oC to +50 ºC
6) Early faults	<5% faults during first 6.000 hours
7) Useful life expectancy	50.000 hours
8) Presence of toxic elements	Meets requirements of the RoHS (Restriction of Hazardous Substances). European Union Ministerial Directive 2002/95/EC.

Source: Global Lighting Challenge (GLC), 2016. Available at: <http://www.globallightingchallenge.org/

[101]Available at : <http://www.superefficient.org/Products/Street-Lighting>



REFERENCES

AGENCE FRANÇAISE DE DÉVELOPPEMENT (AFD); INSTITUTO DE PESQUISA ECONÔMICA APLICADA (IPEA); FUNDACIÓN CIUDAD HUMANA (FCH). *O financiamento da cidade latino-americana: instrumentos a serviço de um desenvolvimento urbano sustentável*. Série Savoirs Communs, n. 16, Mar. 2014.

ARVATE, Paulo et al. *Lighting and violent crime: evaluating the effect of an electrification policy in rural Brazil on violent crime reduction*. Discussion text No.408 – CMICRO, n. 33, Jan. 2016. São Paulo: Escola de Economia de São Paulo da Fundação Getúlio Vargas (FGV-EESP).

BOCK, H. H. *On some significance tests in cluster analysis*. Journal of Classification, n. 2, pp. 77–108, 1985.

CALINSKI, T.; HARABASZ, J. *A dendrite method for cluster analysis. Communications in Statistics*, n. 3, pp. 1–27, 1974.

CARVALHO, A.X.Y.; DA MATTA, D ; RESENDE, G.M. *Clusterização dos municípios brasileiros*. In: CARVALHO, A.X.Y. et al. *Dinâmica dos municípios*. Brasilia: IPEA, 2008.

CATTELL, R. B. *A note on correlation clusters and cluster search methods*. Psychometrika, n. 9, pp. 169–184, 1944.

CENTRO DE ESTUDOS E PESQUISAS EM ADMINISTRAÇÃO MUNICIPAL (CEPAM). *Iluminação pública: Guia do gestor*. São Paulo. Fundação Prefeito Faria Lima. July, 2013

DIETRICH, J. L. *Mecanismos de financiamento para o saneamento básico*. In: PHILIPPI JR., A.; GALVÃO JR., A. C. *Gestão do saneamento básico: abastecimento de água e esgotamento sanitário*. São Paulo: Manole, 2012.

EUROPEAN COMMISSION. Lighting the Cities: Accelerating the Deployment of Innovative Lighting in European Cities. European Commission - Directorate-General Communications Networks, Contents & Technology. June, 2013.

EVERITT, B. S. *Cluster analysis*. 2nd. ed. London: Heinemann Educational Books, 1980.

GOLDMAN SACHS WEBSITE. *The Low Carbon Economy*: GS SUSTAIN: *Equity investor's guide to a low carbon world*, 2015–25. New York: Equity Research, 30 Nov. 2015.

HARTIGAN, J. A. *Statistical Theory in Clustering*. Journal of Classification, n. 2, pp. 63–76, 1985.

IPWEA, 2014. Practice Note11: *Towards More Sustainable Street Lighting* (July 2014). Prepared by Next Energy and Strategic Lighting Partners for the Institute of Public Works Engineering Australasia (IPWEA) and the Australian Centre of Excellence for Local Government (ACELG), University of Technology, Sydney (UTS).

MACQUEEN, J. B. *Some methods for classification and analysis of multivariate observations. Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, n. 1, p. 281-297, 1967.

MILLIGAN, G. W. *An examination of the effect of six types of error perturbation on fifteen clustering algorithms*. Psychometrika, n. 45, p. 325-342, 1980.

MILLIGAN, G. W.; COOPER, M. C. *An examination of procedures for determining the number of clusters in a data set*. Psychometrika, n. 50, p. 159-179, 1985.

NASCIMENTO, E. R.; DEBUS, I. *Lei Complementar n. 101/2000: Entendendo a Lei de Responsabilidade Fiscal*. Brasilia: National Treasury Secretariat, 2002.

PAVAN, K. K. et al. *Robust seed selection algorithm for k-means type algorithms*. Journal of Computer Science & Information Technology (IJCSIT), v. 3, n. 5, p. 147-163, 2011.

Makumbe, P.; Weyl, D.K; Eil,A; Li,J . *Proven Delivery Models for LEDs Public Lighting*. World Bank Group, ESMAP, 2016.

SAADI, M.. *A figura da Cosip e as PPPs no setor de iluminação pública*. Revista Brasileira de Infraestrutura – RBINF, Belo Horizonte, Yr. 3, n. 6, p. 169-183, Jul./Dec. 2014.

SARLE, W. S. *The cubic clustering criterion*. SAS Technical Report A-108. Cary, NC: SAS Institute Inc., 1983.

SINGH, Jas. *Why energy efficiency matters and how to scale it up*. Live Wire, World Bank Group, 2016.

SOKAL, R.; SNEATH, P. *Principles of numeric taxonomy*. San Francisco: W. H. Freeman, 1963.

THE CLIMATE GROUP. *LED adoption by utilities*, 2016. Available at: <http://www.theclimategroup.org/led-adoption>

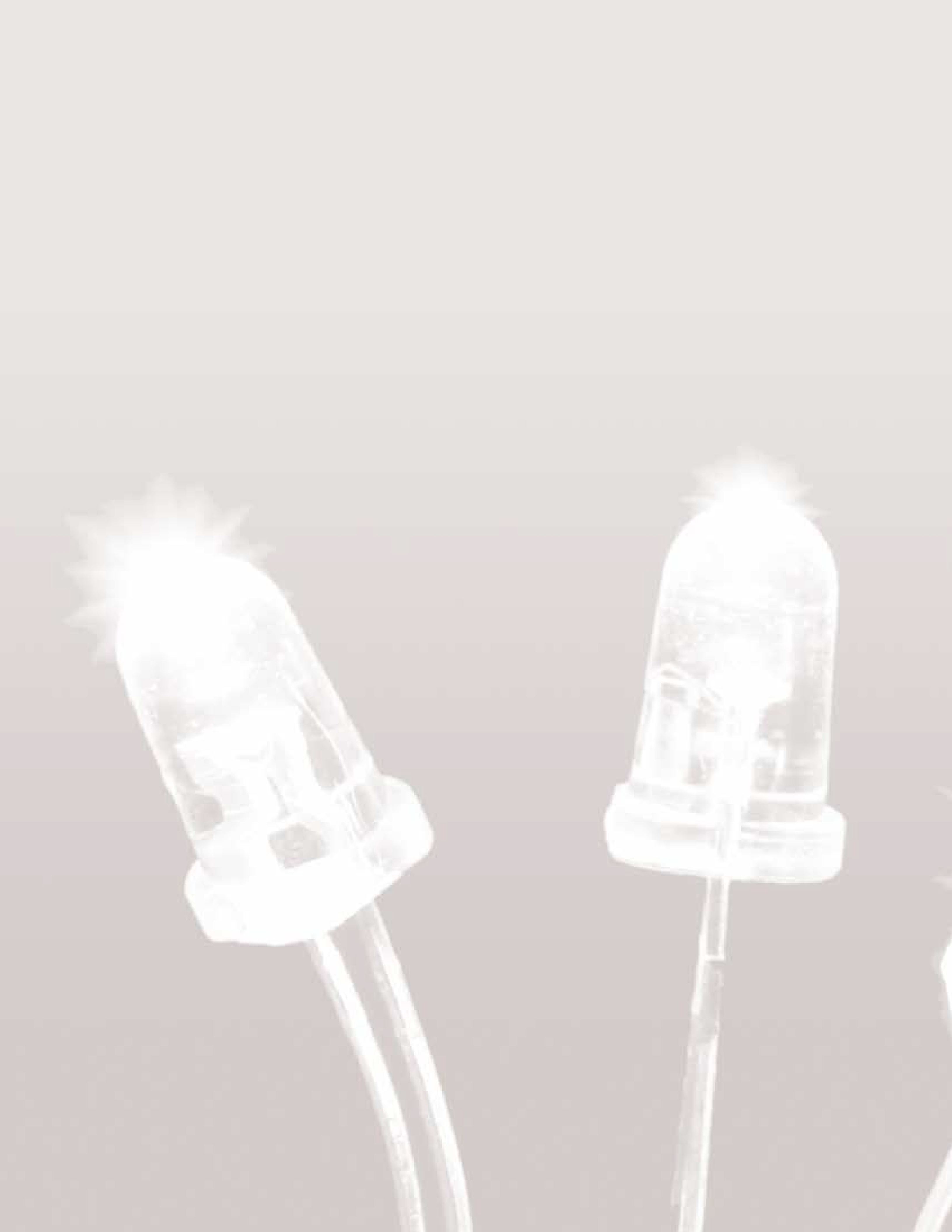
Lighting The Clean Revolution. The rise of LEDs and what it means for cities. June, 2012. Available at: <https://www.theclimategroup.org/news/lighting-clean-revolution>. Accessed 26/10/2016.

The Big Switch: Why it's time to scale up LED street lighting. Sep. 2015. Available at: <http://www.theclimategroup.org/what-we-do/publications/the-big-switch-why-its-time-to-scale-up-led-street-lighting/>. Accessed 26/10/2016.

TRYON, R. *Cluster analysis*. New York: McGraw Hill, 1939.

TUROLLA, F. A.; GABRIELLI, M. F.; GONDIM, I. J. C. *Crédito e financiamento à infraestrutura no Brasil.* Revista Tecnologia de Crédito (Serasa-Experian), v. 1, p. 1, 2013.

WELSH, Brandon; FARRINGTON, D. *Effects of improved street lighting on crime*. Campbell Systematic Review, v. 13, n. 1, 2008.



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