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Powering Côte d'Ivoire. Understanding the Landscape and Exploring Possibilities for Investment

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Abstract

Back in the '90s, Côte d'Ivoire was one of the first nations in sub-Saharan Africa (SSA) to turn to independent power producers (IPPs) to meet its rapidly growing demand and to grant a private utility a concession to operate the distribution and transmission network. Thanks to this strategy, its power system is one of the most reliable and extensive in SSA. Aware of the crucial role electrification plays in sustaining economic growth and accelerating social development, the country has made substantial and rapid progress since the end of the post-electoral conflict in 2011.

However, the sector still faces many challenges. The electricity consumption per capita is 10 times lower than the world average, and 67% of households, primarily in rural areas, do not have an electricity connection. The tariffs and access fees are too high for a significant part of the population but too low to cover the costs of the system, which creates a financial deficit. With regard to electricity generation, the sector is still has a high concentration of players and technologies. Shortages in the supply of domestic natural gas – the main fuel to generate electricity – represent a threat, and the potential of renewable energies (other than hydro) remains locked. Furthermore, demand is growing fast, putting pressure on the country's investment capacity, and the outdated network is suffering high commercial and technical losses.

What are the underlying reasons for these problems? In which direction is the sector moving to resolve them? What else could be done to accelerate progress in a sustainable way? What opportunities are there for private investors that could help boost development in the sector and increase the population's access to electricity?

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This paper seeks responses to these questions by examining the power sector's supply chain – production, transportation, distribution and consumption – with the aim of providing private investors with an overall understanding of the challenges and opportunities in the Ivorian electricity sector and promoting alternatives that could help reduce the situation of energy poverty currently faced by a substantial percentage of the Ivorian population.

Keywords: Energy; Power; Côte D´Ivoire; Electricity; Alternative; Opportunities; Energy poverty

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1. Executive Summary

Back in the '90s, Côte d'Ivoire was one of the first nations in sub-Saharan Africa (SSA) to turn to independent power producers (IPPs) to meet its rapidly growing demand and to grant a private utility a concession to operate the distribution and transmission network. Thanks to this strategy, its power system is one of the most reliable and extensive in SSA. Aware of the crucial role electrification plays in sustaining economic growth and accelerating the social development, the country has made substantial and rapid progress since the end of the post-electoral conflict in 2011. The installed power capacity, electricity production, grid coverage and electricity access has increased, and the current government has set up ambitious targets in all these areas for the next decade.

However, the sector still faces many challenges. The electricity consumption per capita is 10 times lower than the world average, and 67% of households, primarily in rural areas, do not have an electricity connection. The tariffs and access fees are too high for a significant part of the population but too low to cover the costs of the system, which creates a financial deficit. With regard to electricity generation, the sector still has a high concentration of players and technologies. Shortages in the supply of domestic natural gas – the main fuel to generate electricity – represent a threat, and the potential of renewable energies (other than hydro) remains locked. Furthermore, demand is growing fast, putting pressure on the country's investment capacity, and the outdated network is suffering high commercial and technical losses.

What are the underlying reasons for these problems? In which direction is the sector moving to resolve them? What else could be done to accelerate progress in a sustainable way? What opportunities are there for private investors that could help boost development in the sector and increase the population's access to electricity?

This paper seeks responses to these questions by examining the power sector's supply chain – production, transportation, distribution and consumption – with the aim of providing private investors with an overall understanding of the challenges and opportunities in the Ivorian electricity sector and promoting alternatives that could help reduce the situation of energy poverty currently faced by a substantial percentage of the Ivorian population.

Production

Côte d'Ivoire relies on two main technologies to generate electricity: thermal (natural gas based) plants and hydropower plants, accounting for 85% and 15% of the total energy production, respectively. The hydro plants are state owned and operated by the utility company CIE, through a concession agreement. The hydro installed capacity remained the same (604 MW) from 1980 until 2017, when a new hydroelectric power station, Soubré, was inaugurated, adding 275 MW of capacity. Furthermore, the thermal plants— built, owned and operated by independent power producers (IPPs) —doubled their capacity, from 610 MW in 2000 to 1282 MW in 2016.

The Ivorian IPP model uses mechanisms that reduce the risks for private investors, such as (i) long-term power purchase agreements (PPAs), (ii) take-or-pay clauses, (iii) guaranteed supply of domestic natural gas (paid for by the sector, not by the IPPs) and (iv) build-own-operate-transfer (BOOT) contracts, limiting the investment period. The model enabled the rapid increase of the private thermal production in response to growing demand. In fact, the surplus of electricity generated allowed the country to position itself as a net exporter of electricity to other countries within the sub-region (16% of the electricity was exported in 2016).

However, the heavy reliance on domestic natural gas poses a threat, as the proven reserves could be insufficient to meet demand growth in the long term. The use of an expensive backup fossil fuel, heavy vacuum oil (HVO), due to gas shortages, jeopardized the financial balance of the sector in recent years. New combined cycles, the increase in hydroelectric production and an increase in the domestic natural gas supply improved the situation in 2017. To reduce the natural gas deficit in the medium and long term, the infrastructure to import liquid natural gas (LNG) is in development and the exploration of new reserves of natural gas will be promoted through public-private partnerships (PPPs).

The low costs of the energy produced in the amortized hydro plants and thermal production using domestic natural gas have kept electricity production costs at a moderate level in comparison with the levelized cost of electricity (LCOE) estimated in other countries in the West African region.

Taking advantage of its long experience of attracting private investments in the sector, the country will continue to rely on the IPP model to expand power production. With electricity demand still growing fast, the government strategy is to increase the installed capacity but reduce the share of natural gas-based thermal plants, promoting more -large-scale hydropower plants and diversifying the energy mix by incorporating coal and renewables (other than hydro). Thus, the sector offers promising opportunities for private investors, notably:

1) Renewables, such as biomass to electricity, photovoltaic (PV) solar and small hydropower plants. Several projects are in development to harness the potential of renewables in the country, and the plan is that, by 2030, these sources will represent 16% of installed capacity (approximately 960 MW). The price of the PPA will be defined case by case, through agreement (bilateral negotiation) or through a tendering/competitive process.

2) Distributed generation (renewable), with capacity from 0.5 MW to 1 MW if connected at the grid and from 0.2 MW to 0.5 MW if connected at mini-grid level, will benefit from a guaranteed feed-in tariff for a period of five to 10 years.

However, both opportunities will depend on central planning, as it is the government who will put out the calls to tender and define the criteria or the tender process to select the IPPs for the technologies/capacities needed. To unlock the potential of renewables, we recommend: (1) using tendering mechanisms (such as auctions) to increase competitiveness; (2) putting out calls to tender or holding auctions regularly and frequently to contract renewable capacity in response to the evolution of the demand, thus creating a renewable market that is sustainable in the long term; (3) taking advantage of the development of the Economic Community of West African States (ECOWAS) electricity integration to create a regional market for renewable energies. Although complex, the aggregation of the demand and resources of West African countries can attract more investors and decrease prices; (4) simplifying the process for smaller IPPs – especially distributed generation – since the current process can be too expensive and time-consuming for such small producers.

Furthermore, in this scenario of over-dependence on natural gas, the supply of which is limited and could suffer shortages, and where the use of HVO has a significant impact on the system's costs, we suggest assessing the benefits and the economic feasibility of the following improvement opportunities that have been identified:

1. The adoption of methanol as an alternative backup fuel for the thermal power plants. Adjusting the natural gas turbines so that they can also run with methanol has the following benefits: (i) The diversification of fuels improves energy security; (ii) It is possible to select

whichever backup fuel (HVO or methanol) is most economical at the time; (iii) Methanol is more environmentally friendly than oil-based fuels. (iv) HVO forces a derating of the turbine, resulting in reduced electricity output. Methanol can keep the output at the same level. (v) Methanol does not overheat the turbines like HVO.

2. Maximizing natural gas output to recover the natural gas that is flared. The Global Gas Flaring Reduction Partnership estimates, based on satellite observations, that in 2016 a total of 3,743 million cubic feet were flared, the equivalent of 4.2% of the total natural gas production, with an approximate value of US$20 million. If the estimates above are close to the reality, this could justify a technical and economic feasibility assessment of updating/improving the gas extraction facilities by installing a system to recover the associated gas.

3. Improving the treatment processes of the natural gas extracted along the supply chain, to separate it from other hydrocarbon compounds and non-hydrocarbon impurities, can increase the natural gas yields and its quality.

Network Activities

In Côte d'Ivoire, the transmission and distribution grid is state owned and operated by a private concessioner, CIE. There are, therefore, two main companies involved in the network activities: CI-ENERGIES, the state-owned company in charge of the central planning and investments, and CIE, who receive a fee to operate the assets. Through this scheme, it is the state that invests in network infrastructure, limited by the state budget or by the capacity of the government to mobilize the funds needed. It is, therefore, a different model from the IPP model chosen to finance/build the new power plants.

One of the most significant challenges that the network activities face is the high levels of losses. In 2016, the total losses (both technical and non-technical, at production, transmission and distribution level) were approximately 20%, while the average was 15% in Africa and 8.1% in the world. The two main causes of the high losses are an outdated grid and fraud. CI-ENERGIES and CIE are investing in grid renewal and promoting actions against fraud to reduce losses. In our view, the new grid technologies, such as the anti-fraud cables and smart-meters, combined with new payment methods, such as the pre-payment solution implemented in the Programme Electricité Pour Tous (PEPT) can help to reduce the non-technical losses.

In terms of rural electrification, the number of electrified localities has been increasing rapidly, and the coverage rate rose from 34% in 2012 to 56% in 2017. The country aims to electrify all localities by 2025, which means it will be necessary to find cost-effective solutions to electrify the remaining 3,713 localities not served by the grid.

The main solution to achieve the electrification of the rural areas will be to extend the national grid by investing in transmission and distribution infrastructure, probably through the state-owned company CI-ENERGIES. However, the new electricity code created the possibility for new operators to enter the distribution and transmission sector. The state may entrust these operators with the realization of investments in the network (reinforcements, renewal and extensions). The changes are currently being studied and are yet to be defined by the government. Depending on the degree of liberalization finally adopted, the country could migrate to a network system whose expansion is driven by private investment, opening several opportunities for investors.

Furthermore, decentralized systems, led by solar PV in off-grid and mini-grid systems, could be the least-cost solution to provide electricity to some remote areas. CI-ENERGIES identified 96 localities that are suitable for mini-grids, of which 49 already have a project in development, financed by The West African Monetary and Economic Union (UEMOA) and by the European Union (EU). The technology chosen for the 96 projects is hybrid: solar (with storage through batteries) and diesel (as backup), also called PV-diesel.

It is not yet clear what role private companies will finally play in the development of these mini-grids, as the final strategy is still being defined and several aspects remain open (retribution, ownership and operation model, licensing process, tariffs applied). However, decree 787-2016 has already laid the foundations, determining some conditions and potential modalities. The country could opt to retain these investments under the state's umbrella, as has been done so far for the grid, or open up to private investment for the construction and/or operation of these mini-grids through concession agreements.

Should the government adopt the same strategy used to increase the power capacity (rely on private investment), the development and operation of mini-grids could emerge as a promising business opportunity for private investors and help to accelerate the universal electricity access that the country demands. In order to do that, it is crucial that the Ivorian government and institutions set up a clear and consistent regulatory framework, which could lower risks for mini-grid developers and guarantee a fair return on investment while protecting the public service character of the electricity supply.

Another promising opportunity is the adoption of off-grid solutions at a household level, such as small solar home systems. In fact, several companies are already offering these products to households in Côte d'Ivoire without electricity access, generally through the pay-as-you-go (PAYG) model. The country offers good prospects for this model, because:

I. There is still a large potential market to be served. In fact, 71% of households are still not connected to the grid. Although the government plans to electrify all the villages, some localities could have to wait up to 2030. And, even after the electrification of all villages, many households in remote rural areas could remain too far from the grid.

II. It is cheaper and cleaner than kerosene. Using kerosene for lighting costs twice as much as using a solar kit financed through a PAYG model, and it provides less than half the lumens.

III. The penetration of mobile and mobile money accounts – key enablers of the PAYG solar model – is high among the population, and it is increasing fast.

As in the case of mini-grids, the government's approach regarding individual solar systems is not yet defined. There are concerns about supporting a solution that could be considered inferior – and more expensive – than the electricity supply provided by a grid or mini-grid. So far, the companies offering PAYG solutions in the country are not submitted to any limitations, but this could change if the government decides to impose specific rules in this market or to integrate the use of such

Considering the private character of this market, we recommend setting a minimum regulation that can raise investors' and clients' confidence in the model, with these goals in mind: (i) Preserve and promote the competitiveness between private companies; (ii) Impose minimum quality standards for the products and services but without limiting innovation and differentiation; (iii) Inform and update the population and the PAYG companies about the rural electrification calendar, which will help them make informed decisions; (iv) Incorporate the solution in the national electrification plans, shaping a framework that gives opportunities to all private companies to participate instead of favoring a few and thus prevents distortions in the market.

Access Rates and PEPT

The electricity grid is present in 51% of the localities (coverage ratio). The access rate (percentage of the population living in an electrified locality) is 81%; a high score if compared with the average of 37% in SSA. Thus, the grid is present in the most populated areas. However, just 33% of the country's households are effectively connected to the grid (connection rate). It means that a significant part of the population living in electrified areas does not have a grid connection, despite their proximity to the grid.

With an excess of electricity production, a network available to most of the population and moderated electricity prices for households (cheaper than kerosene and solar panels), the main barriers that explain why 67% of the households are not yet connected are:

- The upfront connection costs (connection to the grid, indoor installation and the certification process) are prohibitive for low-income families;
- Although electricity prices are moderate, the electricity bill can represent up to 14% of a family's income.
- The grid still does not cover 49% of the villages, where 19% of the population lives.

PEPT was launched in 2014 to improve access rates, aiming to increase the share of households with electricity from 26% in 2013 to 70% in 2020 by financing the connection costs to low-income families and easing access formalities. PEPT set up a comprehensive and innovative solution and, as result, in its first three years of implementation (2015, 2016 and 2017) more than 350,000 households have been connected through the program; an impressive milestone.

A Sector in Transformation

The new Electricity Code, introduced in 2014, set up the foundations to transform the sector into a more liberalized and competitive market and give solutions to some of the structural problems.

One of the main changes introduced was the end of the state's monopoly on transport, distribution, commercialization, import and export activities, opening them up to competition. Although the exact extent of the reform is yet to be defined, the new code opens up the possibility of redesigning the configuration of the whole electricity market – from the ring-fencing of the value-chain activities (separating generation, transmission, distribution and retail operations in different companies) to a new market design – which has the potential to bring more competition and space for new private operators in all segments.

Furthermore, Côte d'Ivoire and the other West African states, through the Economic Community of West African States (ECOWAS) and its Regional Electricity Regulatory Authority (ERERA), are working to create a regional electricity market, ensuring coordination and harmonization of their policies and programs. The main goal is to approach the energy production, distribution and consumption from a regional perspective, enhancing power interconnections to create a West African wholesale market and share the energy resources.

2. Introduction

Back in the '90s, Côte d'Ivoire was one of the first nations in sub-Saharan Africa (SSA) to turn to independent power producers (IPPs) to meet its rapidly growing demand and to grant a private utility a concession to operate the distribution and transmission network. Thanks to this strategy, its power system is one of the most reliable and extensive in SSA. Aware of the crucial role electrification plays in sustaining the economic growth and accelerating social development, the country has made substantial and rapid progress since the end of the post-electoral conflict in 2011. The installed power capacity, electricity production, grid coverage and electricity access has increased, and the current government has set up ambitious targets in all these areas for the next decade.

However, the sector still faces many challenges. The electricity consumption per capita is 10 times lower than the world average, and 67% of households, primarily in rural areas, do not have an electricity connection. The tariffs and access fees are too high for a significant part of the population but too low to cover the costs of the system, which creates a financial deficit. With regard to electricity generation, the sector still has a high concentration of players and technologies. Shortages in the supply of domestic natural gas – the main fuel to generate electricity – represent a threat, and the potential of renewable energies (other than hydro) remains locked. Furthermore, demand is growing fast, putting pressure on the country's investment capacity, and the outdated network is suffering high commercial and technical losses.

What are the underlying reasons for these problems? In which direction is the sector moving to resolve them? What else could be done to accelerate progress in a sustainable way? What opportunities are there for private investors that could help boost development in the sector and increase the population's access to electricity?

In order to provide responses to these questions, in the next sections we will go through the supply chain of the electricity sector – production, transportation, distribution and consumption – and through the cross-chain issues, such as the institutional framework and the financial sustainability, to:

- Comprehend the landscape of the electricity sector in Côte d'Ivoire;
- Analyze the main problems and challenges of each link;
- Understand the government's strategies;
- Identify potential for improvements and business opportunities that, in our view, can help to guarantee the supply of electricity and increase the access conditions for the part of the population that is still not served by the grid.

In our view, the PPPs could be an effective way to improve the performance of the electricity sector and, ultimately, reduce the situation of energy poverty that a considerable part of the Ivorian population still faces. Therefore, our final goal is to provide the private investor with an overall understanding of the Ivorian electricity sector and its opportunities and promote alternatives that – in our view – should be explored by private initiative and supported by the government.

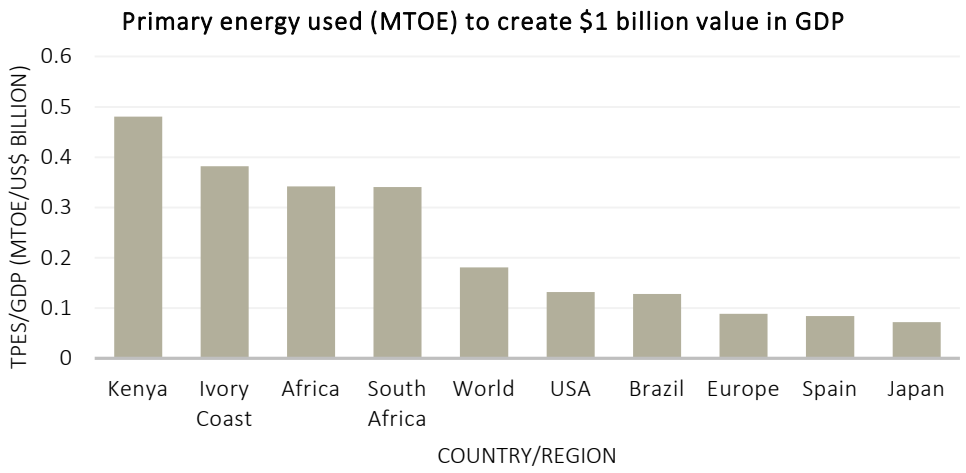
The analysis conducted in this paper is based on information publicly available and on information obtained through interviews with companies, government, agencies and associations operating in the sector.

3. How is Côte d'Ivoire Using Its Energy?

To measure the overall performance of the country's energy usage, we compare the total primary energy used, referred to as total primary energy supply (TPES), in millions of tons of oil equivalent (MTOE) - to generate economic value in gross domestic product (GDP). This TPES/GDP ratio indicates the primary energy needed (in MTOE) to create a fixed amount of GDP (in our comparison, $1 billion). The more efficiently a country operates, the less energy it allocates to generate wealth.

In Figure 1 below, we can see that Côte d'Ivoire uses 0.38 MTOE for each GDP US$1 billion; twice the world average and four times more than European countries.

Figure 1
Energy used (MTOE) to create $1 billion value in GDP in selected countries in 2015

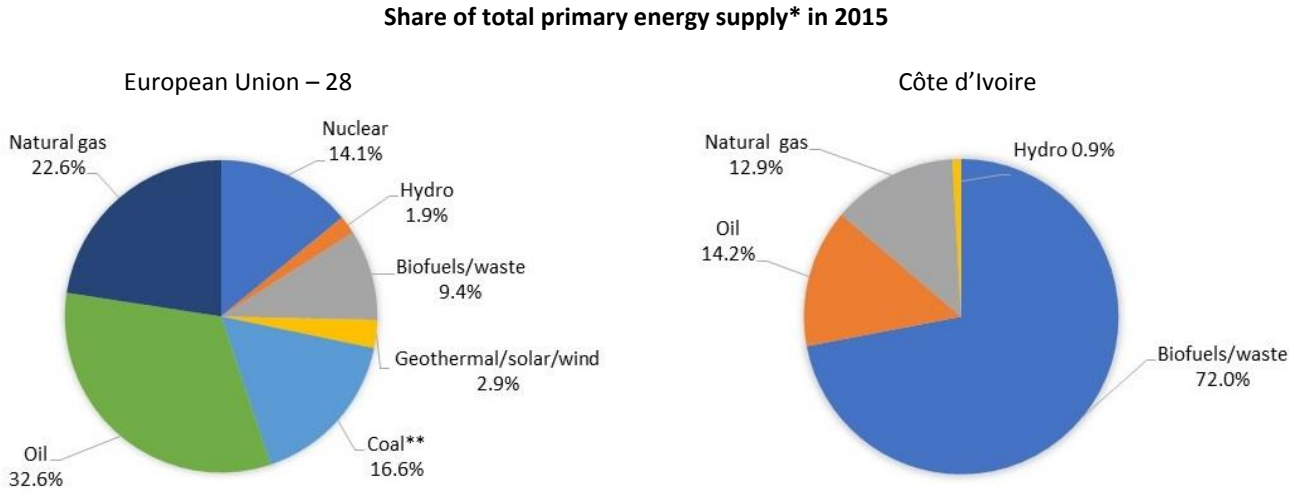


Source: Prepared by the authors. Primary energy supply based on IEA data from Statistics by Country © OECD/IEA [Online]. [Accessed 10 April 2018]. Available from: https://www.iea.org/statistics/statisticssearch/.

This does not mean that Côte d'Ivoire (and Africa) consumes too much primary energy, which would be an inconsistent conclusion if we consider the situation of energy poverty that a considerable part of the population still faces. It shows that the country and the region have room to use their resources more efficiently.

One of the underlying problems is the extensive usage of biomass as a primary energy source (72% in Côte d'Ivoire and just 9.4% in Europe, as it is shown in the Figure 2 below) – mainly charcoal and wood used in an inefficient way for cooking and heating needs.

Figure 2
Share of primary energy supply in 2015 – European Union and Côte d'Ivoire Comparison

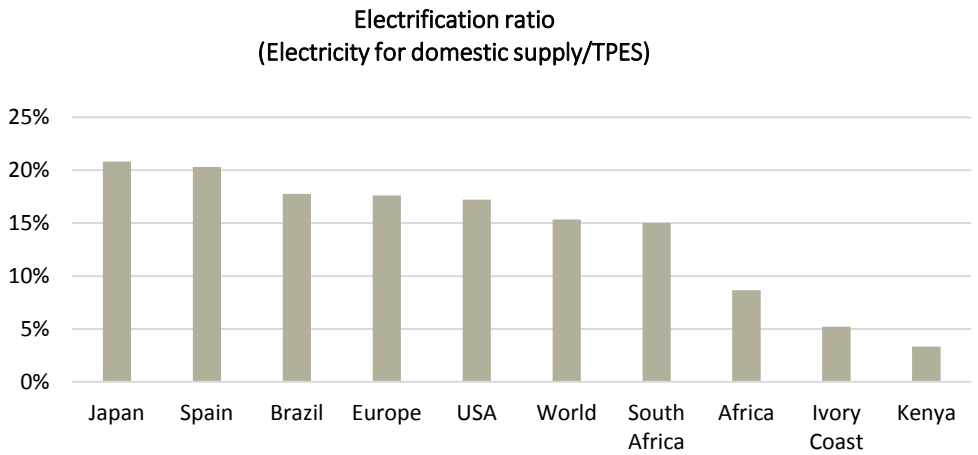


Source: IEA data from Statistics by Country © OECD/IEA [Online]. [Accessed 10 April 2018].
Available from: https://www.iea.org/stats/WebGraphs/COTEIVOIRE4.pdf and https://www.iea.org/stats/WebGraphs/OECDEUR4.pdf.
Notes: Accordingly to the original source:
* Share of TPES excludes electricity trade.
** In this graph, peat and oil shale are aggregated with coal, when relevant

It is, ultimately, a consequence of the lack of access to modern energy sources, such as natural gas or liquefied petroleum gas (LPG) for cooking, and particularly to electricity.

Figure 3 illustrates how much of the TPES is effectively transformed into electricity for internal (domestic) consumption in a set of countries.

Figure 3
Electrification ratio in selected countries (electricity for domestic supply/TPES) in 2015



Source: Prepared by the authors, based on data from IEA, Statistics by Country © OECD/IEA [Online]. [Accessed 10 April 2018].
Available from: https://www.iea.org/statistics/statisticssearch/.

In Côte d'Ivoire, electricity accounts for only 6%, while the world average is 15%. It is no coincidence that the countries/regions that better perform in Figure 1 (those with a lower TPES/GDP ratio) are also the ones with higher electrification ratio in Figure 3 – the most developed regions/countries.

Therefore, increasing the rate of electrification – together with access to other essential infrastructures – is an important goal that Côte d'Ivoire must keep pursuing in order to support and accelerate economic and social growth.

4. Institutional Framework and Players: A Sector Operated by Private Companies With the Government at Its Centre

4.1. Current Situation

Although the sector is operated by private companies throughout the whole value chain (natural gas supply, electricity production, transmission, distribution and retail), it remains strongly regulated and the government retains a central role.

In fact, the state used to have, by law, the monopoly of the electricity network activities (transport and distribution), exports and imports in Côte d'Ivoire – a situation that has changed in 2014, with the new Electricity Code, whose implementation is still in process and has had limited impact in the sector arrangements so far.

However, even under the state monopoly the network activities and the state-owned assets have been operated by a private company, CIE, since 1990, when the government granted CIE a concession for 15 years, which was renewed in 2005 for an additional 15 years. CIE, through this concession agreement, also runs the state-owned generation power plants (mainly hydropower plants). Before 1990, the grid was operated by the state-owned company Energie Electrique de Côte d'Ivoire – EECI).

The state, through the state-owned company CI-ENERGIES, is the owner of the assets operated by CIE. CI-ENERGIES has also retained the responsibilities over some essential activities: central planning, network investments (grid expansions and reinforcements), asset management, development of sector studies and technical monitoring of the operator (CIE). Furthermore, the company oversees the financial balance of the sector and acts as contracting authority for the expansion of the infrastructure.

There is not a proper retail or trading segment. The tariffs applied to the end customers are regulated, determined by the government. The supply of electricity to the end customer and the invoicing activities are part of the distribution activities. CIE's remuneration is a fixed amount (a management fee) per kWh sold.

The power generation activities are not subject to a monopoly, which means that the producers can be Independent Power Producers (IPPs, private companies) or state owned (currently under the CIE concession). The IPPs operate through a concession agreement negotiated with the government, under a build-own-operate-transfer (BOOT) scheme, which means that, when the concession term ends, the asset is transferred to the state, or through a build-own-operate (BOO) scheme. The IPPs' remuneration is negotiated with the government on a case-by-case basis (depending on investment and operating costs), and the power purchase agreement (PPA) includes take-or-pay (TOP) clauses. Nowadays, there are three IPPs operating thermal plants in

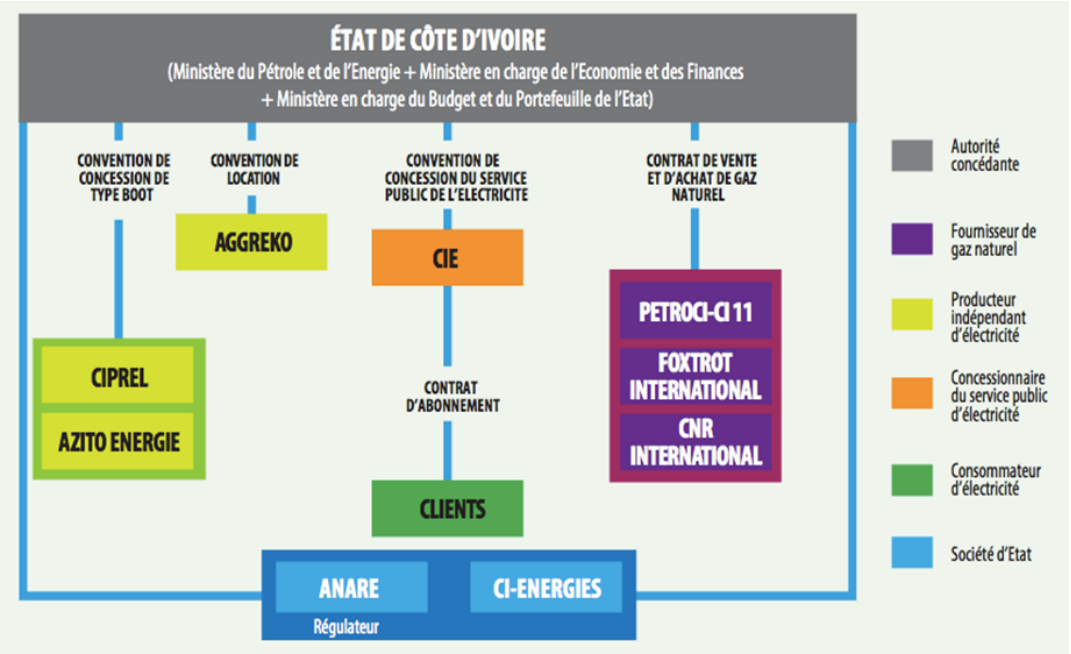
the country: Azito, CIPREL and Aggreko. Furthermore, CIE operates several state-owned hydroelectric plants.

Under this configuration, the state assumes the network investments (grid reinforcement and extensions), leaving private investors in charge of the development of new production capacities.

The IPPs and their thermal plants are supplied with natural gas by three oil and gas companies: PETROCI, Foxtrot and Canadian Natural Resources International (CNRI). Although these gas suppliers are not technically part of the power system, the power sector is its primary client. Curiously, the IPPs do not pay for the natural gas used in their thermal plants. It is the state – using the income of the electricity sector and with CI-ENERGIES as intermediary– who pays for the natural gas.

Indeed, directly or through the state-owned company CI-ENERGIES, the state is the single buyer of the sector: it is the counterparty of all the agreements made with private investors. The state is, therefore, accountable for the payment/retribution of the products and services delivered by the natural gas supplier, by the IPPs and by the transmission and distribution operator, as we can observe in Figure 4 and Table 1 below.

Figure 4
Sector players



Source: ANARE. *Rapport d'Activités 2016.* Graphique 1: Cadre institutionnel du secteur de l'électricité. [Online]. [Accessed 06 April 2018]. Available from: http://www.anare.ci/index.php?id=34.

ANARE is the regulatory agency, monitoring compliance with the regulations and overseeing the sector activities. Currently, the agency does not have normative powers (does not decide on energy policy/regulation/rules), which is done at political/legislative level. However, ANARE, which used to be a state-owned institution, is in the middle of the process to become an independent agency and redefine its role, no doubt to gain even more relevance.

This is part of a broader sectorial change that started in 2014 with the new Electricity Code, which set up the foundations to transform the sector into a more liberalized and competitive market. The exact extent of the reform is yet to be defined, but an in-depth transformation is expected, from the ring-fencing of the value-chain activities (separating generation, transmission, distribution and retail operations in different companies) to a new market design. The restructuring process should be concluded by 2020, coinciding with the end of CIE's concession term (CIE currently has the monopoly of the transmission, distribution and retail operations).

Table 1
Sector players and their main roles

Trust	**Ministry of Finance** **Ministry of the Budget** **Min. of Petroleum and Energy**	http://www.finances.gouv.ci http://www.budget.gouv.ci http://energie.gouv.ci
State companies	**ANARE**	**Regulator** Monitoring compliance with regulations and conventions in force by operators. Settlement of disputes. Protection of consumer interests. Advice and assistance to the state and operators.
	CI-ENERGIES	**Management of the works / Asset owner** Planning of energy supply and demand. Monitoring of energy flows. Monitoring the management of the operation of the concession. Central planning and project management of investments in the extension, reinforcement and renewal of the distribution transmission and rural electrification network. Maintaining the consolidated accounts and monitoring the financial balance of the electricity sector.
Private operators	**CIPREL** **Azito** **Aggreko**	**Independent electricity producers (IPPs)** Independent power producers, thermal plants using natural gas to produce electricity. Buyer-seller relationship with CI-ENERGIES.
	PETROCI **Canadian National Resources** **Foxtrot**	**Natural gas suppliers** They are not part of the power system in a technical way, but they play an important role as they supply the gas to the thermal plants through an intermediary agreement with CI-ENERGIES. Almost all the gas they produce is supplied for the thermal power plants. Buyer-Seller Relationship with CI-ENERGIES.
	CIE	**Electricity transmission and distribution operator (concessioner). Producer operator.** Operates CI-ENERGIES facilities. Concessioner of the network natural monopoly, encompassing the transmission and distribution. They also have the concession of the legacy power plants (mainly hydro).

Source: Prepared by the authors.

4.2. Major Changes in the Electricity Sector

The new Electricity Code adopted in 2014 introduced some important changes in the electricity sector of Côte d'Ivoire, establishing the basis to reform it further and give solutions to some structural problems. The main objectives of the new code are:

- Guarantee the energy independence and the security of the electricity supply;
- Promote the development of new power capacity, including renewables;
- Increase electricity access and energy efficiency;
- Create the economic conditions for fair returns on investments;
- Assure consumers' rights;
- Promote more competitiveness in the sector.

The core change introduced is the end of the state's monopoly on transport, distribution, commercialization, import and export activities – opening them up to competition. Although, in practice, all these activities are still carried out by the private concessioner, CIE, or by the state-owned company, CI-ENERGIES, soon they could be undertaken by one or more private operators, under a previous agreement with the state. The state monopoly will be limited to dispatching activity, which could be subject to a concession agreement with a system operator or a market operator.

Therefore, the new code opened the possibility to redesign the configuration of the whole electricity market. ANARE, in its 2015 Rapport D'Activités (ANARE, 2015), brought several possible models under consideration, starting with different levels of separation of the activities and continuing up to a model with several retail companies competing to sell electricity to the end customer. The scheme that will be adopted has not yet been decided, but we can expect more competition and space for new private operators, thus reducing the participation of the state in these activities.

Other significant changes introduced by the new code are:

- ANARE will become an entity with financial autonomy, thus having more independence.
- The electricity tariffs should be cost-reflective, guaranteeing the economic equilibrium of the sector.
- The introduction of a set of new sanctions against fraud, illegal connections or damages to the electricity network or equipment.

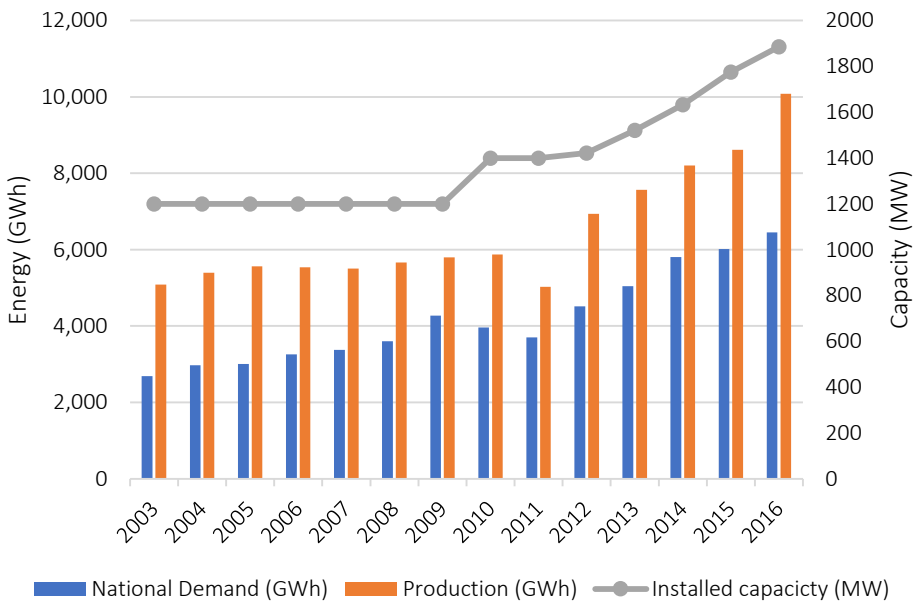
Furthermore, Côte d'Ivoire and the other West African States, through the Economic Community of West African States (ECOWAS) and its Regional Electricity Regulatory Authority (ERERA), are working to create a regional electricity market, ensuring coordination and harmonization of their policies and programs. The main goal is to approach the energy production, distribution and consumption from a regional perspective, enhancing electrical interconnections to create a wholesale market for West Africa and share energy resources.

5. Power Production and Capacity

5.1. Overview

Since the country left behind the 2011 post-election crisis and the political and military situation has stabilized, the demand for electricity has been increasing rapidly – 9.3% compound annual growth rate (CAGR) 2012—2016 – driven by a GDP growth among the highest in the world (around 9%). The installed power capacity and electricity production increased at a similar pace – 7.33% and 9.8% CAGR 2012—2016 – to offer an electricity supply to support the economic and social renaissance of the country. Figure 5 shows the evolution of domestic demand, electricity production and installed capacity.

Figure 5
Evolution of national electricity demand, production and installed capacity 2003—2016



Source: Prepared by the authors, based on data from ANARE, 2012, 2013, 2014, 2015, 2016.

Note: the difference between production and national demand is explained by exports and losses.

5.2. Power Producers, Technologies and Fuels

Côte d'Ivoire relies on two technologies to generate electricity: thermal (natural gas based, IPPs) and hydropower plants (state owned), accounting for 85% and 15% of the total energy production, respectively (see Table 2). Furthermore, there are also 49 isolated diesel power generators sourcing villages (mini-grids) and remote clients that are not connected to the national grid.

Table 2
Electricity production mix in 2016 – technologies and fuels

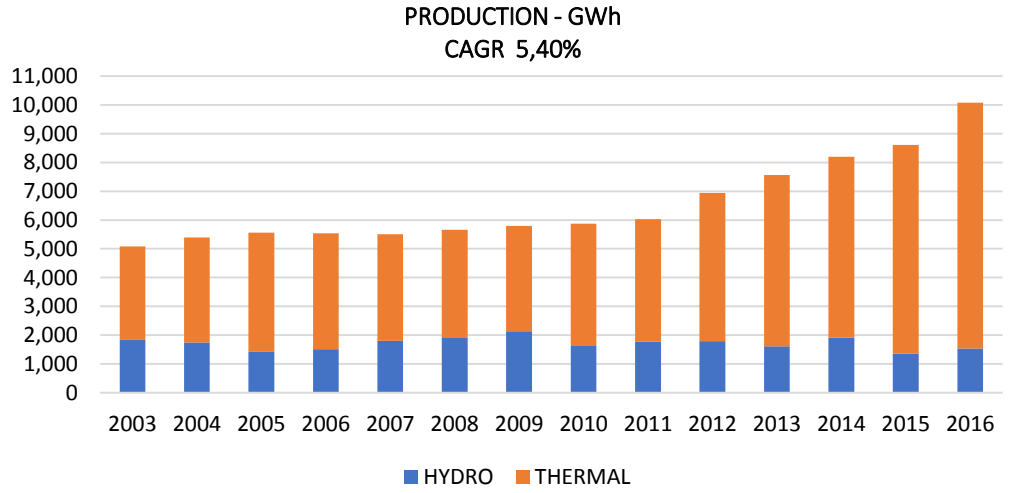
Technology	MW installed	% Capacity	Electricity produced (GWh)	% electricity production	Fuel
Thermal	1,282	68%	8,543	84.2%	Natural gas
			65.8	0.6%	HVO (back up)
Isolated Centrals	NA	NA	7.7	0.1%	Diesel
Hydro	604	32%	1,529	15.1%	Hydro
Total	1,886		10,146		

Source: Prepared by the authors, based on information from ANARE. Rapport d'Activités 2016. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34.

The hydro plants are state owned, and the installed capacity remained the same (604 MW) from 1980 until 2017. Recently (October 2017), a new hydro power plant, Soubré, was inaugurated, increasing the hydro capacity by 275 MW. Sinohydro, a Chinese company, built the plant with financing from the Export-Import Bank of China (85%) and Côte d'Ivoire (15%).

Furthermore, the thermal plants doubled their capacity, from 610 MW in 2000 to 1282 MW in 2016, as a result of the government strategy to increase generation capacity through private investments (IPPs) in thermal plants. It allowed a rapid response to the demand growth and to the challenges faced in the past, when the country was overexposed to hydro capacity and getting short of electricity production during droughts.

Figure 6
Electricity production by source, 200—2016



Source: Prepared by the authors, based on data from ANARE. [Online]. [Accessed 10 April 2018]. Available from: http://anare.ci/

Consequently, the sector has become heavily reliant on natural gas, the share of which rose from 64% in 2003 to 84.2% in 2016 (see Figure 6).

Nowadays there are three IPPs operating the thermal plants: CIPREL (producing 35% of the country's electricity), Azito (30%) and Aggreko (17%). They use mainly natural gas (200 ft^3/day in 2016) but also a significant amount of heavy vacuum oil (HVO) as backup fuel (20,000 tons in 2016). Furthermore, CIE operates six hydroelectric plants (15%), one small thermal plant – V (2%) and 49 isolated diesel generators (0.11%).

Three oil and gas companies, PETROCI, Foxtrot and Canadian Natural Resources, supply natural gas to the IPPs. In fact, 86% of the gas produced is delivered to the thermal plants, under a take-or-pay agreement with CI-ENERGIES. Note that the IPPs do not pay for the gas supply; it is CI-ENERGIES (through CIE) who pays for it, using the electricity sector revenues.

The increase in production – driven by the additional new power capacity – allowed the country to increase the export of electricity to neighbor countries. In 2016, Côte d'Ivoire exported 1,655 GWh, 16% of the gross electricity production, to Ghana, Burkina Faso, Mali, Benin & Togo, and Liberia.

In Table 3 we provide information about technology, installed capacity, output, fuels and the type of contract of the entire generation park.

Table 3
Power plants — key figures, fuels and information in 2016

Plant name	Group name	Type	MW installed	Total - MW	Electricity produced GWh	and %	Fuel	Backup fuel	Type of contract	Natural gas (million cubic feet)	HVO (tons)
Ayamé 1	Ayamé 1	Hydro	20	20	1529	15%	-	-	State owned. CIE operates.	-	-
Ayamé 2	Ayamé 2	Hydro	30	30							
Koussou	Koussou	Hydro	174	174							
Taabo	Taabo	Hydro	210	210							
Buyo	Buyo	Hydro	165	165							
Fayé	Fayé	Hydro	5	5							
TOTAL HYDRO				**604**	**1,529**	**15.17%**					
Vridi 1	TAG 1	Single cycle gas turbine	25	100	237	2%	Natural gas	HVO	State owned. CIE operates.	50,808	2,974
	TAG 2	Single cycle gas turbine	25								
	TAG 3	Single cycle gas turbine	25								
	TAG 4	Single cycle gas turbine	25								
CIPREL	TAG 5	Single cycle gas turbine	33	543	3569	35%	Natural gas	HVO	BOOT		17,825
	TAG 6	Single cycle gas turbine	33								
	TAG 7	Single cycle gas turbine	33								
	TAG 8	Single cycle gas turbine	111								
	TAG 9	Single cycle gas turbine	111								
	TAG 10	Single cycle gas turbine	111								
	TAV	Steam turbine (to combine cycle)	111								
Aggreko	Aggreko 1	Single cycle gas turbine	70	200	1680	17%	Natural gas	HVO	BOO		0
	Aggreko 2	Single cycle gas turbine	30								
	Aggreko 3	Single cycle gas turbine	48								
	Aggreko 4	Single cycle gas turbine	52								
Azito	GT11	Single cycle gas turbine	150	439	3057	30%	Natural gas	HVO	BOOT		0
	GT12	Single cycle gas turbine	150								
	TAV	Steam turbine (to combine cycle)	139								
TOTAL THERMAL				**1282**	**8,543**	**84.76%**				**73,219**	**20,799**
TOTAL ISOLATED CENTRALS					**7.7**	**0.08%**	Diesel		State owned. CIE operates.		

Source: Prepared by the authors, based on information from ANARE. Rapport d'Activités 2016. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34. Column "Type of contract" based on public information.

Solar home solutions and small solar panels are also present in the country, offered by private companies to households without electricity access, usually through the PAYG solar model. As the solar home systems are private and household-level solutions, they are not part of the official energy mix, and there is no official data about the number or capacity of solar kits installed. (See more information in Section 6.5 (iv) Off-grid solutions: solar home systems and the PAYG model.)

5.3. The Ivorian Independent Power Production Model: A Successful Model for Attracting Private Investors

To attract private investment in the power generation sector and guarantee the energy supply, the government has designed a model to balance the risks for the IPPs and state, based on the following pillars:

1. Establishment of long-term PPAs. The price paid for the energy produced by IPPs is based on bilateral agreements (PPAs) between the IPPs and the state of Côte d'Ivoire. This is usually a long-term contract aligned with the plant lifecycle, with a remuneration that allows private investors to cover operational costs, recover investments and have the expected returns on investment. This regulated and fixed-price contract – with periodic reviews/readjustments – is a guarantee that the energy produced will be bought at the price settled upon, reducing the uncertainties and risks for both investors and the country's power system.

2. Inclusion of TOP clauses in the PPA, determining that the IPP must produce certain amounts of electricity (or make available a certain capacity) and that the system is committed to buying it, even when those quantities are not fully needed. In other words, if the IPP finally produces less than the threshold due to factors not attributed to the plant, the administration must pay — even for the energy not delivered— up to the threshold. It could happen, for example, when the demand is lower than expected or when hydro production is abundant or due to lack of fuel to run the turbines. This mechanism is a guarantee for the investor, assuring a minimum level of retribution every year, independent of the real demand.

3. The state (through CI-ENERGIES) is in charge of providing and paying for the supply of natural gas (and HVO) used to run the thermal plants. It means that the IPPs are not exposed to potential fluctuations in the gas prices and are not penalized in the case of shortages of fuel.

4. Usage of the BOOT concession type of contract, for 25 years. After this period, the ownership of the power plant is transferred to the state. For the investor, limiting the investment and retribution period can help the project financing. For the state, having an amortized plant to operate at the end of the period can, potentially, decrease the system costs by that time.

The two biggest IPPs, Azito and CIPREL (which together account for 65% of the energy production) were set up under a BOOT type of agreement. Aggreko, on the other hand, has a BOO contract, retaining the ownership of its power plant and without a long-term contract in force. In fact, Aggreko is an international company specialized in providing emergency and temporary power generation capacity, setting up thermal plants in just a few weeks to supply electricity for short-term needs. Thus, Aggreko is expected to remain in the grid while the long-term infrastructure projects in power generation are being developed.

These arrangements reduce the risks for the investor and help to explain the success that the country has had attracting IPPs and guaranteeing enough capacity to supply the growing demand.

However, the model has some downsides due to its regulated and centralized nature:

- It requires the strong involvement and commitment of the government. The government is the contracting party in all major contracts of the sector, which means that the IPPs need to pass through a complex and time-consuming process, and that the government is the ultimate guarantor of the IPPs' revenues.
- There is no direct competition in the generation activities. In fact, all the pressure to assure moderate production prices stays in the hands of the government and its central planning function, at the moment in which it selects the technology, the investor (IPP) and negotiates the PPA.
- The TOP clauses can be a burden for the system, as they could mean incurring costs for an energy that is not utilized in the end – especially if the demand does not grow as expected or if there is not enough fuel to run the turbines.

Côte d'Ivoire created its own IPP model that seems to have fit the country's needs and resources so far. Introducing more competition into the generation and retail activities has different challenges and threats, requires a mature market and has not been a priority so far. However, we can expect some changes in the future, as the country is in the process of redesigning its electricity sector model, and it is also working with its West African neighbors (through ECOWAS) to set up a regional electricity market. Although the extent of the changes is yet to be defined, we should expect a framework that will settle on IPPs and public-private partnerships (PPPs), bringing new opportunities for private investors

Producer's retribution – case by case

Azito's retribution is partly variable — by the energy produced in MWh — and partly fixed by capacity (per MW). The TOP clause is linked to retribution per capacity. In 2016, the TOP threshold was 420 MW (96% of the total capacity installed), which means that the power plant received a fixed amount for every 420 MW even if it was not fully utilized (in fact, the real capacity factor was 80%). Azito received FCFA 75.75 billion, of which – according to our estimations – 85% is the fixed part (per MW) and 15% is variable according to the energy produced. Also, according to our calculations, the impact of the TOP clause was between FCFA 7 billion and FCFA 11 billion in 2016.

In the case of CIPREL, the TOP clause is linked to a minimum amount of energy, specifically 3,810 MWh in 2016, for which the company received FCFA 71 billion (FCFC 20.1/kWh). As the company was required to produce less (3,569 MWh), the effect of the TOP clause was the difference of approximately FCFA 4.8 billion.

Finally, CIE, the concessioner in charge of the transmission and distribution network that operates the state-owned hydroelectric and the isolated diesel generators, received a fee for it (CIE is a utility, not an IPP). In 2016, the fee was an average of FCFA 7.11 per kWh produced. The exception is the new hydroelectric plant, Soubré, operated by the company that recently built the plant through the IPP model.

5.4. Production Prices

The costs incurred to generate energy in Côte d'Ivoire can be divided into two components:

- fuel costs: the expenditure on natural gas, HVO and diesel
- production cost or producer price: the fee/retribution paid to the power producers to cover their operating costs other than fuel and recover the investment plus the retribution margin.

In Table 4 these costs are detailed by type of source/fuel:

Table 4
Production prices and quantities of fuel used, by technology in 2016

			Fuels					Power production prices per MWh		
Technology	**Electricity produced (GWh)**	**Electricity produced (%)**	**Fuel**	**Quantity**	**Unit**	**Cost per unit**	**Total fuel cost (billion FCFA)**	**Fuel costs (FCFA/MWh)**	**Production costs (FCFA/MWh)**	**Total cost (FCFA/MWh)**
Thermal	8,478	84%	Natural gas	73,219,000,000	Cubic feet	3.35	245.6	28,970	21,640	51,480
	65.8	0.65%	HVO (backup)	20,799,000	Kg	355.79	7.4	112,462		
Isolated Centrals	7.7	0.08%	Diesel	2,724,000	Liters	572.69	1.56	202,597	7,110	209,707
Hydro	1,529	15%	Hydro	NA	NA		NA	-	7,110	7,110
TOTAL	**10,080**	**100%**					**Average**	**25,254**	**19,436**	**44,750**

Source: Prepared by the authors, based on information from ANARE. Rapport d'Áctivités 2016. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34.

Hydro is the cheapest source in the country, not just because the technology does not require oil-based fuels, but especially because the production costs encompass only the fee paid to CIE to operate the plants. Apparently, it does not include any depreciation or margin to recover the investment made in these plants, possibly because the six hydropower stations were built between 1959 and 1983 and may already be fully amortized.

On the other extreme, the 49 isolated generators using diesel (state owned and operated by CIE) produced approximately 7.7 GWh (less than 0.1% of the total production), with a conversion rate of 0.35 liters of diesel per kWh, thus consuming 2.7 million liters of diesel. It results in a cost of FCFA 209,707 per MWh, four times higher than the final cost to produce electricity at the gas-fired thermal plants. These isolated generators are the combustion type and have a capacity ranging from 44 kVA to 440 kVA. CIE is decommissioning them, connecting these isolated mini-grids to the national grid gradually.

In Table 5 we compare the Levelized Cost of Electricity (LCOE) estimated for West African countries in 2010 and 2030 with the electricity production prices in Côte d'Ivoire in 2016.

Table 5
Comparison between LCOE in West Africa and production prices in Côte d'Ivoire, by technology, in 2016

Technology	LCOE (USD/MWh)		PRICE (USD/MWh)
	West Africa 2010	West Africa 2030	Côte D´Ivoire 2016
Electricity Mix			**75**
Dist. diesel 100 kW	320	371	350
HFO Heavy fuel oil	188	216	224
Open-cycle gas turbine (domestic gas)	141	161	85
Combined-cycle gas turbine(domestic gas)	90	102	
Hydro	62	62	12
Biomass	104	86	107*
Combined-cycle gas turbine (imported gas/LNG)	111	126	
Supercritical coal imported coal	101	106	
Small hydro	107	89	
Solar PV (utility)	121	84	

Source: Prepared by the authors. Column "LCOE (USD/MWh)" based on information from IRENA. Merven, B. and Miketa, A. 2013. Table 9. Levelised Cost of Electricity: Assumptions. In: *West African Power Pool: Planning and Prospects for Renewable Energy*. [Online]. [Accessed 12 March 2018]. Available from: http://www.irena.org/publications.

* Biomass price assumed at FCFA 62,000 /MWh, based on public information of Biokala tariff agreement, using a 2017 exchange rate of FCFA 0.00172 /US$.

The LCOE, a proxy for the average price that the power plant must receive to break even over its lifetime, does not include the producer's return on investment. Therefore, it is not directly comparable with the (selling) price in the Côte d'Ivoire column. Moreover, the LCOE of the table above was estimated based on several assumptions, at a regional level, and should not be taken as an indicator of real costs (a real LCOE needs be calculated in a project-by-project basis). Even so, the comparison is worthwhile, and we can conclude that:

- Côte d'Ivoire has an energy mix that guarantees costs at a moderate level (US$75/MWh), if compared with the LCOE range in the region (from US$62/MWh for hydro to US$188/MWh for HFO). This is mainly due to the low costs of the hydro sources (due to amortized plants) and thermal production (using domestic natural gas).
- The price of the electricity produced in Côte d'Ivoire by other sources (diesel, HVO, biomass) is, in general, aligned with the LCOE of the West Africa region. The exception is hydropower, for the reasons already explained.
- The other sources that the country is considering in its plans – imported liquid natural gas (LNG), imported coal, small hydro, biomass – are, in general, more expensive than the current energy mix (although the prices are based on 2010 reality). The exception is solar, the prices of which have decreased considerably since 2010, and PPAs have been signed at less than US$50/MWh in several countries around the world. Therefore,

although diversification can contribute to alleviating dependence on domestic natural gas and HVO and can create several other benefits (such as agricultural development and lower carbon emissions), it could also increase the electricity prices.

That is, perhaps, one of the challenges that the Côte d'Ivoire could face. How to add new generation plants in the power system without increasing the current average production prices? Otherwise, it could be necessary to increase the tariff for the customer, as every new MWh produced costing more the current FCFA 44,750 (US$75/MWh) will increase the average cost. On the other hand, the end of Azito and CIPREL's concession period in the future, and the transfer of their assets to the state, could decrease the thermal costs. In this scenario, CI-ENERGIES will have to skillfully plan how to balance the costs.

5.5. HVO as the Main Backup Fuel to Natural Gas

Although average electricity production costs are moderate, the use of HVO as a backup fuel due to shortages of natural gas has been a significant problem in recent years. The IPPs use HVO in the thermal plants as a substitute, which increases the fuel costs considerably. In fact, in 2016 the fuel cost to produce one MWh of electricity using HVO was four times higher than using natural gas, as we can see in Table 4. The HVO is partially produced by the Société Ivoirienne de Raffinage (SIR) and partially imported. The two power plants that have been using HVO due to natural gas shortages (more precisely when the pressure in the gas pipeline is too low) are CIPREL and Vridi. Apparently, the other two power plants – Azito and Aggreko – have not had to use HVO until now, although Azito's turbines are prepared to use it if needed.

In 2015, a year when droughts affected the hydroelectric production and the natural gas was not enough to meet the increase of the thermal plant's needs, 146,000 tons of HVO were used, with a total cost of FCFA 55.9 billion (approximately US$100 million). In that year, HVO accounted for 18% of the total costs in fuel to produce just 6.2% of the electricity. The high expense of HVO in 2014 and 2015 – two years of exceptionally high HVO usage – were in part responsible for the financial deficit of the sector in those periods. It has led the government to provide subsidies to cover the HVO costs: FCFA 28.8 billion in subsidies in 2015 and FCFA 50.7 billion in 2014.

Furthermore, the IPPs have reported quality concerns with the HVO in 2014,[1] such as poor fuel quality that did not comply with the technical specifications of the power machines – a situation that even led to the shutdown of one of the turbines for a period. Recently, the procurement process of HVO has changed; it is now managed by CIE.

The total volume and cost of HVO has varied substantially every year since 2010. Aware that it can compromise the financial balance of the sector, the government, institutions and companies have been working to reduce its usage to minimum levels. As a result, in 2017 the utilization of HVO was marginal; less than 800 tons to produce 2,400 MWh.[2] The main factors that contributed to this reduction (if compared with the previous years), were:

[1] Information interpreted based on ANARE. *Rapport d'Áctivités 2015*. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34.

[2] Information from interview with stakeholder.

1) The main natural gas supplier, Foxtrot, increased its supply capacity by 20 million cubic feet per day and, potentially, a new field will provide an additional 50 million cubic feet per day in 2018/2019.

2) Azito and CIPREL installed new steam turbines (combined cycle), improving the efficiency of their power plants, insomuch as a combined cycle can double the electricity output with the same amount of natural gas.

3) The hydroelectric production did not suffer from droughts in 2016 and 2017, and production was at normal levels. Furthermore, the new hydro plant, Soubré, has added 275 MW of capacity since October 2017.

With more gas available, there is no shortage foreseen for the period 2016—2020, and HVO use should remain low, only over a few peak hours, in the next few years. However, the deficit of natural gas can pose a threat in the future. To overcome this challenge, the country is assessing the feasibility of extracting additional gas from the current fields and looking for new reserves. Furthermore, there is a project in development to import LNG, which will allow thermal power production to be further increased through new thermal power plants. In the long term, the government strategy is to reduce the share of natural gas-based turbines, building more large-scale hydropower plants and diversify the energy, incorporating also renewables.

5.6. Opportunity: Methanol as an Alternative Backup Fuel for Power Generation

In this scenario of over-dependence of natural gas, the supply of which is limited and could suffer shortages, and where the usage of HVO has a significant impact on the system's costs, we suggest assessing the benefits and the economic feasibility of adopting methanol as an alternative backup fuel for the thermal power plants.

What is Methanol?

Methanol1 is a liquid fuel that is considered much more environmentally friendly than fuels such as HVO or HFO, gasoline, diesel and kerosene. Methanol is already found in some gasoline blends around the world, including in M15, Israel's standard for a 15% methanol-gasoline mix. As a synthesized compound, methanol is pure and, unlike diesel and gasoline, it contains no contaminating elements such as sulfur. Sulfur in traditional liquid fuels creates harmful combustion by-products that can be orders of magnitude more damaging to the environment than carbon dioxide. Unburnt hydrocarbons also take significantly longer to break down under sunlight than alcohols such as methanol. Methanol's most substantial drawback is that it has less than half the energy density of traditional liquid fuels. Therefore, it could be necessary to use double the amount of methanol to produce the same amount energy.

As a synthesized fuel, methanol is derived from a chemical process rather than being found like most hydrocarbons. The synthesis of methanol is usually achieved through a catalytic reaction using a feedstock of natural gas. Methanol is directly derived from a traditional hydrocarbon source and consumes energy during its production, but it is still a clean fuel. Given these characteristics, methanol is rarely chosen as a preferred fuel source when natural gas is readily available. As a synthesized chemical, methanol may be subject to different excise taxes than oil-based fuels.

[1] Methanol's chemical formula is CH3OH and it is in a class of fuels considered to be alcohols.

Adapting the natural gas turbines to also run with methanol as a backup fuel has the following benefits:

1. Energy security/Diversification: including methanol in the portfolio of backup fuels, in addition to HVO, creates an alternative for eventual problems in the supply of natural gas and HVO.

2. The possibility to select the cheaper fuel at any moment: the conversion maintains the turbine's ability to run on either natural gas, HVO or methanol, which leaves the option open to run on whichever backup fuel is most economical at the time. Such technical adaptability could prove beneficial in a changing global energy market.

3. It is cleaner than HVO: as described in the box above, methanol is more environmentally friendly than oil-based fuels. It is also less harmful to the operation of the turbines than HVO.

4. HVO forces a derating of the turbine, resulting in reduced electricity output. Methanol can keep the output at the same level.

5. While HVO can overheat the turbines and reduce their lifespan, methanol does not have these drawbacks.

Converting a turbine to run on methanol and achieve the same power output than using natural gas requires an upgrade of its fuel-injection system and fire suppression system, and the creation of methanol loading and storage facilities. According to our estimates, the investment to adapt a 33 MW turbine, similar the ones used in Côte d'Ivoire, is around US$100,000 per MW (a total of US$3.3 million).

The main downside of methanol is that it has less than half of the energy density of traditional liquid fuels. For example, approximately 1.8 kilograms – 2.05 kilograms of methanol are required to create the same amount of energy as 1 kilogram of HVO or HFO. Therefore, methanol becomes an attractive option, in terms of costs, when its price is 1.8 – 2 times lower than HVO.

The economics of the use of methanol need to be assessed on a case-by-case basis but, according to our preliminary estimates, it could generate savings in fuel costs.

In Table 6, we compare the fuel costs, –using HVO, methanol and natural gas, of generating 65,800 MWh – the amount of energy produced using HVO in 2016 in Côte d'Ivoire. It is important to emphasize that, while the HVO price per kilogram is the real price recorded by the sector (probably including all the transportation costs and taxes to deliver it at the power production facility), the methanol price is based on an international market reference, and it does not include the shipping, handling, distribution costs and taxes. Therefore, depending on the ability of the country to produce or import it, at a regional or international level, the real price could vary substantially and affect the economic feasibility.

Table 6
Comparison of backup fuel costs — HVO and methanol

	HVO	Methanol	Natural Gas
Fuel conversion rate: kg/kWh (real for HVO, estimated for Methanol)	0.307	0.565	
Energy produced	65,800	65,800	65,800
Price per kg (FCFA)	355.79	167.01	
Price per kg (USD)	0.59	0.28	
Production cost (FCFA/kWh)	112.46	94.36	28.75
Total expenses on fuels (FCFA)	7,400,000,000	6,208,992,731	1,891,574,783
Savings per year (FCFA):	1,191,007,269		
Production cost (USD/kWh)	**0.19**	**0.1576**	**0.05**
Total expenses on fuels (USD)	**12,358,000**	**10,369,018**	**3,158,930**
Savings per year using Methanol instead of HVO (USD)	**1,988,982**		

Source: Prepared by the authors. Part of the information is based on:
- HVO, gas prices and energy produced with HVO are based in averages calculated using information from: ANARE. Rapport d'Áctivités 2016. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34
- Methanol price based on average 2016 of Methanex Non-Discounted Reference Price (North America) - Methanex Monthly Average Regional Posted Contract Price History. [Online]. [Accessed 25 March 2018]. Available from: https://www.methanex.com/our-business/pricing

Note: Methanol price does not include shipping, handling, storage and distribution costs. For accurate comparison, should compare with methanol prices delivered to the country. Exchange rate FCFA 0.00167/US$.

In a scenario of methanol at US$0.28/kg (average 2016) and HVO at US$0.59/kg, in 2016 the savings would have been US$2 million. Moreover, according to our estimates, just one turbine of 33 MW would need to be adapted in order to produce this quantity of electricity. It would require an investment of US$3.3 million, and the payback period would be 1.66 years.

Investment costs (US$/MW) - estimated	100,000
Investment for a 33 MW single cycle turbine (US$)	3,300,000
Payback in years (with same level kWh produced in 2016)	1.66
Capacity factor (produce 65,800 MWh w/ 33 MW turbine)	23%

Source: Prepared by the authors.

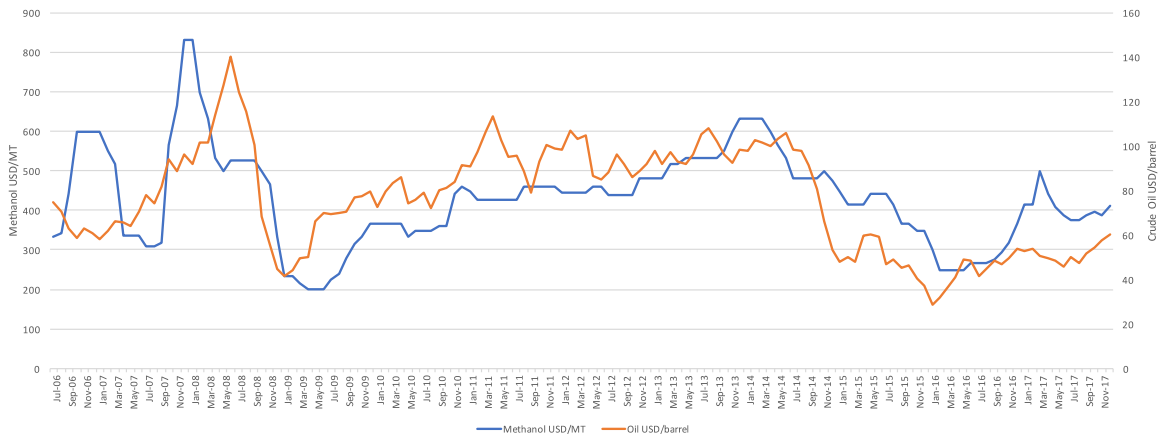
However, if the level of consumption of HVO remains low in the next few years (in 2017 HVO was used to produce just 2,400 MWh), the payback period would be longer.

Moreover, the same exercise for the year 2017 could have had a different outcome. The increase in international methanol prices (from US$0.28/kg on average in 2016 to US$0.41/kg in 2017) would have made its potential usage costlier than HVO – if the HVO price did not increase.[3]

Therefore, the cost-effectiveness of using methanol or HVO can vary with time. In fact, although methanol is not a by-product of oil, its price correlates to some extent with oil prices – and therefore with oil-based products such as HVO — as we can appreciate in Figure 7 — which could limit the opportunities for arbitrage.

However, it is also worth mentioning that the price of methanol is less volatile than the price of crude oil and its derivatives. In the July 2006 to December 2017 data set, the coefficient of variation[4] of crude oil was 30.21%, and the coefficient of variation of methanol prices was 25.72%. Relying on fuels that are less exposed to price volatility can also be beneficial.

Figure 7
Prices of methanol and crude oil, 2006—2017



Source: Prepared by the authors, based on: *Methanex Monthly Average Regional Posted Contract Price History* [Online]. [Accessed 25 March 2017]. Available from: https://www.methanex.com/our-business/pricing and on *West Texas Intermediate (WTI or NYMEX) crude oil nominal prices* [Online]. [Accessed 25 March 2017]. Downloaded from: http://www.macrotrends.net/1369/crude-oil-price-history-chart.

With all these considerations, advantages and risks in mind, we recommend a more accurate assessment of this opportunity, based in the real costs of methanol delivered to the country and considering different scenarios of supply/shortage of natural gas.

[3] We do not know the HVO prices registered in Côte d'Ivoire in 2017.

[4] The coefficient of variation of a series is the ratio between its standard deviation and its mean. For consistency with its calculation, we adjusted seasonally adjusted the series. After that, we calculated the mean and standard deviation of each seasonally adjusted series before finally calculating the coefficient of variation.

5.7. Plans to Increase Power Capacity

Demand is expected to keep growing at a rate of 10% - 12% up to 2020, and 5% — 7% beyond 2020, [5] driven by economic and population growth, the needs of the mining sector and the electrification of the more than 4000 villages still without electricity. To meet this requirement, and according to the Programme National de Développement (PND) 2016—2020, the country intends to double the installed power capacity by 2020 (see Table 7), harnessing PPPs and the IPP model.

The natural-gas-based power plants and hydropower stations will keep their relevance and their position as the main sources of electricity. New natural-gas-based power plants will lead the growth, with an additional 1,000 MW. Hydro will bring another 316 MW (275 MW of which was already delivered in 2017) and for the first time we will see renewable sources (other than hydro) and coal (San Pedro project) in the mix, with considerable shares of 11% and 9%, respectively. This forecast, which includes 1,090 MW to serve the mining sector, is updated periodically following the evolution of demand and the PPAs signed.

Table 7
Power capacity – 2016 and plans for 2020 and 2030

	2016 (real)		2020		2030	
	MW	%	MW	%	MW	%
Natural Gas	1282.00	68%	2280.00	57%	1920	32%
Coal	-	-	360.00	9%	1560	26%
Hydro	604.00	32%	920.00	23%	1560	26%
Renewables	-	-	440.00	11%	960	16%
Biomass	*-*	*-*	*NA*	*-*	*600*	*10%*
Solar	*-*	*-*	*246*	*-*	*360*	*6%*
Total capacity	**1886**		**4000**		**6000**	

Source: Prepared by the authors, based on response from DGE, Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables, 2017 to question sent by authors.

Renewables

In the medium and long term, to take advantage of available natural resources, three sources will be pursued in the new renewable category: small hydro, biomass and solar PV. The country has made clear its intention to promote renewable sources. Several projects have already been identified that are in study, development or construction phase. Moreover, CI-ENERGIES is evaluating the renewable resources available in the national territory in order to have a comprehensive view of the full potential and attract private investors. One of the main

[5] Data from Republique de Cote D'ivoire. 2016. Resume Programme National de Développement (PND 2016-2020). [Online]. [Accessed 05 March 2018]. Available from: http://www.gcpnd.gouv.ci/fichier/doc/ResumePND2016-2020_def.pdf.

challenges will be to find a model that can attract investors, promote cost-efficient technologies and bring competitiveness to the wholesale market.

The First Biomass and Solar Projects on the Way

Biokala, a 46 MW biomass-to-electricity project using palm waste, is being developed by SIFCA Group and EDF. A PPA was signed at the end of 2017 to sell the future electricity produced at FCFA 62,000 per MWh. The agreement was an important milestone in the promotion of renewables in the country, as this will be the largest biomass power plant in sub-Saharan Africa using agro-food waste and it is expected to create 1300 direct jobs in the rural area. The abundant agricultural waste (mainly from cocoa, cotton and palm plantations) offers a promising scenario for this technology.

Furthermore, three solar projects, totaling 107 MW (Korhogo Solaire 20 MW, Poro Power 50 MW and KFW 37.5 MW), are being finalized and will be commissioned in 2018. Another four solar projects totaling 145 MW are expected by 2020. The solar potential is higher in the northern region of the country.

Up to now, apparently, the renewable projects have been agreed with private investors through the same process as the largest hydro and thermal plants: a call for interest launched by the government, followed by an extensive assessment of the project by a steering and technical committee and by bilateral negotiations, culminating in the signature of a PPA — a model that has been successful in attracting international private investors so far.

As the country moves towards a strategy to promote more and smaller renewable power production plants, the current process can represent a time-consuming and complex barrier to business that will not generate the same amount of electricity (and revenues) as the current IPPs. Most of the countries successfully promoting renewables opted for schemes such as a feed-in tariff or a competitive tendering process – although the development of such policies needs to take into consideration the volume of energy to be contracted.

In fact, the Decree 2016-786 offers the possibility, for renewable power plants with a capacity of up to 1 MW (also called distributed generation) or auto-producers with a surplus of production, to sell the electricity produced to the grid and benefit from a feed-in tariff. The aforementioned decree introduced the basis to remunerate and promote renewable sources:

- Prices paid should be lower than the long-term marginal cost of the system. In the case of renewables, if the price is higher, the state could decide to approve the project and subsidize the difference;
- The state will open calls to select renewable projects;
- Distributed generation, with capacity from 0.5 MW to 1 MW if connected to the grid and from 0.2 MW to 0.5 MW if connected to mini-grid, will benefit from a guaranteed feed-in tariff for a period of five to 10 years. The tariffs will be defined by ministerial order, and will depend on the technology and capacity.
- For bigger projects, the price will be defined case by case, through mutual agreement (bilateral negotiation, as has been the case so far) or through a tendering/competitive process.

Our understanding is that the detailed process to become a producer under the distributed generation/renewable category and the amount of the tariff are not yet defined, but are being prepared with the set of regulations that will also outline how the country will implement the off-grid and decentralized solutions.

The effective application of the dispositions above has the potential to raise the interest of private investors and unlock the renewable potential of the country. It could lead to a decrease in the costs of renewable projects and allow the sector to benefit from the low electricity prices offered by solar technology in other parts of the world. We recommend:

1) Using competitive tendering mechanisms (such as auctions) to raise competitiveness;
2) Putting out calls to tender or holding auctions regularly and frequently to contract renewable capacity in response to the evolution of the demand, thus creating a renewable market that is sustainable in the long term;
3) Taking advantage of the development of the ECOWAS electricity integration to create a regional market for renewable energies. Although complex, the aggregation of the demand and resources of West African countries can attract more investors and decrease prices;
4) Simplifying the process for smaller IPPs – especially distributed generation— since the current process can be too expensive and time-consuming for such small producers.

5.8. The Natural Gas Sector: Opportunities for Improvement?

The Ivorian natural gas and power sector are intimately linked and interdependent. While the power sector relies on natural gas to produce 84% of electricity, the oil and gas companies sell 83% of the natural gas produced to the power sector. The remaining 17% is supplied to the industrial sector, through a dedicated distribution network (pipelines) in the Abidjan area, and to the Société Ivoirienne de Raffinage (SIR).

Therefore, all the challenges faced by the natural gas sector affect the electricity activities. In fact, shortages of natural gas in recent years have substantially increased the costs of electricity production, which had to use expensive backup fuel.

Nowadays, there are three companies producing natural gas in offshore blocks: PETROCI, Foxtrot, and Canadian Natural Resources (CNR). In Table 8, we provide an overview of the gas quantities produced by each block and the type of gas produced. Foxtrot is the leading producer, supplying dry gas.

Table 8
Overview of natural gas production

Block and type of gas	Field	Production of gas (million cubic feet)		Companies
		2015	2016	
CI-11 (dry and associated gas)	Lion and Panthère	5,817	4,385	PETROCI-CI 11
CI-26 (associated gas)	Espoir	18,367	18,190	CNR
CI-27 (dry gas)	Foxtrot	53,274	58,218	Foxtrot International
CI-40 (associated gas)	Baobab	2,775	7,089	CNR
Total		**80,235**	**87,884**	

Source: Prepared by the authors, based on information from Direction Généralé des Hydrocarbures, Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables. 2017. *Annuaire des Statisques des Hydrocarbures en Côte d'Ivoire*. Edition 2017. Côte d'Ivoire.

One of the main concerns is the ability of the country to provide all the natural gas needed in the upcoming years and avoid the shortages experienced in the past. Foxtrot has recently increased its output by an additional 20 million cubic feet per day and is assessing a new field that would bring an additional 54 million cubic feet per day in 2018/2019, which would guarantee the supply for the power sector in the short and medium term. With these new gas discoveries, no shortage is expected in the period 2016—2020. In fact, if the demand remains at the same levels of 2016, the proven reserves could guarantee the supply for 12—18 years.[6]

However, the mining sector and new thermal plants could increase the demand substantially in the medium and long term. A 2011 forecast[7] for the period 2012 to 2034 has foreseen a cumulated demand (for the 22 years) of 9,800 billion cubic feet, from:

- Mining of iron and nickel in Western Côte d'Ivoire: 5,000 billion cubic feet, representing 51% of the domestic market.
- Electricity sector: 3,600 billion cubic feet (37%)
- Industrial and transportation sector: 900 billion cubic feet (9%)
- LPG production: 200 billion cubic feet (2%).

In this scenario, the remaining proven reserves, estimated at between 1,000 and 1,600[8] billion cubic feet, could cover just 11% - 16% of the demand. The plans to increase the supply are:

- Continue to promote offshore exploration of new reserves (through partnerships with private oil and gas companies) and further development of the existent blocks. The Plan

[6] 12 years when considering 1,000 billion of proven reserves or 18 years when considering 1,600 billion of proven reserves.

[7] Based on information from Petroci Holding. 2013. *Call for Expressions of Interest for a Liquefied Natural Gas Import Project in Côte d'Ivoire.* [Online]. [Accessed 12 March 2018]. Available from: http://www.petroci.ci/Fichier/Expression_of_Interest_LNG_%2004032013.pdf.

[8] Based on interviews, no official information.

Strategique de Developpement L'Intégrale (Ministère des Mines, du Pétrole et de l'Energie, 2011) had foreseen 13 exploration projects and six 6 development projects, although the drop in oil prices since then could have led to the cancellation or delay of several projects.

- Import LNG, from 2018. A project to build a terminal with a floating storage and regasification unit (FSRU) is under development in Vridi, in the Abidjan area, alongside a pipeline connecting the FSRU to existing and planned power plants in Abidjan, as well as to regional markets. It will increase the natural gas supply to 100 - 140 million cubic feet/day (45% of the current capacity). The consortium in charge to build and operate the terminal is led by Total with the participation of PETROCI, CI-ENERGIES, SOCAR, Shell, Golar and Endeavour Energy.

Considering the relevance and the limitations of the natural gas supply in Côte d'Ivoire, it is fundamental to extract, transport, treat, clean and use this valuable resource in the most efficient way along the entire supply chain, avoiding any unnecessary losses and making sure that the quality of the gas finally delivered to the power plants can yield the maximum electricity output.

Therefore, in the following paragraphs, we highlight two main potential opportunities to maximize the natural gas production.

Recover the Natural Gas Flared

Although we did not find official information about the quantity of natural gas flared in the country, the Global Gas Flaring Reduction Partnership, based on satellite observations, estimates that in 2016 a total of 3,743 million cubic feet was flared, the equivalent of 4.2 % of the total production of natural gas, or 12% of the associated gas, as we can see in Table 9.

Table 9
Natural gas produced, utilized and flared, 2013—2016

Year	Production (million cubic feet)	Demand (million cubic feet)		Gas Flared (million cubic feet) *	Intensity (Cubic Feet Flared per barrel of crude oil extracted) *
		Power Plants	Industries and SIR		
2013	72,228	61,024	11,204	2,895	0.176
2014	76,200	64,970	11,230	3,072	0.193
2015	78,551	67,525	11,026	3,143	0.193
2016	87,884	73,219	14,665	3,743	0.280

Source: Prepared by the authors. Quantity of gas flared at oil production sites and intensity is an estimation based on satellite observation, from The World Bank, *Global Gas Flaring Reduction Partnership*. [Online]. [Accessed 09 March 2018]. Available from http://www.worldbank.org/en/programs/gasflaringreduction#7.

This estimated gas flared has an approximate value of US$17.5 million.[9] If recovered, it could be converted, for example, into 190,000 tons of urea fertilizer (239% of the country's demand) or 615 GWh of electricity (6% of the production in 2016).

The oil and gas producers indicate that there is a strong commitment not to flare gas and that it is flared occasionally for technical reasons.[10] However, if the estimations above are close to the reality, it could justify a technical and economic assessment on the feasibility of updating/improving the gas extraction facilities and installing a system to recover the associated gas.

Improve the Gas Treatment and Cleaning Processes

Improving the treatment processes of the natural gas extracted along the supply chain, to separate it from other hydrocarbon compounds and non-hydrocarbon impurities, can increase the natural gas yields and its quality.

Although we do not know the exact separation and cleaning processes used and the quality of the natural gas delivered in Côte d'Ivoire, project number 29 of the Plan Strategique de Developpement L'Intégrale (Ministère des Mines, du Pétrole et de l'Energie, 2011), entitled "Installation of a high capacity unit to process the natural gas and extract LPG", seemed to indicate that there was still potential to improve the performance. The objective of the project was to ensure the quality of the natural gas supplied and maximize the domestic production of LPG, as "the flows of natural gas transported in the pipelines that cross the Jacqueville peninsula are subjected to a preliminary treatment on the platform, and only the AFREN (PETROCI) and CNR flows are subject to an appropriate treatment through the Lion GPL unit where the contents of acid gas (CO_2) and water (H_2O) and liquid hydrocarbons (condensate and LPG) are returned to acceptable levels. The natural gas from the Foxtrot field has so far not been subjected to this level of treatment, so PETROCI has been forced to install a mini processing unit upstream of its distribution network." (our translation).

5.9. Remarks

Private thermal production, with an IPP model that reduces some risks for private investors, such as take TOP clauses and a supply of domestic natural gas, enabled the country to respond to a rapidly growing demand, while also positioning itself as a net exporter of electricity to other countries within the sub-region. However, the dependence on domestic natural gas poses a threat as the proven reserves could be insufficient to meet demand growth in the long term. The use of an expensive backup fuel, HVO, due to gas shortages, jeopardized the financial balance of the sector in recent years. New combined cycles, the increase in hydroelectric production and an increase in the domestic natural gas supply improved the situation in 2017, and no natural gas shortages are expected before 2020.

Furthermore, imports of LPG from 2018 and potential new natural gas reserves are expected to reduce the deficit of natural gas in the medium and long term. However, two other complementary opportunities should be assessed to maximize the natural gas output: an update

[9] Calculation: 3,743 million cubic feet = 3,817,860 million BTU * US$ 4.57/MBTU. Price per BTU calculated by authors, as average of prices paid to the gas suppliers in 2016, based on information from ANARE. Rapport d'Áctivités 2016. [Online]. [Accessed 13 March 2018]. Available from: http://www.anare.ci/index.php?id=34

[10] When the pressure in the vessel that carries out the first separation process (separating oil and gas) is too high.

of the gas extraction facilities, to recover the natural gas being flared, and an improvement in the gas separation and treatment processes.

The low costs of the energy produced in the amortized hydro plants and thermal production using domestic natural gas have kept electricity production costs at a moderate level in comparison with the LCOE estimated in other countries of the West Africa region.

Taking advantage of its long experience of attracting private investments in the sector, the country will continue to rely on the IPP model to expand power production. With electricity demand still growing fast, the government strategy is to increase the installed capacity but reduce the share of natural gas-based thermal plants, promoting more at-scale hydro plants and diversifying the energy mix by incorporating coal and renewables (other than hydro). Thus, the sector offers promising opportunities for private investors, notably renewables, such as biomass to electricity, PV solar and small hydropower plants and distributed generation.

However, the opportunities will depend on central planning, as it is the government who will put out the calls to tender and define the criteria or the tender process to select the IPPs for the technologies/capacities needed. As a recommendation, the government should implement a framework to simplify the process for potential smaller producers and encourage more competitiveness —changes that are currently underway.

6. Network Activities

6.1. Overview

In Côte d'Ivoire, the transmission (high voltage) and distribution (medium and low voltage) network assets are state owned. The activities of investment and operations are carried on by two different companies/institutions:

- CI-ENERGIES, a state-owned company, plan and execute the investments in the transmission and distribution infrastructures, such as grid extensions, renewals, reinforcements and new substations. CI-ENERGIES is also responsible for the central planning activities (forecasting the demand and assuring the supply), in conjunction with the Minister of Energy, and for mobilizing the resources and funds needed to realize the investments planned. It also oversees CIE activities and the financial balance of the sector.

- CIE, a private company (Eranove Group), has a concession agreement to operate and maintain the grid and to manage the retail activities/customer relationships (connections, customer service and billing). For its services, CIE receives a management fee per energy (FCFC/kWh). CIE collects electricity payments on behalf of the state and manages the financial flow of the sector (keeping its management fee and transferring funds to pay the gas suppliers and IPPs on behalf of the state). The agreement, granting CIE the concession as network operator, was signed in 1990 for 15 years and renewed in 2005 for an additional 15 years until 2020.

The investments in the transmission and distribution network are financed by different sources: the state budget (taxpayers and debt), bilateral loans (AfDB, KFW, France), donors and through the electricity sector's own resources. In fact, the electricity bill includes a rural electrification fee (known as "redevance électrification rurale") to finance the expansion of

the electricity infrastructure in rural areas. However, the sector has been facing a financial deficit and, apparently, in the last few years, income was not enough to cover investments.

As result of this scheme:

- The state keeps control of decisions related to investments in the grid. In other countries, where the concessioner (electricity distributor) has the responsibility to make the network investment, a stronger regulation is needed to guarantee that private companies will make sound investment decisions, aligned with the public interest, and that their remuneration covers these investments plus a fair return.
- The investments in network infrastructure are limited by the state budget, by government strategy and by its capacity to mobilize the funds needed (especially donations).
- Note that the model to finance and build the network infrastructure is different from the one chosen to add power capacity. While IPPs finance the power plants and receive a return on investment from them (ultimately included in the tariff paid by the end customers), in the case of the network infrastructure it is the state who invests.
- Therefore, the sector accounts (and the electricity tariff) do not reflect the total system costs, as the network investment costs and the return on these investments are not directly included. This contributes to preserving the tariffs at moderate levels, but it creates a system that it is not cost-reflective.

Although nowadays CIE is the only distributor (concessioner), the new electricity code (2014) and the subsequent legislation (a set of decrees published in May of 2017) further liberalize the power sector by ending the state monopoly on transport, distribution, commercialization, import and export activities of electricity. All these activities may now be operated by one or more private operators, under a concession agreement negotiated with the state. The new set of regulations also determines that the tariff should guarantee the financial and economic equilibrium of the system, encompassing all the costs. We may, therefore, expect changes in the network concession and financing model from 2020, when the current CIE concession agreement comes to the end of its term.

In Table 10, we can see the infrastructure of the network system and how it evolved from 2012 to 2016:

Table 10
Infrastructure transmission and distribution network, 2012–2016

		225 kV	90 kV	15kV and 33 kV		Low Voltage		Capacity
Year	Number of substation (225 kV and 90kV)	line Length (Km)	line Length (Km)	Number of substation (33 kV/15 kV)	line Length (Km)	Number of substation (33 Kv/BT and 15 kV/BT)	line Length (Km)	MVA
2016	48	2469	2664	10	23516	10268	20746	5669
2015	46	2088	2613	10	22336	10268	19599	4823
2014	46	2088	2641	10	21718	9801	18737	4361
2013	46	2088	2636	10	20300	8077	17660	4071
2012	45	1986	2629	10	20026	7808	17196	3596

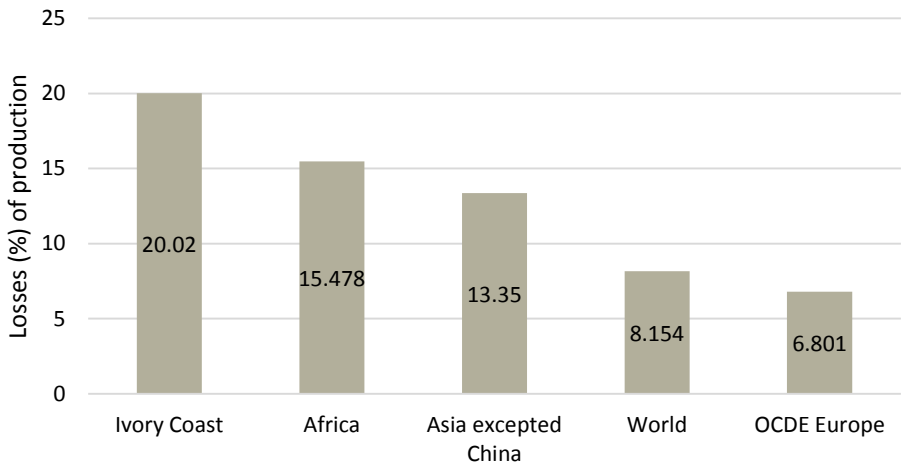
Source : Prepared by the authors, based on data from CI-ENERGIES. *Electrical Statistics 2016*. (leaflet). Table 7-1 and 7-2.

6.2. Energy Losses: One of the Big Challenges to Overcome

High technical and non-technical energy losses affect the transmission and distribution of electricity in Côte d'Ivoire. Technical losses[11] arise during the transport of the energy from the production site to the end customer (mainly due to the heating of the conductors and transformers), and non-technical losses[12] (also called administrative or commercial losses), which refers to the energy consumed but not invoiced, normally occur due to metering problems, invoicing errors or fraud. The energy losses are ultimately a financial loss, as part of the energy produced and paid is lost along the way and cannot be used by the end customers.

Although the losses are an inevitable inefficiency of any power system, in the case of Côte d'Ivoire they are significantly high, as we see in the comparison in Figure 8:

Figure 8
Comparison of loss rates in Côte d'Ivoire and other regions in 2015



Source: Prepared by the authors, based on IEA data from Statistics by Country © OECD/IEA [Online]. [Accessed 10 April 2018]. Available from: https://www.iea.org/statistics/statisticssearch/.

[11] Technical losses originate from the heating of the conductors and iron losses coming from the transformers. These losses are subdivided into several categories:
- Iron losses in live transformers, which depend on the type of transformer and not on the load.
- Joule losses in load transformers and in conductors, which depend on the resistance of the conductor and the intensity that passes through it.
- Dielectric losses in the insulators of the cables, which depend on the voltage and the capacity of the cable.
- Corona losses, which correspond to an electrical discharge caused by the ionization of the environment surrounding a conductor that occurs when the electric field prevailing near the conductor exceeds a critical value.

[12] Non-technical losses are subdivided into several categories:
- Metering problems: poorly calibrated meters, bad IT or TT reduction ratios, failures in recording, incorrect readings, etc.
- Invoicing errors: customers not recorded or not listed, input errors, incorrect billing parameters, etc.
- Fraud: direct connection, meter manipulation, etc.

In 2016, the total losses (at production, transmission and distribution level, both technical and non-technical) were approximately 20% (while the target was 12%), around 2,000,000 MWh lost, or US$150 million[13]. Curiously, at the distribution level, both technical and non-technical, were significantly higher in Abidjan than in other areas (inland areas), as we can see below:

Table 11
Losses in 2016 by type and region – distribution level

	Technical losses	Non-technical losses	Total losses
Other areas	3.5%	4.7%	8.2%
Abidjan	9.7%	9.5%	19.2%
Total	7.4%	7.7%	15.1%

Source : CI-ENERGIES, *Présentation* PowerPoint of 10/11/2017, p 24.

The two main causes of the high losses are an outdated grid and frauds, according to the stakeholders. To reduce technical and non-technical losses, CI-ENERGIES and CIE are running several projects and initiatives, such as investing in grid renewal, new lines at transmission and distribution level and actions against fraud. In fact, the new Electricity Code "includes a range of new criminal sanctions to fight against frauds such as illegal connection to the grid or acts of damages to the electricity network or equipment. The prosecution of any violation of the Electricity Code is also now well-organized." (Wafwana & Associates, 2014). The NPD 2016—2020 also recognizes that to strengthen the governance of the electricity sub-sector, the Government will have to make arrangements for the effective implementation of the electricity code, including the application of enforcement of actions against fraud, theft, and acts of vandalism.

The new grid technologies, such as the anti-fraud cables and smart-meters, combined with new payment methods, such as the pre-payment solution implemented in PEPT, can help reduce the non-technical losses.

6.3. Reliability of the Electricity Supply

In 2016, the average time without electricity or average time of outage, known in Côte d'Ivoire as *temps moyen de coupure* (TMC), registered by CIE was 27.42 hours; an average of 2.3 hours per month — the best achievement since 1997 and significantly better than the 44.63 hours recorded in 2015.

Overall, Côte d'Ivoire's performance is better than the SSA region average in most of the reliability indicators listed in Table 12, although still far away from the performance of the Organization for Economic Co-operation and Development (OECD) high-income countries. Curiously, the percentage of firms identifying electricity as a major concern is considerably higher in the country (62.7%) than in the SSA region (40%). It leads us to wonder if the firms in Côte d'Ivoire are more critical and demanding or if their responses are, in fact, linked with other concerns unrelated with reliability, such as electricity tariffs.

[13] Using the average production cost of US$75/MWh of the energy mix of the country in 2016.

Table 12
Electricity reliability indicators – firms' perception

Indicator	Côte d'Ivoire	Sub-Saharan Africa	OECD High Income
Percent of firms experiencing electrical outages	78.8	78.9	27.5
Number of electrical outages in a typical month	3.5	8.6	0.4
If there were outages, average duration of a typical electrical outage (hours)	5.5	5.7	3.2
If there were outages, average losses due to electrical outages (% of annual sales)	4.9	8.3	0.9
Percent of firms owning or sharing a generator	29.9	52.8	11.4
If a generator is used, average proportion of electricity from a generator (%)	27.3	28.5	7
Days to obtain an electrical connection (upon application)	39.8	35.9	37
Percent of firms identifying electricity as a major constraint	62.7	40	20.4

Source: Prepared by the authors, based on World Bank Group. Enterprise Surveys, Infrastructure. [Online]. [Accessed 10 Feb. 2018]. Available from: http://www.enterprisesurveys.org/data/exploretopics/infrastructure#sub-saharan-africa

6.4. Rural Electrification Review

The electricity grid is present in 51% of the localities (coverage ratio or cover rate),[14] which indicates that significant investments in grid extension or off-grid/mini-grid solutions are still needed. In fact, bringing electricity to rural areas in a cost-effective way is one of the main challenges of many low-income or developing economies.

As we can see in Table 13, the number of electrified localities has been increasing rapidly since 2012 (when the cover rate was as low as 34%); a demonstration of the government's commitment to achieve a cover rate of 80% by 2019 and 100% by 2025 and of its capacity to raise the funds required, especially from international donors.

Table 13
Rural electrification review

Years	Number of electrified communities	Number of electrification projects in process the 31st of Dec	Remaining communities to connect	Cover rate (%)
2016	4537	411	3976	53
2015	4126	448	4387	48
2014	3682	250	5239	43
2013	3032	551	5481	36
2012	2881	54	5632	34

Source: Prepared by the authors, based on data from CI-ENERGIES. *Electrical Statistics 2016*. (leaflet). Table 5.

[14] Number of electrified communities divided by number of total communities.

According to most up-to-date information, by December 2017 there were 3,713 localities not served by the grid, and the cover rate was 56%. The cost of connecting each of these villages is likely to increase, as we can expect them to be in more remote regions. Therefore, it becomes strategic to find cost-effective alternatives to improve the electricity coverage in the short and medium term.

6.5. Plans to Increase the Grid Coverage and Investment Opportunities

1. Investments in the Grid

The government's ambition is, by 2020, to achieve the electrification of all localities with more than 500 inhabitants and of all localities by 2025. However, there are different scenarios under consideration, and the total electrification could be concluded by 2020, 2025 or 2030 (depending on the scenario finally adopted). To this end, the programme national d'électrification rurale (PRONER) was launched in 2015. The main driver to achieve the electrification of rural areas will be the extension of the national grid, with investments in transmission and distribution infrastructure, through the state-owned company CI-ENERGIES. It will require investment in the order of FCFA 500 billion. (Furthermore, additional investment will be necessary to support the demand growth of the already electrified villages and cities).

While the strategy to increase the installed capacity relies on private investment (IPP model), the plan to extend the grid, apparently, remains dependent on the state's funds and on its ability to find international sponsors to finance these state-owned infrastructure projects. Adopting different financing models/channels could impose a different pace in the expansion of the power sector, and the country could end up with a private power production capacity that grows faster than the state-owned grid extension.

However, the new electricity code opened the possibility for new operators to enter the distribution and transmission sector. It also asserts that the state may entrust these operators with the realization of investments in the network (reinforcements, renewal, and extensions). Potential modification on the network operations and investments scheme beyond 2020 (when the CIE concession ends) is currently under study. Depending on the degree of liberalization finally adopted, the country could migrate to a network system whose expansion is driven by the private investors, under a more complex regulatory framework to align these investments with central planning. This change could open up several opportunities for private companies. In fact, some developed economies – such as the United Kingdom – decided to open up network activities to new entrants at distribution and transmission levels, ending the era of the natural monopoly as we knew it.[15]

2. Off-Grid Solutions: Mini Grids (Decentralized Rural Electrification)

Around the world, more and more countries are taking advantage of the decreasing prices of renewable technologies (especially solar) and the promising new generation of batteries to integrate mini-grids and decentralized power production in their rural electrification strategies. Mini-grids are small decentralized electricity systems, isolated from the main grid, producing and distributing electricity at a village level. Although the cost per kWh of off-grid solutions is

[15] In the UK, new transmission lines and new distribution extensions (over a certain threshold of investment) can be built and operated by new entrants, selected under a competitive tendering process.

usually still higher than those of the national grid, they can be the most economical option to electrify remote and small villages, avoiding higher investments in grid expansion.

In Côte d'Ivoire, most of the villages are expected to be connected at the national grid, taking advantage of the economies of scale of the electricity generated by the big hydro and thermal plants. However, CI-ENERGIES plans to serve several remote localities through isolated mini- or micro-grids, as they are the least-cost solutions for these areas.

According to CI-ENERGIES, 96 localities are suitable for decentralized rural electrification, meeting two main criteria: localities suffering voltage drops higher than 10% (70 localities) and localities with less than 250 people located at more than 20 km from the national electricity network. Forty-nine projects (out of the 96) to build mini-grids are already in development and intended to be concluded in 2018, financed by international funding programs. These mini-grids are being built as state-owned assets (like the grid extensions), financed by the West African Monetary and Economic Union (UEMOA) (for 12 projects) and the European Union (EU) (37 projects in the framework of the ENERGOS and Zanzan projects).

The technology chosen for the 96 projects is hybrid: solar (with storage through batteries) and diesel (as a backup), also known as PV-diesel, using combustion-type diesel generators.

Despite all these promising developments, renewable energy mini-grids in developing countries still face constraints related to policy, regulation and financing. Even though the mini-grids are recognized as the least-cost solution to achieve universal electrification for an increasing number of developing countries, and several companies and initiatives were created around this market, there is no such thing as the best business, regulatory and economic model to promote it. Different countries are adopting different frameworks, and there are still constraints and gray areas related to policy, regulation and financing. Typically, models pivot around these interdependent axes:

- Ownership of the assets: utility, state owned, private companies other than utility, communities, NGOs.
- Operation (utility, private companies other than utility, communities, NGOs).
- Retribution model: return on investment, operation fee, margin on electricity sold, feed-in tariff.
- Tariffs applied to the end customer: national tariff, tariff cap, or based on costs.
- Technology: decided by the investor or based on central planning/government determinations.
- Licensing or registration process: while some countries call for a complex licensing process, others opt for a simple registration process. The need for authorization can also depend on the size/power capacity of the mini-grid.
- Criteria to select investor/operator: driven by government (as a competitive process, or call for interest, followed by bilateral negotiation with local authorities) or driven by interested companies (first-come-first-served).
- Exit strategy: define what happens when the grid arrives.
- Community engagement: some countries require the active participation of the local population throughout the process, especially if the tariffs applied are different from those applied for the grid customers.

In the case of Côte d'Ivoire, it is not clear what role that private companies will finally play in the development of these mini-grids. The strategy is still being assessed, which will ultimately shape many of the aspects mentioned above. The country could opt to retain these investments under the state's umbrella and operated by the utility, as has been done so far for the grid, or open up the construction and/or operation of these mini-grids to private companies through concession agreements (following the example of the IPP model). Although there is still much to be decided and regulated, the Decree 787-2016 has already laid the foundations, determining some conditions and potential modalities to exercise the activities of mini-grid and individual, isolated systems:

- These activities may be carried out by private companies (under a concession agreement to be agreed with the state) or by the state (under its own expenses or via donations). In the latter scenario, the state could grant the operation to one private company (concessioners).
- The concessions will be limited by geographic area, although one or several companies may get a concession to operate in the same area.
- The typology of the installations, model of exploitation of the activity, modalities of subscription for the customer, invoicing and payments would be defined through regulation. Thus the mini-grid activities will be developed in a regulated market.
- The remuneration of the private operators/investors will be related to the investments made (return on investments), if any, and, in part, to remunerate the operations.

The Electricity Code would allow the application of different tariffs for the customer served by off-grid solutions. Nevertheless, the main stakeholders argue that the tariffs applied to the customers served by mini-grids should be the same as tariffs applied in all the national territory. In the same way, the government argues that mini-grids should offer rural populations a supply of electricity with a quality comparable with that of the national grid, attending the needs not just of households but also the needs of farmers, agro-industries and small businesses, to boost the social and economic development of the area. These guidelines – if confirmed – will serve to avoid inequity/discrimination towards an already disadvantaged low-income population. Furthermore, CI-ENERGIES argues that the mini-grids must be built to meet technical standards that allow for an eventual connection with the national grid.

Should the government adopt the same strategy used to increase the power capacity (rely on private investment), the development and operations of mini-grids could emerge as a promising business opportunity for private investors and help to accelerate the universal electricity access that the country demands. In order to do so, it is crucial that the Ivorian government and institutions set up a clear, dedicated and consistent regulatory framework, defining rules around the axes cited above that can lower risks to mini-grid developers and guarantee a fair return on investment, while protecting the character of public service of the electricity supply.

The report "Africa 2030: Roadmap for a Renewable Energy Future" (IRENA, 2015) highlights other good practices in the adoption of mini-grids that, in our view, could be appropriate for the country:

- "Shifting focus away from a project-by-project approach towards one that supports the development of a sustainable market in the long-term.
- Establishing an institutional framework that enhances dialogue and coordination between different stakeholders involved, in order to improve clarity and define roles and responsibilities for off-grid electrification initiatives.

- Adopting an integrated approach to policy making that leverages on the synergies with other sectors critical for socio-economic development."

3. Off-Grid Solutions: Solar Home Systems and the PAYG Model

Off-grid solutions at a household level, such as small solar home systems, are already being offered by private companies to households without electricity access, generally through the PAYG model. Through this model, the company installs a solar kit that includes a small solar panel (normally with a capacity from 10 W to 20 W), a battery and basic appliances such as LED lights, a mobile charger and a radio, in exchange for a small upfront payment.

The customer then makes small payments in advance (credit), through mobile money, to use the service. Once the payment has been received, the system is enabled, and when the account runs out of credit, the company can disable the solar panel, which will not work again until the customer tops up. After a period of one to two years (depending on the company), asset ownership is transferred to the customer, who no longer needs to pay for its use. The model, started by M-KOPA in Kenya and well developed in East Africa, has been adopted by many startups across SSA.

Côte d'Ivoire was not left behind and, although the sector is still less developed than in East Africa, several companies have started operations in the country in the past few years, such as PEGAfrica, Zola, Lumos and Mobisol. As the solar home systems are private, household-level energy solutions, there is no official data about the number of solar kits installed (our estimate is between 10,000 and 40,000 households).

These companies have found an attractive market in the country. Like them, we believe that the PAYG solar model is an interesting business opportunity to provide electricity for the households who have not yet been connected, for the following reasons.

A Huge Potential Market to be Served

There are 15 million[16] inhabitants without electricity access in Côte d'Ivoire due to the grid not reaching their community or the lack of financial capability to afford the grid connection and pay the bills. Although the government plans to electrify all villages, the planned dates can still vary, depending on the government's capacity to raise the funds needed. Depending on the scenario, some localities may have to wait until as late as 2030. The PAYG solar model can provide an alternative for these households, at least until the main grid arrives. But even after the electrification of all localities, many families living in remote rural areas could remain too far from the grid and, here again, these micro-financing solar solutions could be the least-cost alternative.

Cheaper Than Kerosene: A Good Choice for Off-Grid households

Although highly contaminant and inefficient, kerosene lamps are still one of the main alternatives for low-income households in the country without an electrical connection, especially for lighting purpose. In Table 14, we compare the costs and lumens provided by one regular light bulb connected to the grid, a set of three kerosene lamps and a set of three ultra-bright LED lights from a typical solar kit.

[16] Our estimation, based on a connection rate of 33% of the households and a population of approximately 22 million.

Table 14
Cost comparison for lighting purposes: grid-based electricity, kerosene and off-grid solar PAYG

Type	Light (lumens)	Electricity Consumtion per hour (Watts)	Kerosene (*petrole lampant*) consumption per hour (liters)	Cost of 10 hours of lighting (FCFA)
Light bulb 50 W - Grid connection	580	50	-	**44.00**
Light bulb 50 W - Grid connection, including upfront PEPT costs	580	50	-	**54.00**
3 Kerosene *(petrole)*lamp	96		0.06	**237.11**
3 LED lamp through Off-Grid Solar Home System (PAYG)	220	6-10		**113.67**

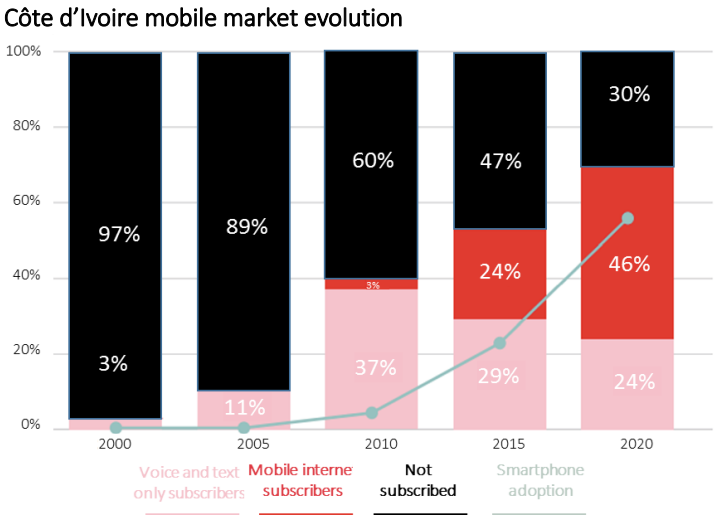
Source: Prepared by the authors.

Using kerosene for lighting costs twice as much as using a solar kit financed through a PAYG model, and it provides less than half the lumens. The off-grid solar home solutions are, therefore, the most economical alternative for households out of the reach of the grid – and a cleaner choice, too. That said, the electricity provided by the grid (if available), is cheaper than both.

High - and Growing – Penetration of Mobile and Mobile Money Accounts

Mobile money technology is a key enabler of the PAYG solar model, as it is the platform through which clients buy credits to use the electricity generated by the solar system. As we can observe in Figure 9, in Côte d'Ivoire, the penetration of mobile services has increased substantially, from 11% in 2005 to 53% in 2015, one of the highest rates in SSA (in Kenya, the penetration rate is 59% and, in Ghana, it is 67%). It is expected to reach 70% in 2020. (GSMA, 2017).

Figure 9
Mobile market evolution



Source: GSMA. 2017. *Country overview: Côte d'Ivoire Driving mobile-enabled digital transformation*. [Online]. [Accessed 13 April 2018]. Available from https://www.gsmaintelligence.com/research/?file=d1553a76179408fc82301b75174bc281&download

Moreover, 33% of adults have a mobile money account – while less than 20% have a bank account. This data puts the country in the selected set of the ten economies worldwide where more adults have a mobile money account than have a financial institution account (together with Burkina Faso, Chad, Gabon, Kenya, Mali, Senegal, Tanzania, Uganda, and Zimbabwe).

Should the solid economic and population growth of the past years continue, we will see an increasing penetration of mobile and mobile money accounts, especially among the rural population, as they have less access to formal financial institutions. This translates to good prospects in the PAYG solar market.

Government Strategy and Recommendations

As in the strategy around mini-grids, the approach of the government regarding individual solar systems is not yet defined. The government seems to recognize the potential of using this type of alternative to provide electricity, but also shows concerns about supporting a solution that could be considered technically inferior (due to its limited capacity) and more expensive than the electricity supply provided by a grid or mini-grid.

So far, the companies offering PAYG solutions in the country are not subjected to any limitations/licensing process to operate, but this could change if the government decides to impose specific rules on this market or to integrate the use of such systems in its rural electrification program.

Considering the private character of this already competitive market, we recommend setting a minimum regulation that can raise investors' and client's confidence in the model, with these goals in mind:

- Preserve and promote the competition between private companies, which will benefit the end customer in terms of lower prices and broader product choices. To this end, it is recommended that companies' activities are not limited through complex licensing or registration processes or by restricting the concession area of their activities.
- Impose minimum quality standards for the products and services, but without limiting innovation and differentiation. It is important to find a balance in protecting the customers against low-quality products and abusive conditions and guaranteeing that, at the same time, the companies enjoy the freedom necessary to offer innovative products and services – which will ultimately bring more choices to customers.
- Inform and update the population and the PAYG companies about the rural electrification calendar. Being transparent about when each locality is expected to be electrified will (i) help the PAYG companies to focus on areas where solutions are greatly needed (the areas that are not likely to be electrified in the short term) and (ii) help the customers in these areas to make informed decision about subscribing or not to a PAYG solar system.
- In the case that the government incorporates solar home systems in the national rural electrification plan (for example, by subsidizing the kits), it is important to create a win-win framework that allows all the private companies to benefit; for example, by offering their kits at subsidized prices. Otherwise, it could create market distortions and damage a market with the potential to improve the life of many.

7. Financial Situation and Electricity Total Costs

The electricity sector has been suffering significant financial distress, at least in the past ten years. For several years, the revenues have not been enough to cover the system costs, or the cash flows have been negative. Year after year, partial solutions have been adopted, and it is forecasted that in 2017 and 2018 the income statement will be positive. However, the situation of financial imbalance is still a concern.

The main reasons behind these imbalances and losses vary, depending on the period. In general, we can point to:

- The increase in international prices of crude oil (as the prices of domestic natural gas were linked to it);
- The increase in the value of the dollar (as the contracts with the IPPs and gas suppliers were linked to it);
- Use of HVO, an expensive backup fossil fuel, to generate electricity (due to occasional shortages of natural gas to meet power demand, especially in years of low hydro production/droughts);
- Payment of TOP clauses with no revenue associated;
- National consumption or exports below the forecast;
- High technical and non-technical losses;
- Difficulties in collecting revenues (unpaid bills and payment delays), especially for exported energy.

The government, companies and institutions in the sector acted in several ways:

- Increasing the tariffs, particularly for non-residential activities and exports;
- Renegotiating the contracts with the gas companies and IPPs;
- Promoting new gas explorations;
- Installing combined cycles in thermal plants to increase the efficiency of the turbines;
- Increasing hydropower capacity (the Soubré project);
- Reducing the average time of outages;
- Renegotiating/enforcing payments of debts.

The increase in electricity tariffs in 2016 was controversial among the population and generated a crisis. As a result, the revision was canceled some months later.

In Table 15, we can see the financial result of the operations, in 2015 and 2016.

Table 15
Operational results/accounts of the sector, 2015 and 2016

	2015 (in billion FCFA)	2016 (in billion FCFA)
SALES		
National Energy sales	403.5	438.4
BT	*228.9*	*253.9*
HTA	*174.6*	*184.5*
Export sales	61.1	110.9
TOTAL SALES	**464.6**	**549.3**
EXPENSES		
Expenses of category A		
Remuneration of CIE	**116.9**	**123.4**
Expenses of category B		
Purchase of gas, of which:	249.9	245.6
Share of State	55.6	66.8
Share of Private Sector	194.3	178.8
Purchase of liquids fuels, of which	58.9	9.6
liquid fuel (DDO and DIESEL)	3	2.2
HVO	55.9	7.4
Subtotal purchase of gas and liquids fuels	**308.8**	**255.2**
Purchase of Energy	126.9	184.5
Subtotal B	**435.8**	**439.6**
Subtotal A and B	**552.6**	**563**
Cash balance available	**-88**	**-13.8**
Subsidies (HVO Subsidy)	28.8	0
BALANCE AFTER SUBSIDIES	**-59.2**	**-13.8**

Source. Prepared and translated by authors based on Tableau 5: Compte d'exploitation du secteur de l'électricité 2015–2016 in ANARE. Rapport d'Áctivités 2016. [Online]. [Accessed 10 April 2018].
Available from: http://www.anare.ci/index.php?id=34.

The expenses of the electricity sector are clustered in groups (categories), establishing a priority system to pay the suppliers:

- Category A: remuneration of CIE (network activities)
- Category B: purchase of fuels and energy production (IPPs and gas suppliers)
- Category C: institutions in charge of the sector (CI-ENERGIES and ANARE)
- Category D: investments
- Category E: other expenses
- Category F: sector stabilization funds

The income statement above does not include the costs of the categories C, D, E and F. As the income was not enough to cover all the expenses of categories A and B in recent years, part of the payment due to the IPPs and natural gas suppliers is currently in arrears.

7.1. Costs Components of the Electricity Supply

In Table 16, we show the detailed costs of the electricity supplied, per kWh, and the weight of each component (%). In the final rows, we compare the total cost and the sale price.

Table 16
Cost components of electricity in 2015 and 2016 – FCFA and percentage per kWh

	2015		2016	
Cost	**FCFA/kWh**	**%**	**FCFA/kWh**	**%**
Production cost, of which:	**51.95**	**64%**	**44.75**	**64%**
Fuels (natural gas, HVO, diesel)	*NA*	*NA*	*25.25*	*36%*
Production (IPP)	*NA*	*NA*	*19.50*	*28%*
CIE remuneration, of which:	**15.47**	**19%**	**13.67**	**20%**
Remuneration on Transport (estimated)	*5.11*	*6%*	*4.51*	*6%*
Remuneration on Distribution (estimated)	*10.36*	*13%*	*9.16*	*13%*
Cost of losses, of which:	**14.03**	**17%**	**11.05**	**16%**
Production losses	*0.55*	*1%*	*0.58*	*1%*
Transport (transmission) losses	*3.66*	*4%*	*3.43*	*5%*
Distribution losses	*9.82*	*12%*	*6.89*	*10%*
Cost of import purchases	0.00	0%	0.15	0%
Total cost	**81.45**		**69.62**	
Sale price (national average)	**68.00**		**67.90**	

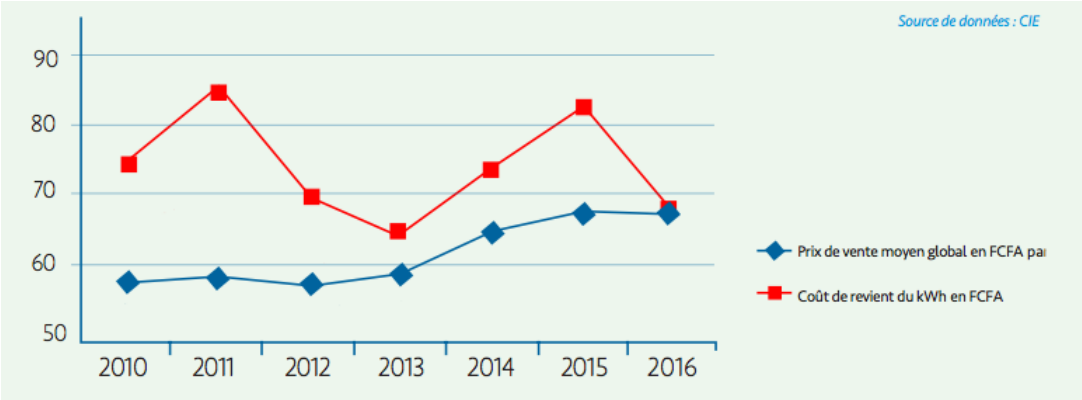
Source: Prepared and translated by the authors based on Tableau 21: Évolution du Cout de Revient du kWh en ANARE. Rapport d'Activités 2016. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34.

We remark:

- The significant share of the fuel cost component (36%) and losses (16%).
- The national average of the sale price (total sales divided by the electricity sold) was lower than the cost, which means that the tariffs are not cost reflective and are insufficient to recover the system costs (see also Figure 10 below).
- These operational costs do not include infrastructure costs (the investment to extend and maintain the grid). Therefore, the real costs of the system are even higher.

In fact, as we observe in Figure 10, the average sales price of the electricity (kWh) – blue line – has been lower than the costs – red line – at least since 2010; a structural problem threatening the feasibility of the model.

Figure 10
Evolution of the cost and sales price of electricity per kWh



Source: ANARE. *Rapport d'Activités 2016*. Graphique 21: Évolution du Côut de Revient du kWh. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34

The set of actions taken, year after year, to reduce the costs and improve the overall efficiency of the sector, has given results in 2016, but the financial equilibrium of the sector is not guaranteed and the government and its institutions will have to keep working to find a sustainable model.

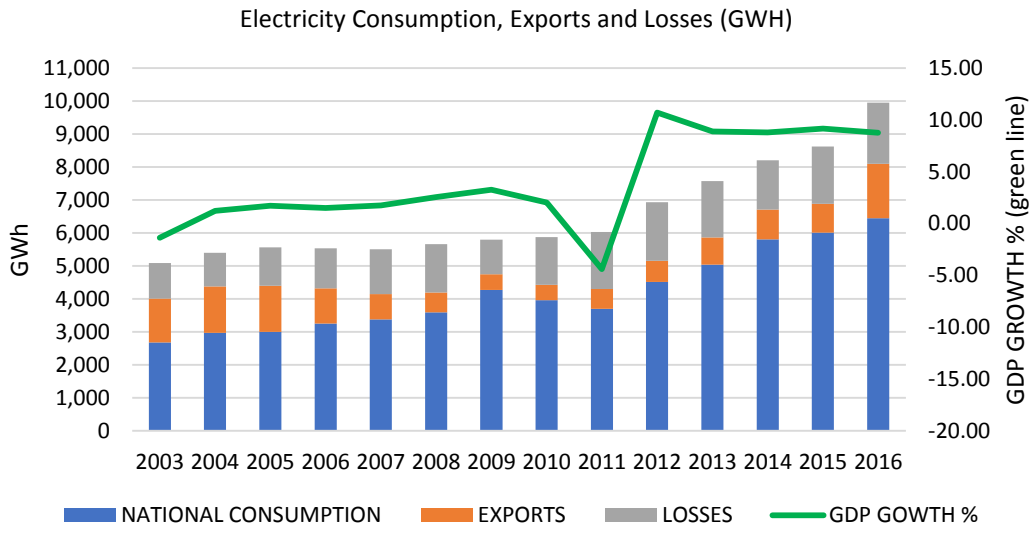
In fact, the new electricity code determines that tariffs should cover all system costs (including infrastructure costs and a fair return on these investments). However, the need to keep tariffs at moderate levels, on one hand, and invest in new power capacity and grid expansion to meet the growing demand, on the other hand, leaves the system caught between cost recovery and affordability, a challenging equation to solve.

8. Consumption and Access Rates: Landscape and Challenges

8.1. Consumption

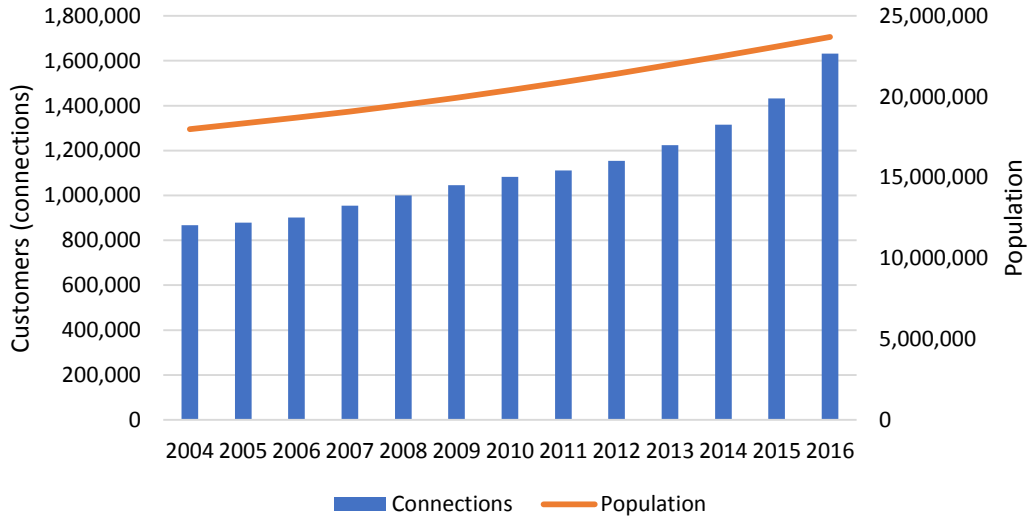
The total electricity consumption increased from 2,974 GWh in 2004 to 6,444 GWh in 2016 (6.7% CAGR), and in the five years following the 2010—2011 Ivorian crisis, the CAGR was even higher, at 9.3% (Figure 11). This impressive growth, higher than the GDP growth for the period, indicates the efforts to ease electricity access to the population. Indeed, the number of subscribers (connections, residential and businesses) rose from 866,736 (2004) to 1,631,443 (2016), growing at a faster pace than the population (Figure 12).

Figure 11
Electricity consumption, exports and losses vs. GDP growth, 2013—2016



Source: Prepared by the authors, based on data from ANARE. *Rapports d'Áctivités 2012, 2013, 2014, 2015 and 2016*. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34 and from The World Bank, *World Bank national accounts data.* [Online]. [Accessed 10 April 2018]. Available from: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CI.

Figure 12
Electricity customers (connections) and population, 2004—2016

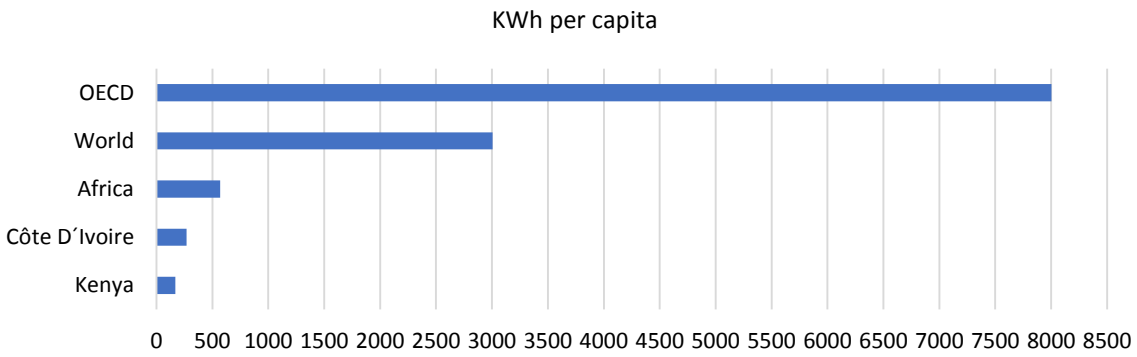


Source: Prepared by the authors, based on data from: ANARE. *Rapports d'Áctivités 2012, 2013, 2014, 2015 and 2016*. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34.
The World Bank. Data *Population, total*. [Online]. [Accessed 18 Feb. 2018]. Available from: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CI.

The average consumption per connection (kWh per year consumed by a household or company), on the other hand, grew moderately: just 2% CAGR for users connected at low voltage (households and small companies) and 0.9% per user connected at high voltage (bigger companies and industries). Of the accumulated increase in consumption in the period 2004—2016, just 24% is due to the rise in the consumption of existing clients. The rest (76%) is explained by the new customers (households and companies).

The electricity consumption per capita, of 270 kWh (IEA, 2015), remains low if compared with the world average or with developed countries, as we observe in the Figure 13 below.

Figure 13
Electricity consumption per capita in 2015 – comparison



Source: Prepared by the authors, IEA data from Statistics by Country © OECD/IEA [Online]. [Accessed 10 April 2018]. Available from: https://www.iea.org/statistics/statisticssearch/.

This can be explained by two main reasons: first, just 33% of households have an electricity supply. Secondly, even the households connected to the grid consume little: on average, 1,363 kWh per year,[17] while in Europe the average is 3,680 kWh per year (EUROSTAT, 2015).[18] The difference becomes greater if we consider the average of inhabitants per household: 2.3 in Europe (EROSTAT, 2016) and more than five in Côte d'Ivoire.

8.2. Access Rate, Connection Rate and Grid Coverage

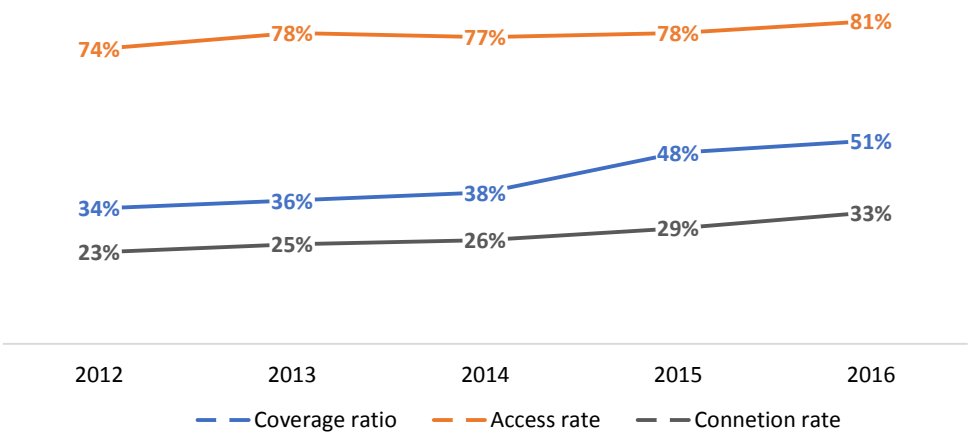
According to ANARE (Rapport d'Áctivités 2016), the grid is present in 51% of the localities (coverage ratio). Furthermore, the access rate[19] is 81% (percentage of the population living in an electrified region); a high score when compared with the 31% in Kenya and an average of 37% in SSA. The grid is, therefore, installed in the most populated areas.

[17] Calculation based on data from ANARE 2016, page 45, tableau 22: total consumption at domestic tariffs divided by number of connections.

[18] Calculation based on info from EUROSTAT (online) 1,6MWh per capita (2015) * 2,3 inhabitants per household (2016).

[19] "Access rate" is a terminology which meaning and calculation can vary from source to source. In this case, it refers to the ratio between the total population living in electrified localities and the total population living in the country.

Figure 14
Access indicators: coverage ratio, access rate and connection rate, 2012—2016



Source: Prepared by the authors, on information from ANARE. *Rapports d'Áctivités 2012, 2013, 2014, 2015 and 2016*. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34.

Although 81% of the population lives in electrified cities or villages, just 33% of the country's households are effectively connected to the grid (connection rate). It means that a significant part of the population living in electrified areas does not have a grid connection, despite the proximity to the grid.

Most of this population still does not use solar panels or domestic generators. Non-electrified households rely mainly on flashlight, with disposable batteries and kerosene lamps. In 2008 kerosene lamps were the main source of lighting, used by 38.7% of the low-income households.[20] However, it appears that, since then, flashlights have gained market share, being used by 43.2% of these households in 2015, while just 5.7% still use kerosene (Table 17). It is also worth mentioning the electrification gap between urban and rural areas.

Table 17
Distribution (%) of low-income households by major source of lighting

	Abidjan	Other urban areas	Rural area	Average
Electricity	92.5	70.3	28.7	46.2
Generator (diesel) or solar energy	0.4	2	6.7	4.8
Lamps and others	3.8	5.2	6.2	5.7
Torch (flashlight)	3.4	22.5	58.3	43.2

Source: Translated by the authors from the Tableau 3.20: Répartition (en %) des ménages pauvres selon la principale source d'éclairage from Institut National de la Statistique. 2015. Enquéte sur le niveau de vie des ménages en Côte D'Ivoire (ENV 2015). Online]. [Accessed 12 March 2018]. Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42.

[20] Institut National de la Statistique. 2018. Enquete sur le niveau de vie des menages (ENV 2008). Online]. [Accessed 05 Febr 2018]. Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42

In the sections below, we analyze the barriers preventing this significant part of the population that has access to the grid from getting a connection and becoming electricity users.

8.3. Barriers to Electricity Access

The household decision-making process for switching from traditional energy systems to modern energy systems (electricity) is complex and, although it has been widely discussed in the literature (especially through the contributions of the energy ladder[21] and energy stacking[22] theories), there is no comprehensive and accurate model that is universally accepted that can explain it. However, the main factors affecting the household energy transition process (switch and usage) are known and generally accepted (although the weight of each variable affecting the household energy transition process remains uncertain). Table 18 summarizes these factors.

Table 18
Summary of factors determining household energy choice

Categories	Factors
Endogenous factors (household characteristics)	
Economic characteristics	Income, expenditure, landholding
Non-economic characteristics	Household size, gender, age, household composition, education, labor, information
Behavioral and cultural characteristics	Preferences (e.g. food taste), practices, lifestyle, social status, ethnicity
Exogenous factors (external conditions)	
Physical environment	Geographic location, climatic condition
Policies	Energy policy, subsidies, market and trade policies
Energy supply factors	**Affordability**, availability, accessibility, reliability of energy supplies
Energy device characteristics	Conversion efficiency, cost and payment method, complexity of operation.

Source: Kowsari, R and Zerriffi, H. 2011. *Three dimensional energy profile: A conceptual framework for assessing household energy use.* Energy Policy 39. [Online]. [Accessed 10 April 2018]. Available from: (http://www.sciencedirect.com/science/article/pii/S0301421514004960).

[21] The energy ladder describes a pattern of fuel substitution as a household's economic situation changes. The model was developed based on the correlation between income and uptake of modern fuels (e.g. electricity). (R. Kowsari, H. Zerriffi, 2011).

[22] The energy stacking model says that the switching is not unidirectional and people may switch back to traditional biofuels, even after adopting modern energy carriers. Fuels are imperfect substitutes and often specific fuels are preferred for specific tasks; instead of simply switching between fuels, households choose to use a combination of fuels and conversion technologies, depending on budget, preferences, and needs. (R. Kowsari, H. Zerriffi, 2011).

Between all these factors, those related to the energy supply (affordability, accessibility, and reliability) and policies (subsidies, market, and trade policies) are the aspects which the energy stakeholders (public and private initiative) can act upon, promoting conditions to facilitate the transition toward modern energy sources. Indeed, the policy factors influence the affordability, accessibility and reliability of the electricity supply directly, and these are the final factors that a household takes into consideration in a practical instance. These three axes relating to electricity adoption can be defined as:

- Whether families can afford the up-front connection fees and monthly electricity bill (affordability);
- Physical access to the electric grid (availability);
- Whether electricity is readily available on demand (reliability).

In most of the SSA countries, accessibility is one the main challenges: the electricity network coverage is limited, and most of the villages and rural areas remain in the dark. In Côte d'Ivoire, however, the situation is different. Although the grid coverage is still a challenge (49% of the villages are not electrified yet), most of the population (81%) lives in electrified areas.

The total generation capacity (reliability) is not a problem in the country: while many SSA countries suffer from lack of a generation capacity — which prevents promoting the entry of new customers and grid development — Côte d'Ivoire is currently exporting 16% of its electricity production and has several projects to add capacity in the pipeline.

If the grid is available (accessible), why are just 33% of the households effectively connected? Are the electricity prices and the upfront connection fees the main barriers preventing the households from moving up in the energy ladder? In the sections below we will analyze how affordable the electricity prices and the connection fees are in Côte d'Ivoire.

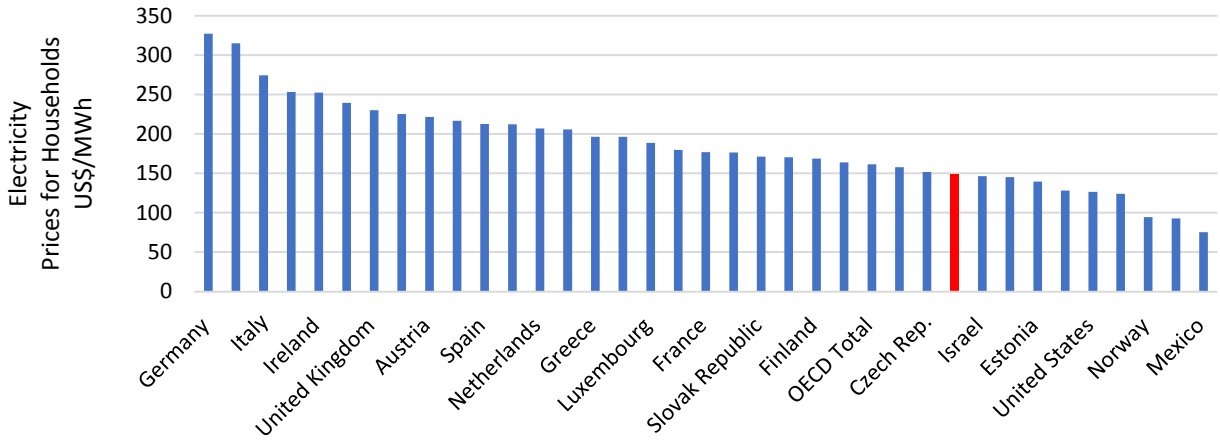
1. Retail Electricity Prices

In the first analysis, we compare the retail electricity price in Côte d'Ivoire and OECD countries, for households (Figure 15) and industries (Figure 16). While the average electricity retail price for households in Côte d'Ivoire ranks among the lowest, for industries it is among the highest.

Recently, the government decided to further increase the tariff for businesses, to improve the financial balance of the sector, while maintaining the tariff for households, which could have broadened the gap between electricity prices for houses and firms.

Figure 15

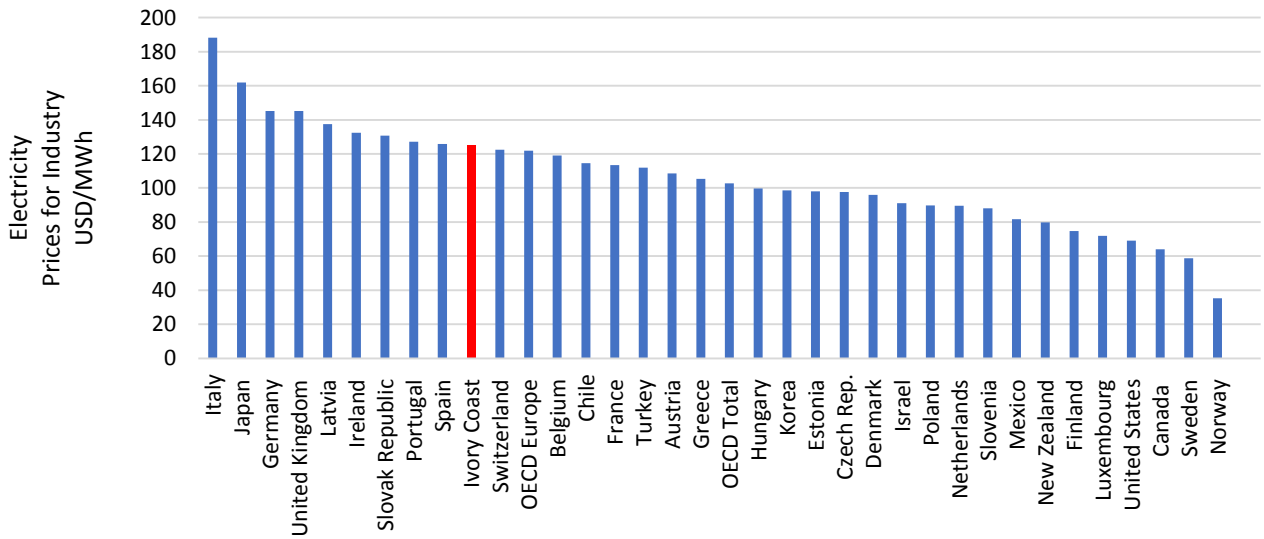
Electricity prices for households ($/MWh) in 2015 – international comparison



Sources: Prepared by the authors, based on IEA data from *Energy prices and taxes. Third Quarter 2017*. IEA Publishing. Licence: www.iea.org/t. For Côte d'Ivoire, it is the author´s' calculation based on public information (ANARE and CI-Energies) about average consumption and tariffs.

Figure 16

Electricity prices for industries ($/MWh) in 2015 – international comparison



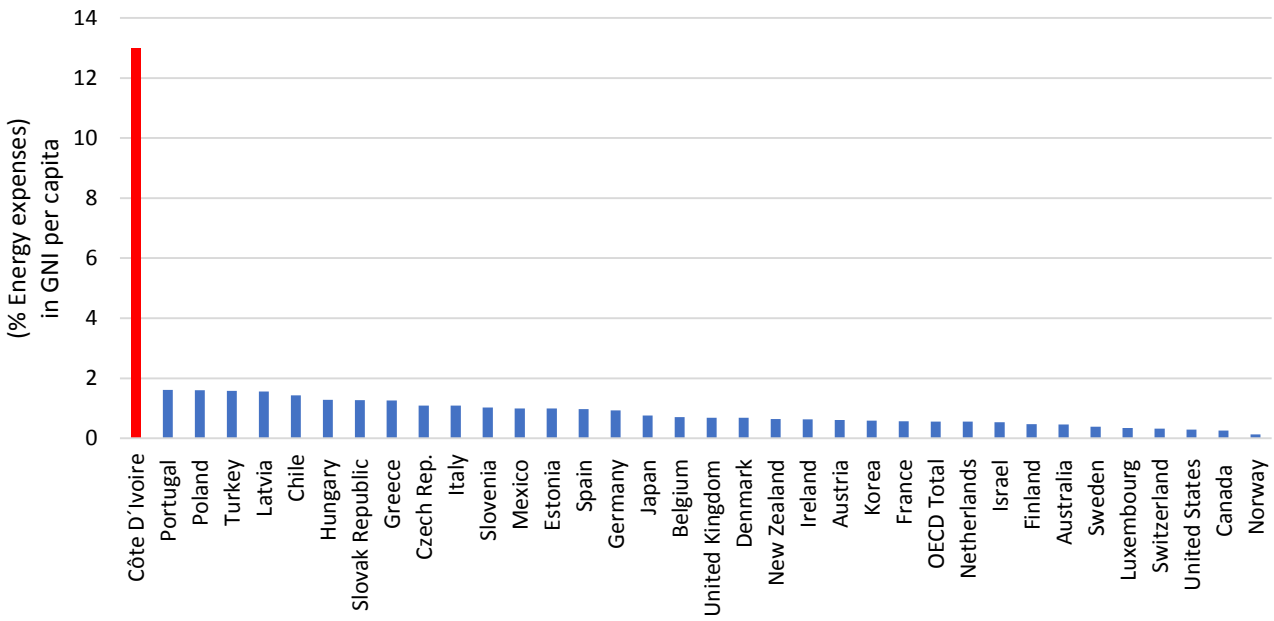
Sources: Prepared by the authors, based on IEA data from *Energy prices and taxes*. Third Quarter 2017. IEA Publishing. License: www.iea.org/t. For Côte d'Ivoire, it is authors' calculation based on public information (ANARE and CI-Energies) about average consumptions and tariffs.

The comparisons above serve to conclude that the retail electricity prices in Côte d'Ivoire are in an acceptable range, if compared with the developed countries, in nominal values. The retail electricity prices are defined by the government, which has kept the household tariffs at a moderate level, harnessing on low electricity production costs (based on thermal and hydro plants) and the fact that the current tariff does not include all the system's costs.

In the second analysis (Figure 17) we compare the percentage that a typical Ivorian electricity bill (based on annual consumption of 1.3 MWh) represents over the gross national income (GNI) per capita, for Côte d'Ivoire and other selected countries (OECD countries).

Figure 17

Affordability: percentage of a household's income (GNI per capita) spent on electricity expenses per year



Sources: Prepared by the authors, based on data from The World Bank. Data GNI. [Online]. [Accessed 10 April 2018]. Available from: https://data.worldbank.org/indicator/NY.GNP.ATLS.CD and based on IEA data from *Energy prices and taxes. Third Quarter 2017*. IEA Publishing. License: www.iea.org/t.
For Côte d'Ivoire, it is the authors' calculation based on public information (ANARE and CI-Energies) about average consumptions and tariffs.

Note: For comparison, we used a consumption of 1,300 kWh per year, the average that a household consumed in Côte d'Ivoire accordingly in 2016.

We can conclude that, although the nominal electricity retail prices are in a normal range (compared with the OECD countries), the share of the GNI per capita needed to cover electricity expenses at a household level is much higher in Côte d'Ivoire, a low-income economy.

However, the affordability best measure is the relationship between the household's net income and the costs incurred to use the electricity (periodic electricity bill). A study conducted by the World Bank argues that "the affordability threshold is typically defined as spending on subsistence power needs of between three and five percent of the total household budget."[23]

In the case of Côte d'Ivoire, in 2015 a household with a *Tarif Domestique Général* — the tariff of 60% of households — spent, on average, FCFA 283,980 per year[24] on electricity bills (approximately US$480). In our estimations, this represents 14.7% of total annual expenditure, a considerable amount, which could reach up to 21% of the budget of a household living on the poverty line. A household family with a *Tarif Domestique Social* spent, on average, FCFA 37,410 (approximately US$63) in electricity bills per year,[25] up to 6% of the budget of a low-income household (see Table 19).

Table 19
Affordability: percentage of electricity expense for households

		Income	
	Average	**Poverty line**	**13% Poorest**
Total expenditure per household - Average per year (FCFA)	1,931,075	1,345,375	620,012
Total expenditure per household - Average per year (USD)	3,267	2,276	1,049
% of expense in electricity, Tariff Domestique Général, per year	**14.71%**	21.11%	45.80%
% of expense in electricity, Tarif Domestique Social, per year	1.94%	2.78%	**6.03%**

Source: Authors' calculations. Total expenditure calculated considering five people per household with expenditure per capita based on data from Institut National de la Statistique. 2015. Enquete sur le niveau de vie des menages en Cote d'Ivoire (ENV 2015). [Online]. [Accessed 12 March 2018]. Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42. Expenditure on electricity from ANARE. Rapport d'Áctivités 2016. [Online]. [Accessed 10 April 2018]. Available from: http://www.anare.ci/index.php?id=34. See footnotes 26 and 27.

Note: total expenditure per household is based on year 2015 and electricity expenditure is based on year 2016.

In a country where 46.3% of the population still lives below the poverty line,[26] the extended application of the *Tarif Domestique Social* — the subsidized social tariff that benefits 40% of the population — is crucial to allow this low-income population to enjoy – at least at minimum levels — the use of electricity.

2. Comparison with Substitutes (Kerosene)

Although highly contaminant and not efficient, kerosene lamps are still one of the main alternatives for the low-income households without electricity, especially for lighting purposes, and are perhaps the only option that does not require significant upfront payment.

[23] Cecilia Briceño-Garmendia and Maria Shkaratan, Power Tariffs: Caught Between Cost Recovery and Affordability, Policy Working Paper 5904 (The World Bank, Africa Region, Sustainable Development Unit, December 2011), p. 29.

[24] ANARE, 2016, page 45: bimonthly bill ("Tarif Domestique Général - Facture moyenne bimestrielle TTC") multiplied by 6.

[25] ANARE, 2016, page 45: bimonthly bill ("Tarif Domestique Social - Facture moyenne bimestrielle TTC") multiplied by six.

[26] Poverty threshold is FCFA 269,075 per year, per capita, based on info from Institut National de la Statistique. 2015. Enquete sur le niveau de vie des menages en Cote D'Ivoire (ENV 2015). Online]. [Accessed 12 March 2018]. Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42

Even with the increasing penetration of solar and battery flashlight where the electricity has yet to arrive, the residential sector consumed 9,000 tons of kerosene in the country in 2015.[27]

Aware of the importance of the product, the government regulates its price — currently at 380 FCFA/liter – and subsidizes it (does not apply full taxes), keeping it at a lower price than gasoline and diesel (sold at FCFA 580 /liter), although their refinery prices are similar. However, as indicated in Table 20, the kerosene to supply three hurricane lamps costs four times more than the electricity needed to light one bulb – which in turn produces six times more lumens (lighting capacity). This demonstrates that kerosene prices – even when being subsidized - are not an incentive for the customers who prefer it over the electricity.

3. Connection Costs

If the electricity bill can take a significant part of a tiny domestic income, the connection costs are certainly a huger barrier. According to CIE, a household expends between FCFA 150,000 and FCFA 250,000 to cover indoor installation, the security certification process, connection costs (the cable and works needed to connect the house to the grid) and the access fee. It can represent up to 25% of the annual income of low-income families, an amount out of reach for these households. Furthermore, these costs do not include the appliances needed to use the electricity beyond lighting purposes.

Table 20.
Connection costs including all expenses

	Income		
	Average	**Poverty line**	**13% Poorest**
Total expenditure per household - Average per year (FCFA)	1,931,075	1,345,375	620,012
Total connection costs (range)	250,000	200,000	150,000
% of annual expenditure committed to get a connection	**12.95%**	**14.87%**	**24.19%**

Source: Total expenditure calculated considering five people per household with expenditure per capita based on data from Institut National de la Statistique. 2015. Enquete sur le niveau de vie des menages en Cote D'Ivoire (ENV 2015). [Online]. [Accessed 12 March 2018]. Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42.

4. Remarks

With an excess of electricity production, a network accessible to 81% of the population and moderated electricity prices for households (cheaper than kerosene and lower than the world average), the key reasons explaining why 67% of the houses are not yet connected are:

- The upfront connection costs are prohibitive for low-income families;
- Although electricity prices are moderate, the electricity bill can represent up to 14% of a family's income.
- The grid still does not cover 49% of villages, where 19% of the population lives.

[27] ©OECD/IEA. Data Statistics by Country. [Online]. [Accessed 10 April 2018]. Available from: https://www.iea.org/statistics/statisticssearch/

8.4. Plans and Initiatives to Facilitate Access: the Programme Electricité Pour Tous (PEPT)

Aware of these problems, the state-owned company CI-Energies and the network concessioner CIE have set up several initiatives. To improve grid coverage, we remit to the previous Section 6.4 (Rural Electrification Review) and Section 6.5 (Plans to Increase Grid Coverage).

PEPT was launched in 2014 to improve access rates, aiming to increase the share of households with electricity from 26% in 2013 to 70% in 2020, from 1.1 million households connected in the rural and urban areas to 2.7 million, by financing the connection fee to low-income families and easing access formalities. In its first three years of implementation (2015, 2016 and 2017) more than 350,000 households have been connected through the program; an impressive milestone.

Although the full success of the PEPT plan has yet to be proved, there is no doubt of the progress made. Starting with an accurate diagnosis of the problems limiting electricity access, especially for low-income families, PEPT set up a comprehensive and innovative solution. Below we highlight the main features of the program:

- Payment facilities to cover the connection cost: the customer makes a small upfront payment (FCFA 1,000, less than US$2) and pays the balance via small installments over variable periods of up to 10 years, together with the electricity consumption.
- Reduction of the connection costs: the requirements and the technical standards to connect a household to the grid were reviewed/simplified, and a standard, less expensive kit is used.
- Indoor installation included: the connection also includes the internal installation (in cases where the household does not have one) and efficient lights.
- Simplification of the certification mechanisms: the process to certify the indoor installations used to be expensive and time-consuming. PEPT simplified it and included its costs in the program as well.
- Pre-payment: PEPT uses smart-meter and prepayment methods. It helps the families to control their electricity expenses and improves the recovery of funds.
- Financing arrangements guaranteeing the sustainability of the program: PEPT utilizes an autonomous revolving fund financing mechanism.

Therefore, the PEPT program is a solution beyond the simple financing or subsidy of the connection costs, structured to be sustainable, address all the major constraints and reach all of the population.

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