# Infrastructure Financing Needs: Forecasting Analysis of Côte d'Ivoire, Ghana, Nigeria, And Senegal to 2030

Technical Annex

May 2022

DEVELOPMENT REIMAGINED

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## 1. Introduction

### 1.1 COVID-19 and infrastructure investment

The COVID-19 pandemic has put additional financing pressure on African countries. Financing fiscal policy measures to support the domestic economies and the costs associated with the vaccine rollout has resulted in constrained fiscal space for many African countries. Concurrently, economic activity has slowed down as a result of social distancing measures, increasing energy prices, and international trade disruptions. All these factors have put additional strain on public finances, with external debt repayments also adding further financial pressure.

This constrained fiscal space as outlined above hinders the access of African countries to debt capital markets. This is further exacerbated due to the deeply flawed process of Debt Sustainability Assessment (DSA) by the International Monetary Fund (IMF) and the World Bank. The DSA classifies countries as high, moderate, or low risk of debt distress by effectively limiting "stable" debt levels to 60% of a country's Gross Domestic Product (GDP). This comes although many countries across the world have developed with significantly higher debt levels, as debt is used to finance infrastructure assets that are essential for growth. There are two reasons why the DSA is problematic.

First, the existence of an assessment provides a negative signal about a country's investment potential. The DSA is applied only to relatively poorer countries – specifically, countries that are eligible to access concessional loans from the World Bank This implies poorer countries that borrow need surveillance. Yet, as the 2008 global financial crisis demonstrated, it is not just poor countries that meet financial challenges or have problematic debt market structures. By default, a disproportionate number of African countries are assessed publicly as "in or at risk of debt distress" compared to the rest of the world. The existence of an assessment provides a negative signal about investment potential in African countries, leading demand and therefore prices to collapse, and to what others have called the "Africa Risk premium".

Second, the DSA ignores the *positive* side of debt. Country debt can be spent on very different activities – including on investments in infrastructure – which can have "spillovers" that create new growth that would not have been there otherwise. For example, a new railway project can cut travel costs and create new markets, which translates into higher productivity. Yet, none of this examination of the potential new "goods" or "assets" created by the debt incurred is included in DSA.

Subsequently, this makes it increasingly difficult for African countries to address large investment gaps, especially in infrastructure, to stimulate post-COVID-19 economic recovery, meet the United Nations (UN) Sustainable Development Goals (SDGs) and contribute to the African Union's (AU) 2063 Agenda. Tackling these investment gaps is something that many African countries have been proactive in, securing billions of dollars in external financing from a range of creditors. However, the existing DSA does not support the ambition of these countries to achieve sustainable and long-term development through investments in infrastructure assets and hinders the ambition of African countries to address their investment gaps.

### 1.2 Introduction to our methodology

Tackling infrastructure challenges requires - as a first step - the identification of infrastructure gaps at a national and sectoral level. To this end, Development Reimagined (DR) has designed an econometric model to predict the infrastructure investment spending needs in four West African countries, namely Côte d'Ivoire, Ghana, Nigeria, and Senegal (collectively referred to as the "countries under consideration").

The prediction of infrastructure investment spending needs is a two-step process. The first step is to estimate the level of infrastructure stock that is either implied by the current, or Business as Usual (BAU), trend of infrastructure investment or required to achieve a specific target or goal. To do so, one needs to determine which sectors account for most of the infrastructure investment in a particular country, understand the specific parameters that affect infrastructure investment in each sector and, finally, forecast the evolution of the level of infrastructure stock up to a specific point in future. For instance, the Organisation for Economic Cooperation and Development (OECD) defines infrastructure as "*the system of public works in a country, state or region, including roads, utility lines and public buildings*".[1] This definition indicates which sectors should be considered as part of the umbrella term "infrastructure investment".

The second step is to estimate the unit costs of infrastructure investment. Unit costs capture the cost of building one unit of a given type of infrastructure (for example, how much it costs in United States Dollars (USD) to generate one megawatt (MW) of electricity, or, for example, how much it costs to build one kilometre (km) of road). Unit costs, when multiplied by the level of annual infrastructure investment provide the annual infrastructure need in USD terms.

The two-step methodology outlined above requires several intermediate steps and an iterative process which requires the researcher to constantly revisit her assumptions and polish the methodological framework. This exercise becomes more difficult if we take into

[1] OECD, (2002). *Glossary of Statistical Terms*. Accessed: February 17th, 2022.

consideration that the previous attempts to forecast infrastructure investment in Africa, which are publicly available, are limited.

Infrastructure investment is crucially important for development, as a driver of economic growth with several economic and societal implications. However, resources are not abundant, therefore, one of the key challenges that policymakers face today is to fine-tune the resources that are available to them. The goal of this analysis is not only to provide a forecast of the future investment needs in the countries under consideration but to also illustrate the size of the financing needs of these countries regarding their current capabilities and GDP. Finally, we highlight the urgent need for the existing DSA to be revised to account for high-quality, productive debt conducive to development.

This technical annex is structured as follows. Section 2 sets out the summary of conclusions of the analysis and Section 3 provides an overview of the different scenarios we have considered. Section 4 discusses, in turn, the various aspects of our methodology and Section 5 provides our results. Finally, Section 6 sets out our concluding remarks. This technical annex is also supported by five appendices that provide background information for the countries under consideration, the annex, and the methodology we have used.

## 2. Summary of conclusions

DR has designed an econometric model to predict the infrastructure investment spending needs in four West African countries, Côte d'Ivoire, Ghana, Nigeria, and Senegal, under two scenarios from 2021 to 2030.

- In Scenario 1, future infrastructure investment needs are assessed with reference to the trend implied by the current infrastructure investment in these countries.
- In Scenario 2, future financing needs are calculated with reference to what is needed from these countries to achieve their national and international pledges.

The shortfall between the two scenarios is our forecast of the infrastructure investment gap.

As **Table 1** shows, we conclude that Côte d'Ivoire, Ghana, Nigeria, and Senegal face an annual infrastructure investment gap that ranges between USD 4.0 - 5.1 billion (for Ghana) and USD 43.3 - 55.7 billion (for Nigeria).[2]

**Table 1: Average annual infrastructure financing gap in the countries under consideration**

| Country | Annual infrastructure financing gap (USD Billion) |
|---|---|
| Côte d'Ivoire | 5.8 - 7.4 |
| Ghana | 4.0 - 5.1 |
| Nigeria | 43.3 - 55.7 |
| Senegal | 4.8 - 6.5 |

The size of the annual infrastructure investment gap is an indication that the financial challenges that Côte d'Ivoire, Ghana, Nigeria, and Senegal must face to invest and develop various infrastructure sectors and subsectors. We conclude our assessment with the following message that should be clear to all stakeholders involved in the field of development - infrastructure investment is expensive, a prerequisite for sustainable development and severely hindered by the DSA by the IMF and the World Bank, which requires fundamental revisions to enable African countries to develop through investments in infrastructure.

[2] Ghana has the lowest infrastructure investment gap in absolute terms while Nigeria the largest one.

## 3. Forecasting the infrastructure investment spending

We have collected historical data from 2005 to 2020 (inclusive) and have forecasted the infrastructure investment spending of the countries under consideration between 2021 and 2030.

Our decision to use historical data between 2005 and 2020 was influenced by two factors. The first factor was data availability. The time series of the independent (to a lesser extent) and dependent (to a greater extent) variables we have included in our regressions were - in many instances - incomplete. Data availability became more problematic the further we went back in time. For this reason, 2005 was a compromise between selecting time series that were adequately complete and having time series that were long enough to be used in our forecasting analysis. In addition, models estimated using shorter time series are usually more stable than those with longer time series because a longer time series increases the chance that the underlying economic conditions have changed (consequently rendering the model unreliable).[3] Thus, there is a trade-off between the increased statistical reliability when using longer time periods and the increased stability of the estimates when using shorter periods. We consider that using historical data between 2005 and 2020 is appropriate in the circumstances – although shorter than the historical period used in most of the comparable studies we have reviewed (**Table 2**). Our data sources and the approach we have followed to fill in the missing observations are set out in **Appendix 1**.

Our decision to forecast infrastructure investment spending up to 2030 was also influenced by two factors. Forecasting accuracy reduces the further we move from the present, therefore we decided to forecast the infrastructure investment spending up to 2030, being ten years after the end of the historical period. In addition, 2030 is the milestone that the international community has set to achieve the SDGs, making 2030 a useful benchmark and a reasonable forecast endpoint. It is also consistent with the forecasting horizon length used in most of the comparable studies we have reviewed.

### 3.1 Previous attempts to forecast infrastructure investment needs

The existing literature on the topic is limited. However, we reviewed the most relevant studies which have sought to forecast infrastructure investment needs in various countries and regions. These studies have served as a useful benchmark for our work (**Table 2**).

[3] Source: CFA Institute.

**Table 2: Previous studies considered in our analysis**

| Paper title | Financing the Future: Infrastructure Needs in Latin America, 2000-2005 | Investing in Infrastructure: What is Needed from 2000 to 2010? | Meeting Asia's Infrastructure Needs | Global Infrastructure Outlook: Infrastructure Investment Needs | Estimating Demand for Infrastructure in Energy, Transport, Telecommunications, Water and Sanitation in Asia and the Pacific |
|---|---|---|---|---|---|
| **Author** | Fay, M (2001) | Fay, M., and T. Yepes (2003) | Asian Development Bank (2017) | Global Infrastructure Hub & Oxford Economics (2017) | Bhattacharyay, B. (2010) |
| **Region covered** | Latin America | Global | Asia | Global | Asia |
| **Sectors included in the analysis** | Transport (road and rail), telecommunication (telephone mainline), power (electricity), water and sanitation | Transport (road and rail), telecommunication (telephone mainline and mobile phone), power (electricity), water and sanitation | Transport (road, rail, airport, and seaport), energy (electricity), telecommunication (mobile, telephone, and broadband), water and sanitation | Transport (road, rail, airport, and seaport), energy (electricity), telecommunication (mobile, telephone, and broadband), water and sanitation | Transport (road, rail, airport, and port), telecommunication (landlines and mobile phones), energy (electricity), water and sanitation |
| **Number of regressions** | One regression per sector | One regression per sector | One regression per sector | One regression per sector | One regression per sector |
| **Econometric model adopted** | Fixed-effect panel | Fixed-effect panel | Fixed-effect panel | Fixed-effect panel | Fixed-effect panel |
| **Independent variables** | GDP per capita, agriculture and manufacturing share of GDP, urbanization, population density, | GDP per capita, agriculture and manufacturing share of GDP, urbanization, population density, | Lagged value of infrastructure stock, GDP per capita, population density, urbanization rate, and | Different specification of the regression model for each sector considered | GDP per capita, agriculture share of GDP, manufacturing share of GDP, urbanization, and population density |

| | | | | | |
|---|---|---|---|---|---|
| | openness of the economy | openness of the economy | agriculture and industry share of GDP | | |
| **Estimation and forecasting methodology** | Described in the section below | Identical to Fay (2001) | Identical to Fay (2001) | Authors rely on the perpetual inventory method to convert the infrastructure investment flows into stock equivalent | Identical to Fay (2001) |
| **Length of time series** | 1960 to 1995 (five-year intervals) | 1960 to 2000 (five-year intervals) | 1970 to 2011 (yearly data) | 2007 to 2015 (yearly data). Authors mention that to use the perpetual inventory method long timeseries data are important. Data traced back to 1980 | 1960 to 2005 (yearly data) |
| **Forecast period** | 2000 to 2005 | 2000 to 2010 | 2016 to 2030 | 2015 to 2040 | 2010 to 2020 |

### 3.2 Sectors of infrastructure considered

As **Table 2** shows, there is a broad consensus amongst the existing studies as to which sectors of infrastructure investment should be considered to best determine the level and size of infrastructure investment. All studies and authors disaggregate infrastructure investment in four main sectors; (i) transportation; (ii) energy; (iii) telecommunication; and (iv) water and sanitation.

In **Table 3** we set out the different sectors and subsectors of infrastructure investment that collectively represent the lion share of infrastructure investment requirements of the countries under consideration as well as the measurement units we have used to proxy infrastructure investment in each of these sectors.

**Table 3: Specification of infrastructure investment sectors that are considered in our analysis**[4]

| Sector | Infrastructure stock variables measurement |
|---|---|
| Road | Kilometres of road per 1,000 km2 of land area |
| Rail | Kilometres of rail line per 1,000 km2 of land area |
| Airport | Number of passengers per 100 inhabitants |
| Seaports | Twenty-Foot Equivalent Units (TEU) per 100 inhabitants |
| Electricity | Kilowatt (KW) of installed electricity generation capacity per capita |
| Fixed telephone | Number of subscriptions per 100 inhabitants |
| Mobile telephone | Number of subscriptions per 100 inhabitants |
| Broadband | Number of subscriptions per 100 inhabitants |
| Water | Percent with access |
| Sanitation | Percent with access |

Having established:

1. The time period covered by the historical data (i.e., 2005 to 2020);
2. The length of the forecasting period (i.e., 2021 to 2030);
3. Which sectors of infrastructure investment should be considered; and
4. How infrastructure investment should be measured in these sectors.

We now discuss the scenarios we considered in our assessment.

[4] Asian Development Bank, (2017). Meeting Asia's Infrastructure needs, page 119.

### 3.3 Current trend or BAU scenario - 'Scenario 1' -

Generating our baseline estimates concerning the future infrastructure investment needs for Côte d'Ivoire, Ghana, Nigeria, and Senegal in the current trend scenario requires estimating the relation between the various categories of physical infrastructure stock we have considered (for instance, kilometres of rail line, percentage of people with access to water and sanitation services etc.) and several key socioeconomic factors that influence the demand and supply dynamics for infrastructure assets.

#### 3.3.1 Rationale for our selection of the same independent variables across our regressions

Following the example of Fay (2001), Fay and Yepes (2003), Bhattacharyay (2010) and the Asian Development Bank (ADB) (2017), we have run a separate regression for each sector of infrastructure investment we have considered versus the same set of independent variables. Our selection is influenced both by the approach assumed by most researchers who have forecasted infrastructure investment assets in the past and also by our understanding that all sectors of infrastructure investment are influenced by the same set of external socioeconomic factors. For instance, an increase in the manufacturing share of GDP in a particular country will drive infrastructure investments in different sectors of the economy. Such sectors are electricity generation, taking into consideration that electricity is a key input in the manufacturing process, and road and rail line investments which are necessary for the swift transportation of raw materials and finished goods to and from the production sites. The example highlights the effect of socioeconomic factors on all sectors of infrastructure investment alike. Its validity can be witnessed through real-life examples such as the Addis Ababa-Djibouti railway line that links the capital city of Ethiopia to the port of Djibouti.

**Box 1: The Addis Ababa - Djibouti railway line**

The Addis Ababa-Djibouti railway is one of the largest transportation infrastructure projects implemented in Africa. With the new railway, Ethiopia's trade hurdles were profoundly reduced as the transportation of goods to and from the Djibouti port became more efficient. The first transnational electrified railway of Africa allows trains to reach a speed of 160 km per hour, has reduced the travel time of passengers and freight from 7 days to 11 hours and has enabled the transportation of up to 3000 tons of cargo in a single trip.

The creation of the railway line has led to the creation of various industrial parks near the rail line. For instance, the Bole-Lemi Industrial Park, the Dire-Dawa Industrial Park, and the Adama Industrial Park are all placed on the rail route creating a strategic economic corridor. This corridor plays an important role in attracting foreign investors to the Horn of Africa and promoting the development of rural cities and their transformation into urban centres and market hubs.

**Figure: Illustration of the Addis Ababa - Djibouti railway line**


The creation of the Addis Ababa-Djibouti railway line is a relevant example highlighting the cause-and-effect relationship between socioeconomic factors (i.e., the manufacturing share of GDP) and infrastructure investment.

The socioeconomic variables we have considered as independent variables for our modelling are the (i) lagged value of the sector's physical stock; (ii) GDP per capita; (iii) agriculture and manufacturing share of GDP; (iv) urbanisation rate; and (v) population density.

### 3.3.2 Model specification

After pinning down the various sectors which - on aggregate - determine the level of infrastructure investment required in each country, we determined a suitable regression form which enabled us to (i) estimate the regression coefficients in the historic period; and, using these coefficients, (ii) forecast the level of infrastructure stock in the forecast period. We concluded that a fixed-effect panel model is the appropriate model to use. A fixed-effect panel model is also employed in all the analyses we have seen on this topic. Our model is specified as follows:

$$I^{s}_{it} = \beta_0 + \beta_1 I^{s}_{it-1} + \beta_2 Y_{it} + \beta_3 AGR_{it} + \beta_4 MAN_{it} + \beta_5 URB_{it} + \beta_6 POPDEN_{it} + \delta_i D_i + \in_{it}$$

(**Equation 1**)

Where:

$I^{s}_{it}$ = physical stock of infrastructure sector j of country i at year t.
$I^{s}_{it-1}$ = lagged value of physical stock of infrastructure sector j of country i at year t-1
$Y_{it}$ = per capita income of country i at year t
$AGR_{it}$ = agriculture share of GDP of country i at year t
$MAN_{it}$ = manufacturing share of GDP country i at year t
$URB_{it}$ = urbanisation rate of country i at year t
$POPDEN_{it}$ = population density of country i at year t
$D_i$ = dummy for country i and $\delta_i$ country fixed-effect for country i

We discuss further our econometric methodology and the output of our regression in STATA (statistical software) in **Appendix 2**.

The relation between the various categories of physical infrastructure stock and the socioeconomic factors we have described above is estimated using historical data for the countries under consideration between 2005 and 2020. Following the methodology implemented by most researchers, we have estimated future physical infrastructure stocks using projections of the same socioeconomic factors used in the historic period (2005-2020). Then, annual needs for additional infrastructure are calculated as the year-on-year difference in infrastructure stocks for each sector. Finally, empirically estimated unit costs are then applied to the annual increments in infrastructure stock to derive the monetary values of new investment needs.[5] We discuss our forecasting methodology in Section 4 of this annex.

### 3.4 Meeting the SDGs scenario - 'Scenario 2'.

The assessment of infrastructure financing needs for the countries under consideration in the meeting the SDGs scenario is different from the BAU scenario. Instead of calculating the future financing needs using forecasts from the econometric regressions, we have sought to benchmark the future financing needs with reference to what investment spending is required from these countries to meet the SDGs or any other national pledges. We provide a short background of the countries in **Appendix 3**.

Ideally, we would like to base our forecasts in Scenario 2 on the national and international pledges of the countries under consideration. However, this would require the identification of recent national and international commitments until 2030, which has not been feasible for the sectors we have considered. In the absence of such information for some sectors, we have relied on the economic concept of club convergence instead. According to this hypothesis, countries with similar features will see their economies converge over time. Therefore,

[5] Asian Development Bank, (2017). *Meeting Asia's Infrastructure Needs*.

"poorer" countries will gradually converge to the standards of the "richer" members of the same club.

### 3.4.1 Forecasts based on the international pledges of the countries under consideration

The SDGs are a relevant benchmark to forecast the infrastructure investment spending. For instance, according to SDG 6: "*Ensure availability and sustainable management of water and sanitation for all*", by 2030, there should be universal and equitable access to (i) safe and affordable drinking water; and (ii) sanitation and hygiene.[6] Therefore, for water and sanitation sectors, we have interpolated for all countries the current percentage of access and 100% (universal access), to determine the infrastructure investment needed for these sectors in Scenario 2.

Furthermore, according to SDG 9: "*Build resilient infrastructure, promote sustainable industrialization and foster innovation*", there should be universal and affordable access to the Internet in least developed countries by 2020. The progress towards this goal is measured with reference to the number of mobile cell phone subscriptions (per 100 people), and the share of a given population using the internet (on any device).[7] In 2020, all countries under consideration had either exceeded or almost reached the first target (i.e., mobile subscriptions per 100 people). Therefore our assessment of mobile telecommunications investment in the meeting the SDGs scenario is the same as the BAU scenario.

For broadband connectivity, we have interpolated between the current number of users (per 100 people) and 100 to ensure that we forecast universal access up until 2030. Finally, in the SDGs scenario, for fixed-line telecommunications, we have used the same forecasts as per what is implied in the current trend scenario. This is due to our understanding that this will not be an area of investment focus for Côte d'Ivoire, Ghana, Nigeria, and Senegal since mobile and broadband technology has made fixed-line telecommunications less significant. For the remaining sectors, international and national commitments did not provide a useful benchmark and therefore, we have based our assessment on the club convergence hypothesis.

### 3.4.2 Club convergence

Convergence clubs are useful for examining economic development in a specific country relative to other countries. We have sought to identify a pool of comparable developing countries which have managed to achieve significant growth over the last decades. These

[6] SDG Tracker, (2021). *Ensure access to water and sanitation for all*. Accessed: March 27th, 2022.
[7] SGD Tracker, (2021). *Build resilient infrastructure, promote sustainable industrialisation, and foster innovation*. Accessed: March 27th, 2022.

countries are namely China, Chile, Colombia, Costa Rica, Malaysia, Mexico, Thailand, and Turkey (henceforth "Convergence club"). These countries are relevant for several reasons:

1. All countries have sea access and had to invest in marine traffic and sea transportation;
2. All countries in the convergence club are not located in the Global North; and
3. Some countries are now members of international organisations that unite the world's most advanced economies such as the G-20 (China, Mexico, and Turkey) or the OECD (Chile, Colombia, Costa Rica, Mexico, and Turkey). This indicates that the countries in the Convergence Club have managed to develop faster than their counterparties over the last decades.

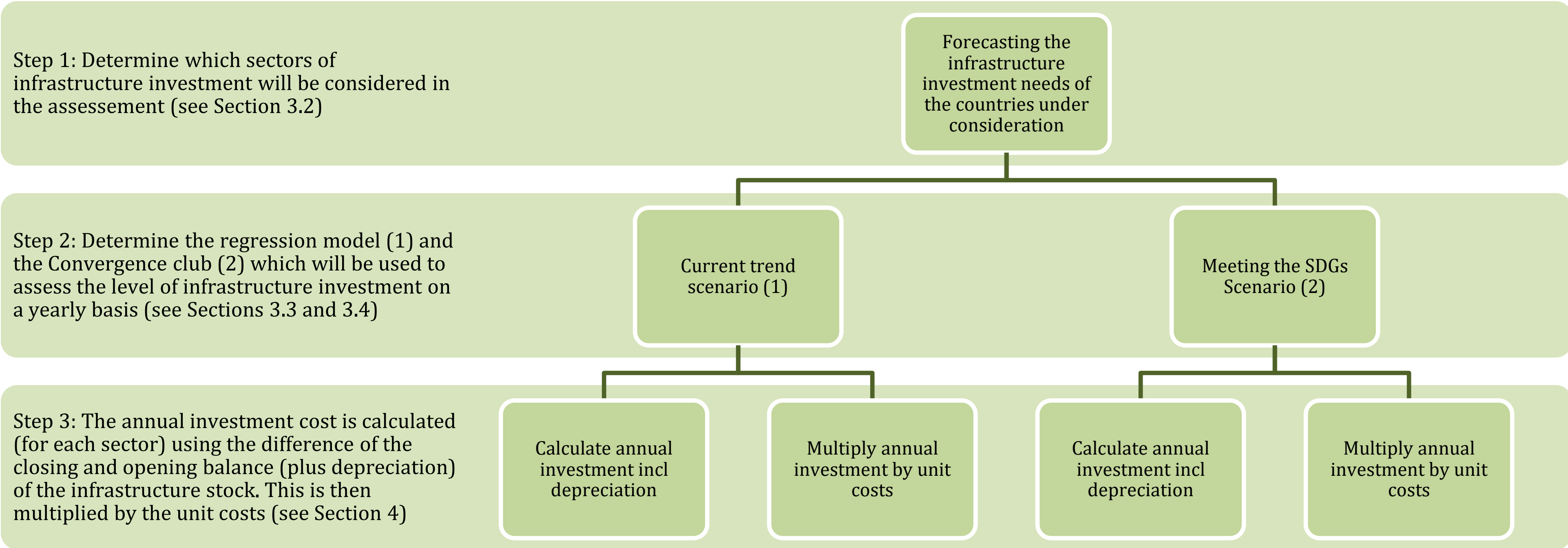
Following the determination of the Convergence club, we calculated the infrastructure stock of these countries on an (i) per square kilometre basis (relevant for the road and rail subsectors); or (ii) per capita basis (relevant for air and sea transportation and energy generation). The average of the stock in these countries for each sector in 2020 acted as the benchmark that Côte d'Ivoire, Ghana, Nigeria, and Senegal should achieve by 2030.[8] We have linearly interpolated between the current (2020) and future (2030) level of infrastructure stock to calculate the annual infrastructure investment that will allow the countries under consideration to reach the infrastructure stock of the countries in the Convergence club.

[8] For the road and rail sectors we have assessed a 75% convergence and for the energy sector we have assessed a 50% convergence. This was driven by the fact that a 100% convergence would not be feasible given the low current stock of these infrastructure sectors in the countries under consideration.

## 4. Methodology and estimation technique

In this section, we summarise the qualitative discussion provided above and also provide further details on our estimation methodology. In Step 1 (Section 3.2) we have determined which sectors of infrastructure investment will be considered in our assessment. In Step 2, in the current trend scenario, we have used **Equation 1** to determine the coefficients of the regressions using historical data between 2005 and 2020. We have calculated the forecast values using the chain rule of forecasting (i.e., for instance, the 2021 forecast for the road network in Ghana is equal to the constant estimated in the regression, plus the fixed-effect for Ghana times the dummy variable for Ghana, plus the sum product of the coefficients of the independent variables multiplied by the forecast values of the independent variables in 2021). Similarly, in the meeting the SDGs scenario, we have used linear interpolation to link the current level of asset stock and the future values up to 2030. **Figure 1** below provides an illustration of the various steps of our methodology in Scenarios 1 and 2.

**Figure 1: Methodology and estimation technique**



The output of Steps 1 and 2 in the current trend and the meeting the SDGs scenario provides the level of infrastructure investment stock for each sector for each country at the end of each year.

### 4.1 Annual infrastructure investment and depreciation rates

The incremental stock of infrastructure investment in each year and for each sector is expressed as: $\Delta K_{it} = K_{it} - K_{it-1}$, where i is the respective country and t the respective year. The expression for $\Delta K_{it}$ provided above however, does not take into consideration maintenance investment (i.e., the investment that is required to replenish existing investment which depreciates over time). To that end, $\Delta K_{it}$ is adjusted as follows $\Delta K'_{it} = KI_{it} - K_{it-1} + \delta_{it}$ (**Equation 2**).

#### 4.1.1 Introduction to depreciation rates

Depreciation rates are a key input which needs to be considered when assessing physical infrastructure stock and any investments made towards increasing its level in a particular country. Tangible fixed assets, such as roads and railway lines, depreciate over their useful economic lives (UELs). The UEL of an asset is assessed against several factors such as the:

- expected usage of an asset;
- expected physical wear and tear which in turn depends on operational factors and the care and maintenance of the asset while idle;
- technical or commercial obsolescence arising from changes or improvements in production, or from a change in the market demand for the product or service output of the asset; and
- legal or similar limits on the use of the asset.[9]

Once the UEL of an asset has been determined, we can estimate the annual depreciation rate, being the rate at which the value of the asset is diminishing year on year. Long-lived assets such as roads and railway lines have longer UEL versus short-lived assets such as computers and mobile phones which can become obsolete as early as every three years. When an asset reaches the end of its UEL, it needs to be (fully) replenished. An asset's depreciation rate is calculated as per **Equation 3** below.

$$Depreciation\ rate\ (\%) = \frac{1}{UEL\ (in\ years)} \times 100\% \quad \textbf{(Equation 3)}$$

[9] IFRS, (2020). IAS 16: Property, Plant and Equipment, paragraph 56, page A1052.

#### 4.1.2 Depreciation rates and infrastructure investment

Investment in infrastructure assets have two components; (1) investment required in terms of adding new assets to a country's asset base; and (2) investment required to replenish the existing assets. In our analysis, we have therefore sought to estimate net infrastructure investment, being the investment needed to constantly increase the asset base of a particular country. Put differently, we not only need to estimate infrastructure needs for new assets but also the infrastructure needs that are required to replenish and maintain the existing asset base. Total capital stock is assumed to evolve as per the equation below:

$$K_{it} = K_{it-1} * (1 - \delta_{it}) + I_{it} \text{ (Equation 4)}$$

Where $I$ is the gross additions to the asset base and $\delta$ is the rate of depreciation. We need to estimate for each category of infrastructure investment a respective depreciation rate which will be a key factor in terms of modelling the annual infrastructure investment. In **Table 4**, we set out the depreciation rates used in previous studies and other sources, and which have served as a useful benchmark for our assessment of the depreciation rates in our analysis.

**Table 4: Depreciation rates per sector of infrastructure investment used in previous studies and other sources (*)**

| | ADB (2017) | Fay and Yepes (2003) | Fay (2001) | Bhattacharyay (2010) | BEA(*) |
|---|---|---|---|---|---|
| Road | 3% | 2% | n.a | 2% | 2% |
| Port | 2% | n.a | n.a | 2% | n.a |
| Rail | 2% | 2% | n.a | 2% | 2% |
| Air | 2% | n.a | n.a | 2% | n.a |
| Energy | 2% | 2% | n.a | 2% | 2.1% |
| Water and Sanitation | 3% | 3% | n.a | 3% | n.a |
| Telecoms | 8% | 8% | n.a | 8% | 2.4% |

*Notes: (1) BEA stands for the U.S. Bureau of Economic Analysis. (2) n.a stands for "not available".*

#### 4.1.3 Our assessment of depreciation rates

To inform our choice and select the most suitable depreciation rates for each sector of infrastructure investment, we have sought to combine the depreciation rates used in previous studies with independent research and understanding of the economic and asset accounting reality. There is broad consensus amongst studies on the depreciation rates that should be selected, in which we agree for most of the relevant sectors. An exception is the depreciation rates used in the energy and telecommunications sectors.

For telecommunication sector, we have sought to identify a respective depreciation rate for fixed telecommunications, mobile telecommunications, and broadband connections. GSMA, a global organisation representing mobile operators and organisations across mobile telecommunications and adjacent industries,[10] has published a report comparing the cost structures of mobile and fixed telecommunications. We observe that:

1. Base stations, transmission and switching components in mobile telecommunication technology all have a UEL equal to 10 years. Other mobile telecommunication components have higher UEL. Based on this observation and Equation 3 above, we infer that the most suitable depreciation rate for mobile telecommunications is between 8% and 10% per annum. We have decided to use a depreciation rate of 8% for mobile telecommunications as we consider it close to the actual depreciation rates of mobile telecommunication infrastructure; and
2. Buildings, trenches, and cables used in fixed telecommunications have a UEL between 20 and 40 years. However, we believe that the UEL of fixed telecommunications assets is closer to 25 years and based on **Equation 3**, we infer that the most suitable depreciation rate for fixed telecommunications is 4% per annum.[11]

Further, a paper by Nokia Siemens Networks concerning broadband technology suggested that "*monthly network CAPEX + OPEX can be kept below 3 EUR per subscriber over an eight-year depreciation period if average mobile broadband penetration is at least 500 subscribers per site*". Based on this statement and **Equation 3** above, we have selected a depreciation rate of 12.5% for broadband connectivity.[12]

Finally, we consider the annual depreciation of 2% (which translates to a UEL of 50 years) for energy infrastructure, as suggested in most of the studies we have reviewed, rather low. Renewable energy infrastructure assets such as wind turbines and solar panels normally have shorter UELs than traditional energy assets such as coal and nuclear plants. For instance,

[10] GSMA, (2022). About us. Accessed: February 17th, 2022.
[11] GSMA, (2012). Comparison of fixed and mobile cost structures. Accessed: February 17th, 2022.
[12] Nokia Siemens Networks, (2010). Mobile broadband with HSPA and LTE - capacity and cost aspects. Accessed: February 17th, 2022.

according to the Japanese Procurement Price Calculation Committee, the procurement period for solar and wind energy equipment is 20 years.[13] This translates to an annual depreciation rate of 5%. Taking into consideration that renewable energy assets will represent an ever-growing share of investment in energy assets during the forecasting period (2021-2030), we acknowledge that the most appropriate depreciation rate to use is between 2% and 5%. We have selected a depreciation rate equal to 3% for energy assets on the basis that renewable energy resources represent a minority share of electricity generation in the countries under review. We set out the depreciation rates selected along with the rationale underpinning our selection (**Table 5**).

**Table 5: Depreciation rates selected in our analysis**

| Sector | Our selection | Rationale for selection |
|---|---|---|
| Road | 2.5% | Based on the average of the depreciation rates suggested in ADB (2017) and Fay and Yepes (2003) |
| Port | 2.0% | Based on the consensus estimate provided in ADB (2017) and Bhattacharyay (2010) |
| Rail | 2.0% | Based on the consensus estimate provided in ADB (2017), BEA (2010) and Fay and Yepes (2003) |
| Air | 2.0% | Based on the consensus estimate provided in ADB (2017), Bhattacharay (2010) |
| Energy | 3.0% | See discussion above |
| Water and Sanitation | 3.0% | Based on the consensus estimate provided in ADB (2017) and Bhattacharyay (2010) |
| Fixed telecoms | 4.0% | GSMA (2012) |
| Mobile telecoms | 8.0% | GSMA (2012) |
| Broadband | 12.5% | Nokia Siemens System (2010). |

*Source: **Table 4** and discussion above.*
*Note: We realise that we have relied on depreciation rates from studies and/or sources published at various points in time over the last 20 years. However, we do not consider our approach simplifying on the basis that UEL of assets are generally stable and are not highly sensitive to the passage of time.*

### 4.2 Unit costs of infrastructure investment

[13] PriceWaterhouseCoopers, (2022). Accounting Issues Concerning Businesses of and Investments in Renewable Energy. Accessed: February 17th, 2020.

Unit costs of infrastructure investment refer to the cost of building each type of physical infrastructure asset. For instance, unit costs of infrastructure investment determine how much it costs to build one kilometre of road or how much it costs to install one MW of electricity generation capacity. When multiplied by the annual incremental stock of infrastructure investment, unit costs provide the annual cost of infrastructure investment - i.e., the investment needed in monetary terms. Put differently, the investment needs for new infrastructure assets, in any given future year t, is calculated as per **Equation 5** below:

$$M_{it} = c \times (\boldsymbol{K_{it}} - \boldsymbol{K_{it-1}} + \delta_{it}) \quad \textbf{(Equation 5)}$$

where *c* is the unit cost for each type of infrastructure investment, and $\boldsymbol{K_{it}} - \boldsymbol{K_{it-1}} + \delta_{it}$ is the gross additions to the asset base which account for both the creation of new assets and the replenishment of existing ones (see the relevant discussion in the Section above).

### 4.2.1 Unit costs used in previous studies

A different unit cost should be calculated for each type of infrastructure investment. To calculate the unit costs for each type of infrastructure investment we have followed a similar methodology as with the depreciation rates. In **Table 6** below, we set out the unit costs of infrastructure investment provided in the literature.

**Table 6: Unit costs of infrastructure investment used in previous studies (in USD)**

| Sector | Unit | ADB (2010 prices) | Nunez & Wei (2011 prices) | Fay & Yepes (2000 prices) |
|---|---|---|---|---|
| Road | Km | 600,000 | n.a | 410,000 |
| *Paved* | *Km* | *n.a* | *500,000* | *n.a* |
| *Unpaved* | *Km* | *n.a* | *51,000* | *n.a* |
| Port | TEU | 400 | 360 | n.a |
| Rail | Km | 3,855,000 | 1,200,000 | 900,000 |
| Air | Passenger | 7 | n.a | n.a |
| Energy | KW | 2,513 | 2,700 | 1,900 |
| Sanitation | Person | 168 | 150 | 700 |
| Water | Person | 161 | n.a | 400 |
| *Urban* | *Person* | *n.a* | *150* | *n.a* |
| *Rural* | *Person* | *n.a* | *80* | *n.a* |
| Telecoms | Line | | | |
| *Fixed-line* | *Line* | *261* | *From 200 to 300* | *400* |
| *Mobile line* | *Line* | *127* | *From 90 to 130* | *700 from 2000 and 580 from 2005* |
| *Broadband* | *Person* | 3 | *n.a* | *n.a* |

*Note: The table above, only includes studies which provide the unit costs of infrastructure investment used.*

### 4.2.2 Our assessment of unit costs

To inform our choice and select the most suitable unit costs for each sector of infrastructure investment, we have sought to confirm the unit costs provided in previous studies with our independent research and assessment. The infrastructure projects we reviewed and the different sources we rely on, present cost data from projects implemented at different points in time. Infrastructure costs vary year on year for reasons such as inflation, currency fluctuations and movements in the cost of raw materials. However, factoring in our analysis the effect of movements in the price of raw materials on the cost of building infrastructure assets, would require detailed technical knowledge and would result in a spurious level of precision. For this reason, we have not factored in our analysis differences in costs that arise because of changes in the prices of the raw materials used in the production of infrastructure assets. Nevertheless, we have used the constant USD methodology to account for the effect of inflation on unit costs (see Box 2 below).

**Box 2: The constant (2010) USD methodology**

To apply the constant (2010) USD methodology we have followed the standardised approach prescribed by the World Bank. To apply this methodology, we divide the total infrastructure cost (in USD) by an index. This index expresses the value of one USD at the year the investment is completed (if the project spans in multiple years we assess the value of one USD with reference to the year the project is completed) versus the value of one USD as of 2010 (thus, 2010 will be equal to the base cost of one USD). For instance, the cost of an investment completed in 2015 using the constant 2010 USD methodology is given by the formula below:

$$Cost\ in\ 2010\ (constant\ USD)\ =\ Actual\ cost\ \times \frac{CPI\ in\ 2010}{CPI\ in\ 2015}$$

The purpose of this methodology is to make costs incurred at different points in time comparable by eliminating the effect of inflation.[14] This formula can be adjusted in cases where costs are incurred in non-USD denominated currencies.

Once we estimate the costs - in 2010 constant USD - for each category of infrastructure investment we then inflate the final figure to get the corresponding cost expressed in 2020 USD terms. Further, putting a specific number to our estimates of unit costs is overly simplistic and have therefore calculated a low and a high end of unit costs for each infrastructure investment category. We believe that the actual value of unit costs lies within that range. We discuss all ten sectors, in turn, below.

#### 4.2.2.1 Road infrastructure

A number of significant road infrastructure projects have been completed in the countries under consideration. In 2020, a Ghanaian executive disclosed that "*for every kilometre of road constructed in Ghana, the State pays GH¢ 1.5 million*".[15][16] In addition, evidence from Nigeria suggests that the cost of building 1 kilometre of road should not surpass ₦ 238 million.[17][18] According to the African Development Bank (AfDB) the median maintenance cost per kilometre of unpaved roads is between USD 9,600 and 11,300 depending on the road size. The same range for the construction of paved roads is between USD 147,100 and 227,800.[19]

[14] World Bank, (2021). What is your constant U.S. dollar methodology? Accessed: February 21st, 2022.
[15] GhanaWeb, (2021). *1km of asphalt road costs GH¢1.5 million - Roads minister.* Accessed: February 21st, 2022.
[16] GH¢ 1.5 million is equal to c. USD 260,000 based on the average exchange rate between the GH¢ and the USD in 2020.
[17] Naijacarnews, (2019). What is the cost of road construction in Nigeria? Accessed: February 21st, 2022.
[18] ₦ 238 million is equal to c. USD 640,000 based on the average exchange rate between the ₦ and the USD in 2019.
[19] AfDB, (2014). Study on Road Infrastructure Costs: Analysis of Unit Costs and Cost Overruns

Therefore, considering this alongside data provided in **Table 6**; and assuming an 80% proportion of paved roads and a 20% proportion of unpaved roads as a share of the total, we assess the range of unit cost of road infrastructure (in 2020 USD terms) between USD 360,000 and 560,000.

#### 4.2.2.2 Rail infrastructure

Our research has indicated that number of rail infrastructure projects that have completed in the countries under consideration between 2010 and 2020 is limited. An exception is the Kano-Maradi rail line in Nigeria. The contract cost for 284 kilometres of rail line was c. USD 2 billion - suggesting a cost of USD 6.9 million per kilometre of rail constructed.[20] Furthermore, the European Union estimates that the cost of building conventional rail lines is approximately EUR 4.4 million per kilometre or an equivalent of USD 5.4 million in 2020 USD terms.[21] Considering the information available to us, we assess the unit cost of rail infrastructure (2020) as between USD 4,610,000 and 5,370,000.[22]

#### 4.2.2.3 Energy

Estimating the unit cost of infrastructure investment in the energy sector up to 2030 is challenging. Several assumptions must be made (for instance, a forecast of the energy mix of the countries under consideration needs to be made up to 2030). We assume that three-quarters of the infrastructure projects that will be implemented in Côte d'Ivoire, Ghana, Nigeria, and Senegal up to 2030 will reflect investments in traditional energy sources and the remainder will reflect investments in renewable energy. The International Renewable Energy Association (IRENA) has published a study setting out the costs of generating power from several renewable sources in 2020. These costs are set out below.

Statistics Department (ESTA) of Road Infrastructure Projects in Africa. Accessed: February 21st, 2022.

[20] The Guardian, (2021). Nigeria's rail costs exceed AU's estimates by over 100%. Accessed: February 21st, 2022.

[21] European Commission, (2018). Assessment of unit costs (standard prices) of rail projects (CAPital EXpenditure). Accessed: February 21st, 2022.

[22] We note that the investment costs for rail infrastructure provided in the existing studies are substantially lower than the costs implied by the actual investment projects we have considered. Therefore, our assessment lies between the various assessments – albeit skewed towards the actual investment costs.

**Table 7: Unit costs of renewable energy resources**

| Renewable resource | Cost (2010 USD/Kw) | Cost (2020 USD/Kw) |
|---|---|---|
| Bioenergy | 2,619 | 2,543 |
| Geothermal | 2,620 | 4,468 |
| Hydropower | 1,269 | 1,870 |
| Solar PV | 4,731 | 883 |
| Concentrated Solar Power | 9,095 | 4,581 |
| Onshore wind | 1,971 | 1,355 |
| Offshore wind | 4,706 | 3,185 |

*Source: IRENA.*[23]

The average unit cost of renewable energy resources in 2020 as per the Table above is USD 2,698 per KW. Renewable energy assets are generally more expensive than traditional energy assets and therefore this average unit cost is undoubtedly in the upper end of the energy unit cost. Therefore, we believe that a range between USD 2,300 (being 15% lower than the upper end of the range) and USD 2,700 is reasonable.

#### 4.2.2.4 Water and sanitation

In January 2016, the World Bank published a study discussing the costs of meeting the 2030 SDG targets on Drinking Water, Sanitation and Hygiene.[24] In Appendix E of the World Bank report, the authors discuss the unit costs of providing access to water and sanitation for each developing country in the world. We replicate their findings in the table below.

[23] IRENA (2020). Renewable Power Generation Costs in 2020. Accessed: February 21st 2022.
[24] World Bank (2016). The Costs of Meeting the 2030 Sustainable Development Goal Targets on Drinking Water, Sanitation and Hygiene. Accessed: March 26th, 2022.

**Table 8: Capital costs per person served in 2015 (in USD)**

| Country/ sector | Urban areas | Rural areas |
|---|---|---|
| **Ghana** | | |
| *Water* | *149.2* | *72.6* |
| *Sanitation* | *311.7* | *109.1* |
| **Côte d'Ivoire** | | |
| *Water* | *113.1* | *242.7* |
| *Sanitation* | *151.7* | *75.9* |
| **Nigeria** | | |
| *Water* | *154.6* | *20.8* |
| *Sanitation* | *180.8* | *118.6* |
| **Senegal** | | |
| *Water* | *122.5* | *181.5* |
| *Sanitation* | *66.1* | *44.1* |

The numbers are then weighted by the urbanisation rate in each country under consideration in 2020 to calculate the cost of providing access to basic water and sanitation services for each of the countries. We calculate that the low end of the unit cost range for providing access to water services is USD 100 per person while the high end of the range is USD 190 per person. The respective costs for sanitation services are USD 125 and USD 250 per person, respectively.

#### 4.2.2.5 Other sectors

Moving on to the remaining sectors we note the following.[25] In mobile telecommunications (as of 2018) there were 300,000 cell towers installed in the U.S. Using the population of the U.S. as a reference point, we estimate that one cell tower is required per 800 to 1,000 people. The average cost to build a cell tower is USD 175,000 which translates into a cost between USD 175 and 220 per capita.[26] However, bearing in mind the difference in the economic development between the U.S. and the countries under consideration, it is safe to assume that each cell tower will be serving more people in the countries under consideration. Therefore, a cost between USD 100 and 125 is deemed reasonable given the split of the same cost to a greater number of people.

[25] Because of absence of designated data for African countries, we have resorted to data available on an international level.
[26] Sior pulse (2018). Cell tower leases add big value with little maintenance. Accessed: March 26th, 2022.

In broadband connectivity, we have reviewed a study by Nokia suggesting that the monthly network capital and operational expenditure per broadband connection should stay below EUR 3 per subscriber per month, [27] which translates to an annual cost of EUR 36 per annum. We are using the equivalent of this number in USD as a proxy for the broadband connectivity unit cost (rather than this number times the UEL of broadband assets) to take into consideration that there is some overlap between costs for broadband connectivity and mobile telecommunications.

Finally, the OECD projects the total capital expenditure regarding air transportation to be around USD 120 billion per annum between 2015 and 2030.[28] According to the International Civil Aviation Organisation, in 2017, the global air traffic was around 4.1 billion passengers.[29] Therefore, the corresponding cost per passenger flown in 2017 is USD 30. We will use this figure as the lower end of our assessment and a cost of USD 40 as the high end of our assessment of air transportation unit costs.

In the absence of any superior evidence, we consider the range of infrastructure costs provided in Nunez and Wei (USD 360, in 2011 prices) and ADB (USD 400, in 2010 prices) for seaport transportation reasonable. If we express these figures in USD 2020 values, then the corresponding range is between USD 410 and 480. Following the same methodology, we calculate a range for fixed-line telecommunications unit costs between USD 230 and 345 in line with assessment provided in the studies we have reviewed on this matter.

#### 4.2.2.6 Conclusion

In the table below, we present the unit costs of infrastructure investment we have selected for our analysis.

[27] Nokia Siemens Networks. Mobile broadband with HSPA and LTE – capacity and costs aspects. Accessed: March 26th, 2022.
[28] OECD, (2011). *Strategic Transport Infrastructure Needs to 2030*. Accessed: March 26th, 2022.
[29] ICAO, (2017). *Future of aviation*. Accessed: March 26th, 2022.

**Table 9: Unit costs of infrastructure investment per sector considered (in USD 2020 prices)**

| Sector | Low end | High end |
|---|---|---|
| Road | 360,000 | 560,000 |
| Port | 410 | 480 |
| Rail | 4,610,000 | 5,370,000 |
| Air | 30 | 40 |
| Energy | 2,300 | 2,700 |
| Water | 100 | 190 |
| Sanitation | 125 | 250 |
| Fixed telecoms | 230 | 345 |
| Mobile telecoms | 100 | 125 |
| Broadband | 50 | 60 |

## 5. Infrastructure investment spending in the countries under consideration

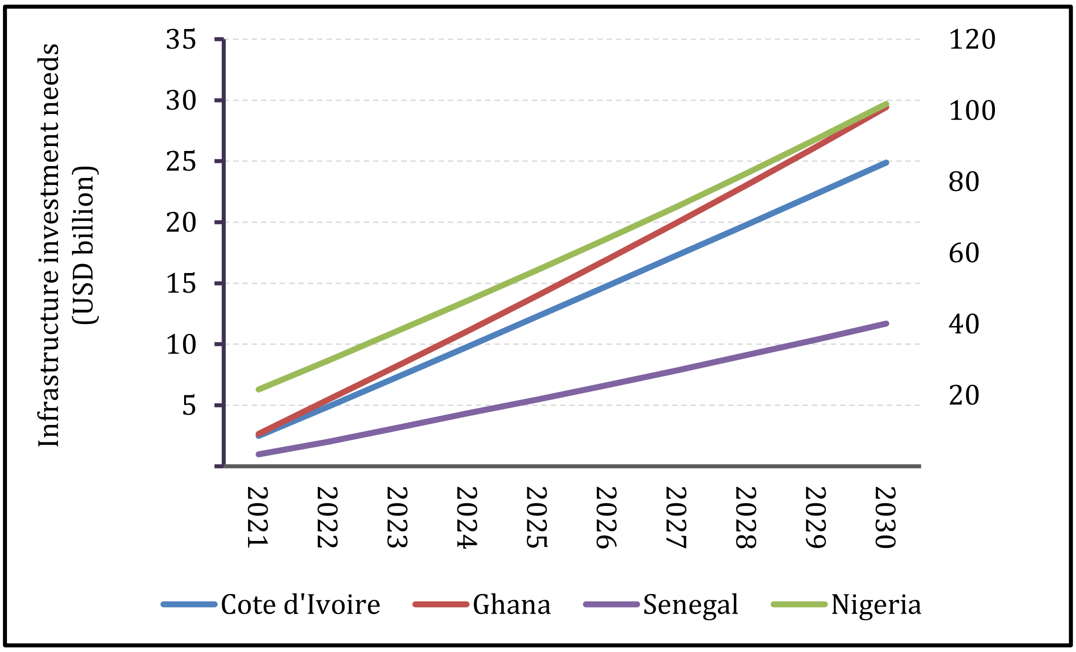
In this section, we provide an overview of the results of our infrastructure investment need forecasts in the current trend and the meeting the SDGs scenarios.

### 5.1 Infrastructure investment spending in the current trend scenario

In **Figure 2** and **Figure 3**, we set out the cumulative infrastructure investment needs in the countries under consideration in the current trend (or BAU) scenario.

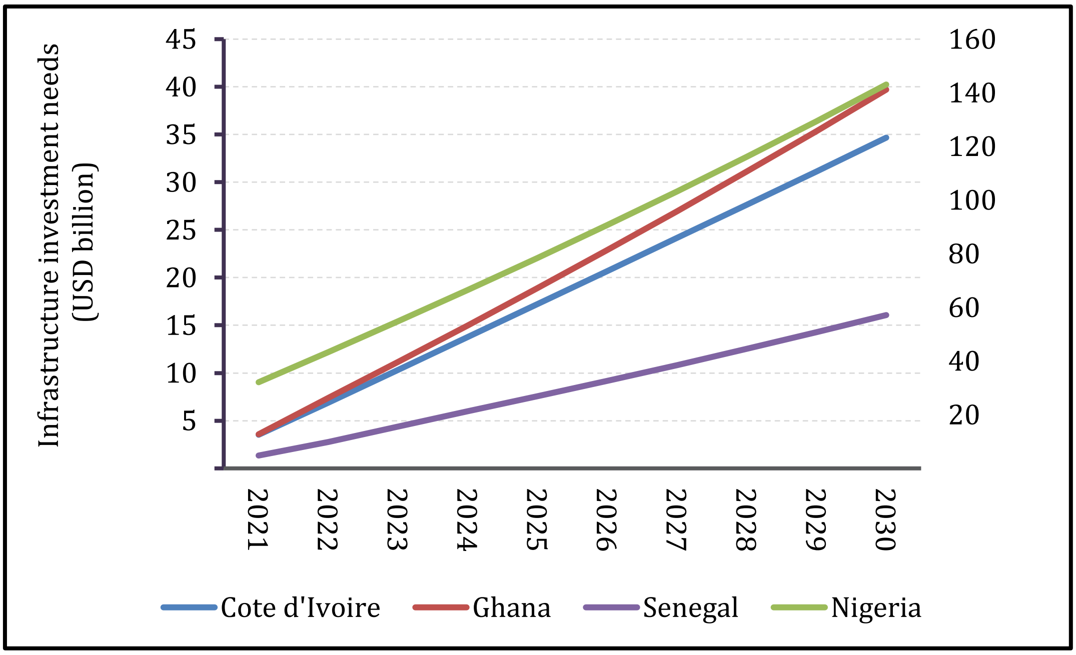
Total infrastructure investment between 2021 and 2030 ranges between USD 11.7 (16.1) (for Senegal) and 101.8 (143.1) billion (for Nigeria) using the low (high) end of the unit costs discussed in the previous section. The relevant figures for Côte d'Ivoire and Ghana are USD 24.9 (34.7) and 29.4 (39.7) billion, respectively. Infrastructure investment spending in the BAU is mainly driven by investments in the mobile telecommunications, energy, and road infrastructure sectors.

**Figure 2: Cumulative Infrastructure Investment Need In The Countries Under Consideration – Current Trend Scenario (Low Unit Costs)**




*Note: The time series for Nigeria is plotted on the secondary (right) axis.*

**Figure 3: Cumulative Infrastructure Investment Need In The Countries Under Consideration – Current Trend Scenario (High Unit Costs)**




*Note: The time series for Nigeria is plotted on the secondary (right) axis.*

In **Table 10**, we:

- Provide a comparison between the range of the infrastructure investment need calculated in the current trend scenario (the low end of the range represents the infrastructure investment calculated with reference to the low end of unit costs, while the high end of the range represents the infrastructure investment calculated with reference to the high end of unit costs); and
- Compare our results, with these provided by GIH which serves as a reference point for our conclusions.

Based on the 2020 GDP data available for Côte d'Ivoire, Ghana, and Senegal, these countries will need to spend on average **4%-6% of their GDP per annum** on infrastructure investment up to 2030. The equivalent proportion for Nigeria is lower. This is to be expected taking into consideration the economies of scale in infrastructure investment which can be achieved when countries undertake infrastructure investment projects at a larger scale.

Furthermore, the average infrastructure investment we calculate for Nigeria and Senegal is lower than the one calculated by the GIH between 2021 and 2030. However, the infrastructure investment needs (in GDP percentage terms) provided by the Global Infrastructure Hub (GIH) for Nigeria (let alone Senegal) are materially higher than those provided for Ghana and Côte d'Ivoire. Our range of values is consistent across the different countries under review.

We believe that the range of values we have provided in the BAU scenario are closer to reality. Our conviction is solidified from the consistency of our results and their proximity with the actual investment spending made in the countries under consideration. Other things equal, the calculation of higher investment needs in the BAU leads to a lower assessment of the infrastructure gap. When constructing our model, we have been cautious to not understate the infrastructure gap of these countries.

**Table 10: Comparison between the range of the average annual infrastructure investment need calculated in the current trend scenario versus the results provided by the GIH**

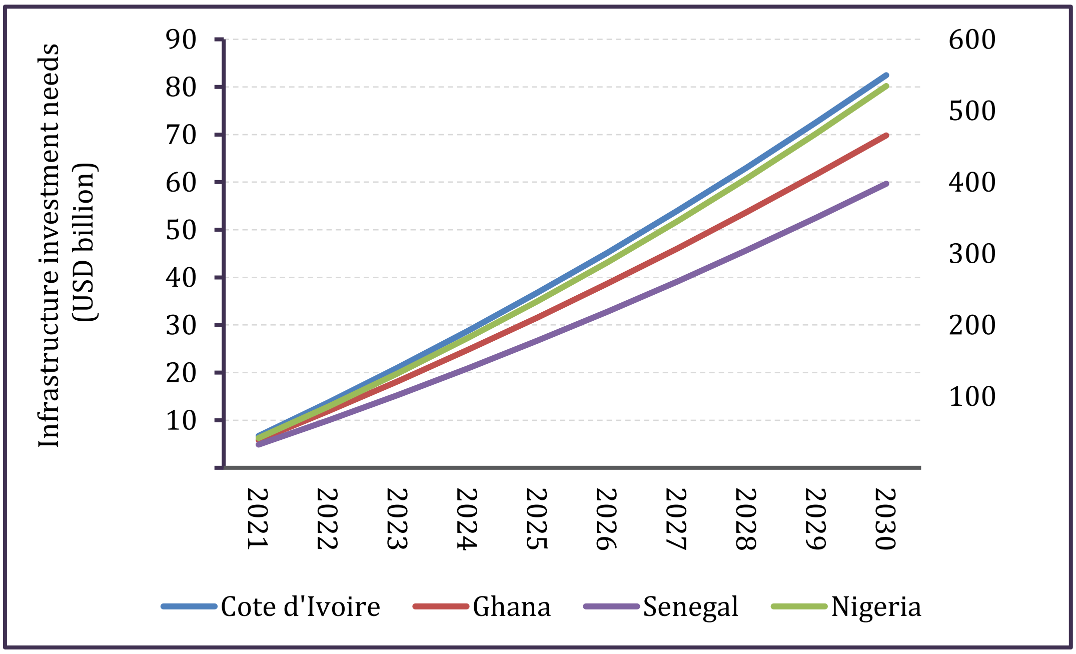
| Country | Development Reimagined | | GIH | |
|---|---|---|---|---|
| | Range | % Of GDP | Range | % Of GDP |
| Côte d'Ivoire | 2.5 - 3.5 | 4.0% - 5.6% | 2.4 | 3.9% |
| Ghana | 2.9 – 4.0 | 4.1% - 5.5% | 2.7 | 3.7% |
| Nigeria | 10.2 - 14.3 | 2.4% - 3.3% | 24.9 | 5.8% |
| Senegal | 1.2 - 1.6 | 4.7% - 6.5% | 2.3 | 9.2% |

### 5.2 Infrastructure investment spending in the meeting the SDGs scenario

In **Figure 4** and **Figure 5**, we set out the cumulative infrastructure needs in the countries under consideration in the meeting the SDGs scenario. Total infrastructure investment from 2021 to 2030 ranges between USD 59.7 (81.1) (for Senegal) and 534.6 (700.4) billion (for Nigeria) using the low (high) unit costs of infrastructure investment respectively. The relevant figures for Côte d'Ivoire and Ghana are USD 82.5 (108.4) and 69.8 (91.0) billion respectively.

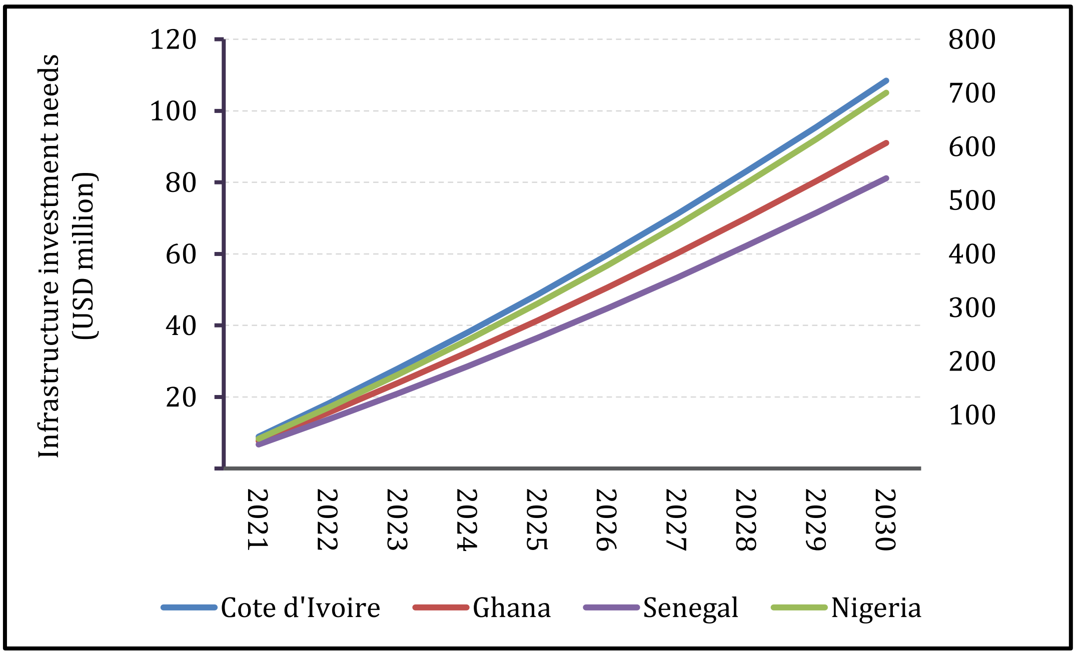
In this scenario, infrastructure investment spending is mainly driven by investments in the energy sector, followed by investments in the rail and road sectors. This is not surprising taking into consideration the direct link between these sectors of infrastructure investment and economic development.

**Figure 4: Cumulative Infrastructure Investment Need In The Countries Under Consideration – Meeting the SDGs Scenario (Low Unit Costs)**




*Note: The time series for Nigeria is plotted on the secondary (right) axis.*

**Figure 5: Cumulative Infrastructure Investment Need In The Countries Under Consideration – Meeting the SDGs Scenario (High Unit Costs)**




*Note: The time series for Nigeria is plotted on the secondary (right) axis.*

Based on the 2020 GDP data available for Côte d'Ivoire, Ghana, Nigeria, and Senegal, these countries will need to spend on average 15% or more of their GDP per annum to achieve the SDGs and move closer to the countries in the Convergence Club up to 2030 (**Table 11**). This is higher than the average of 12% calculated by the GIH. This is not surprising in the sense that international organisations often understate the costs that need to be borne by developing countries in order to develop.

**Table 11: Comparison between the range of the average annual infrastructure investment need calculated in the Meeting the SDGs Scenario versus the results provided by the GIH**

| Country | Development Reimagined | | GIH | |
|---|---|---|---|---|
| | Range | % Of GDP | Range | % Of GDP |
| Côte d'Ivoire | 8.2 - 10.8 | 13.4% - 17.6% | 5.7 | 9.3% |
| Ghana | 7.0 - 9.1 | 9.7% - 12.6% | 8.1 | 11.2% |
| Nigeria | 53.5 - 70 | 12.4% - 16.2% | 46.6 | 10.8% |
| Senegal | 6.0 - 8.1 | 24.0% - 32.6% | 4.0 | 16.1% |

### 5.3 Comparison between the infrastructure investment needs between Scenario 1 and 2

Further, to make the comparison between our results more clear, in **Figure 6** to **Figure 13**, we set out a comparison between the cumulative infrastructure investment needs in the countries under consideration between the BAU and the meeting the SDGs scenario.

Figure 6: Côte d'Ivoire - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (Low Unit Costs)

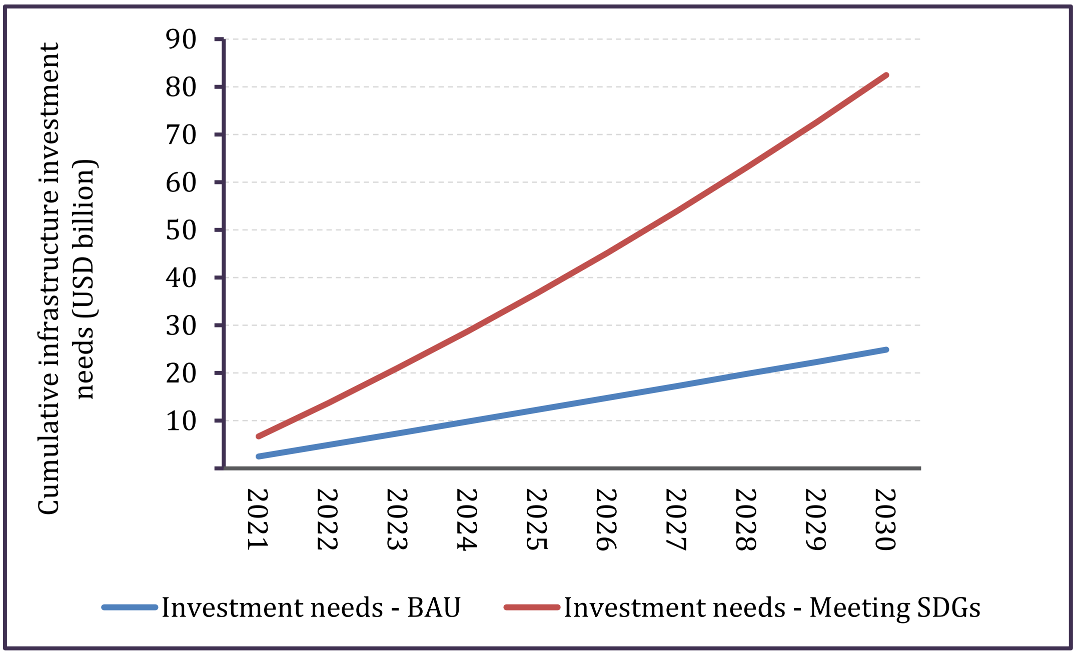



Figure 7: Côte d'Ivoire - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (High Unit Costs)

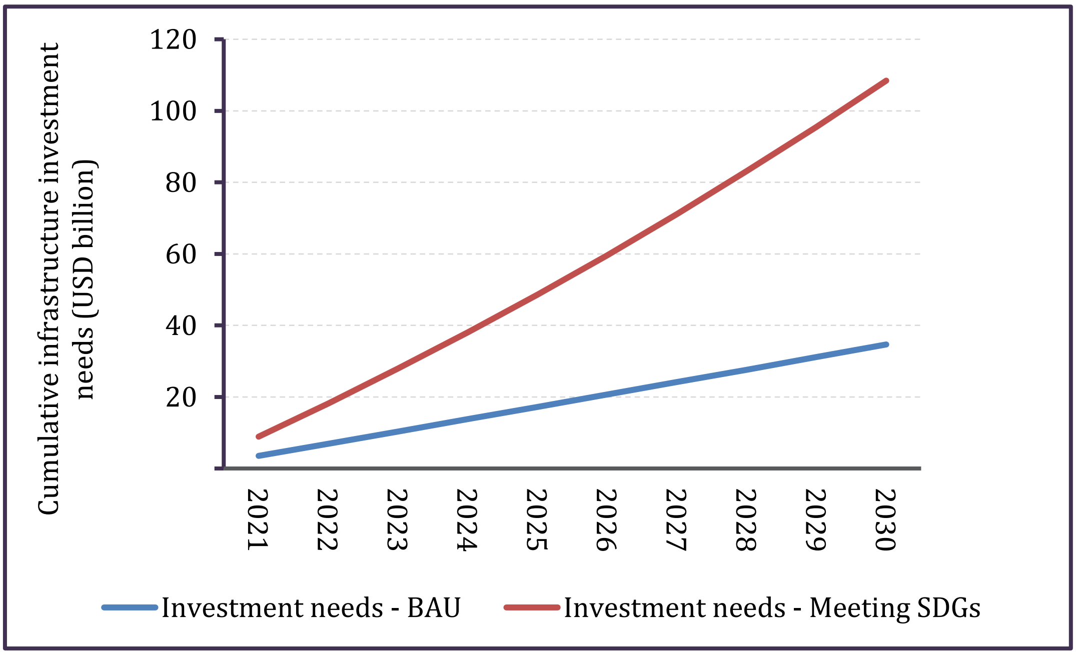


Figure 8: Ghana - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (Low Unit Costs)

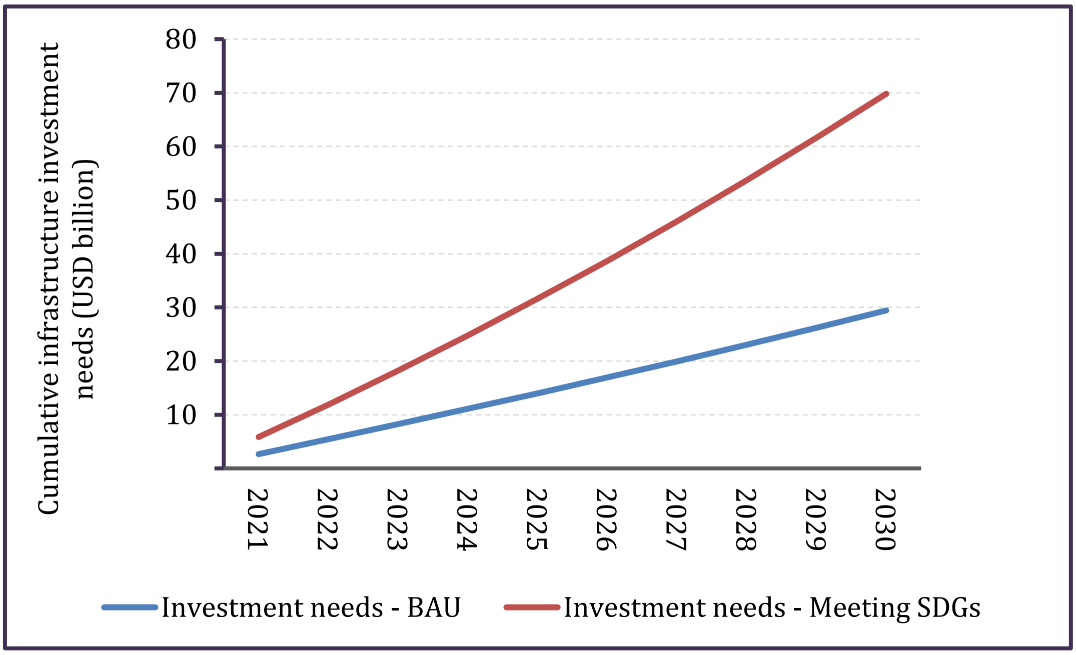



Figure 9: Ghana - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (High Unit Costs)

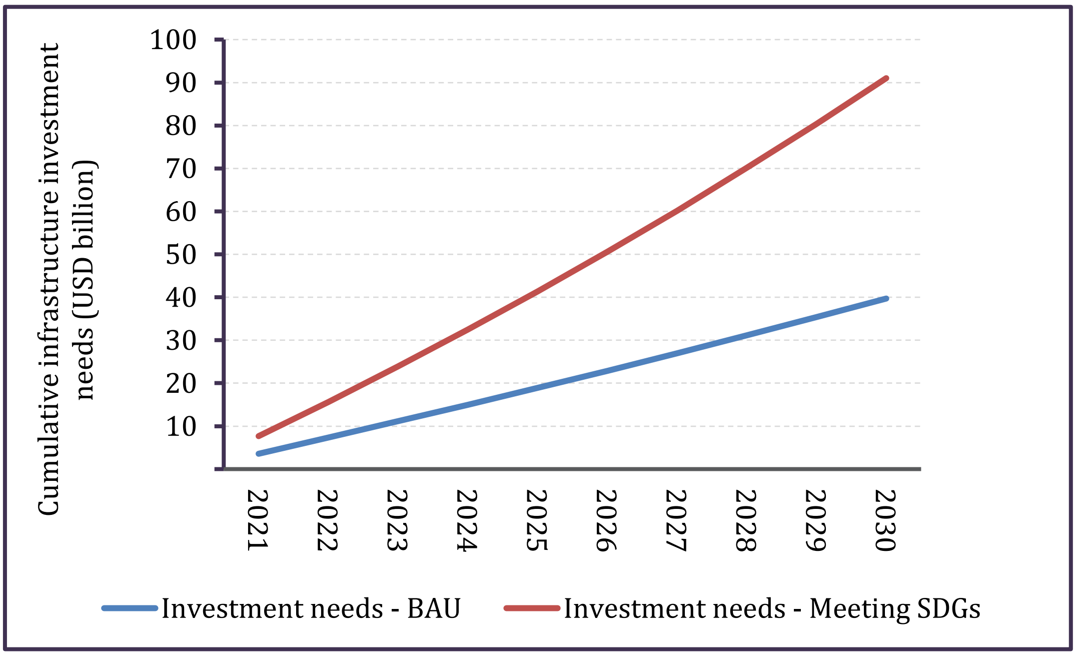


**Figure 10: Nigeria - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (Low Unit Costs)**

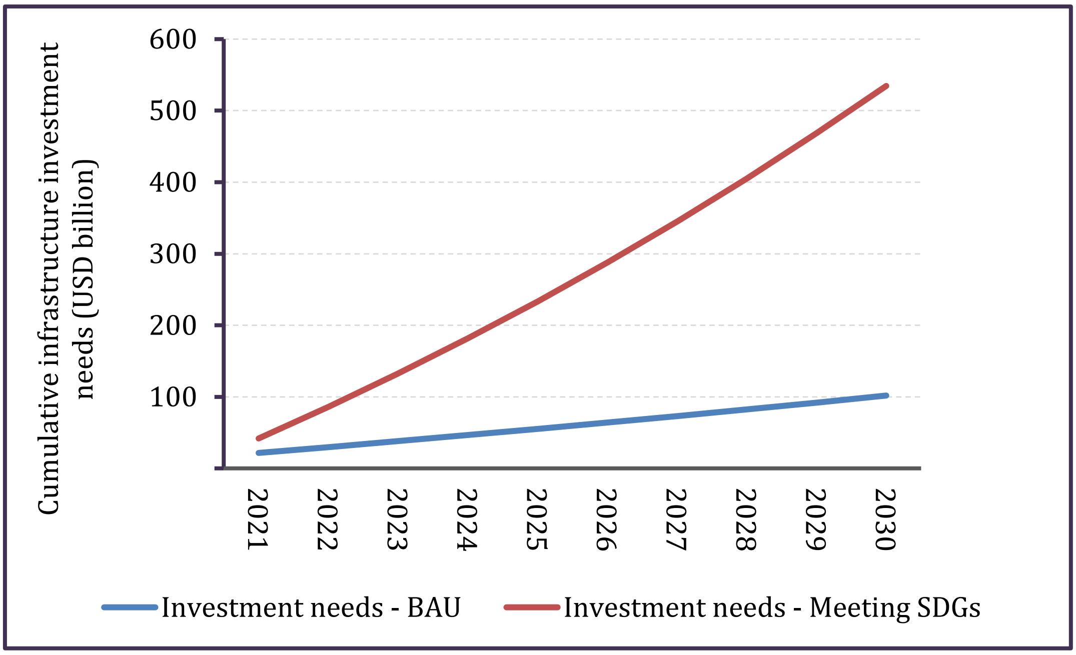



**Figure 11: Nigeria - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (High Unit Costs)**

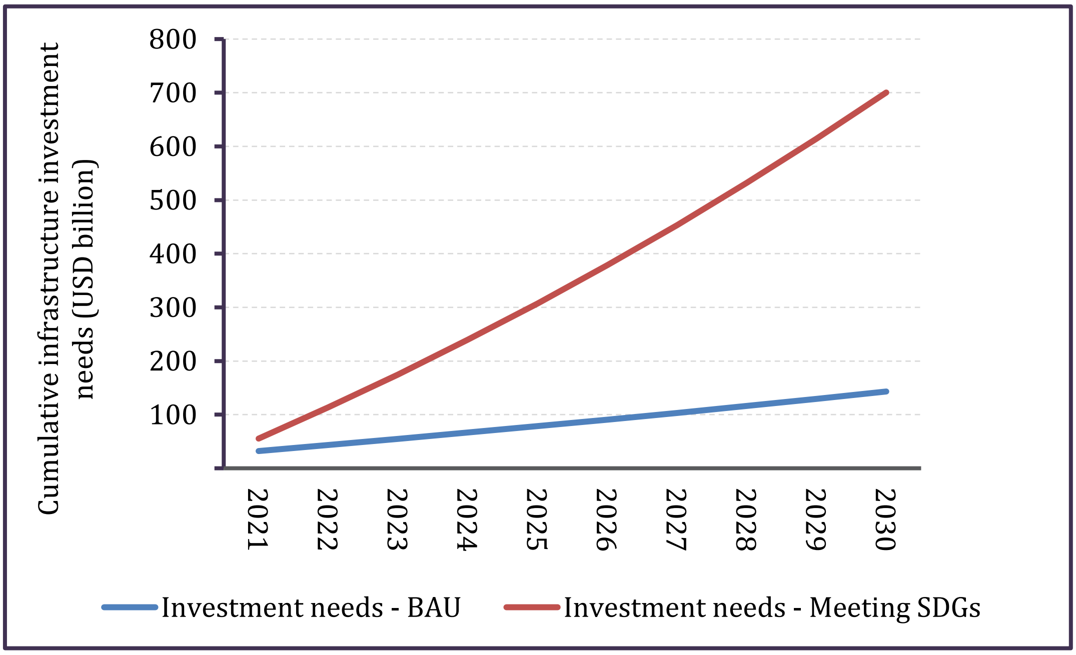


Figure 12: Senegal - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (Low Unit Costs)

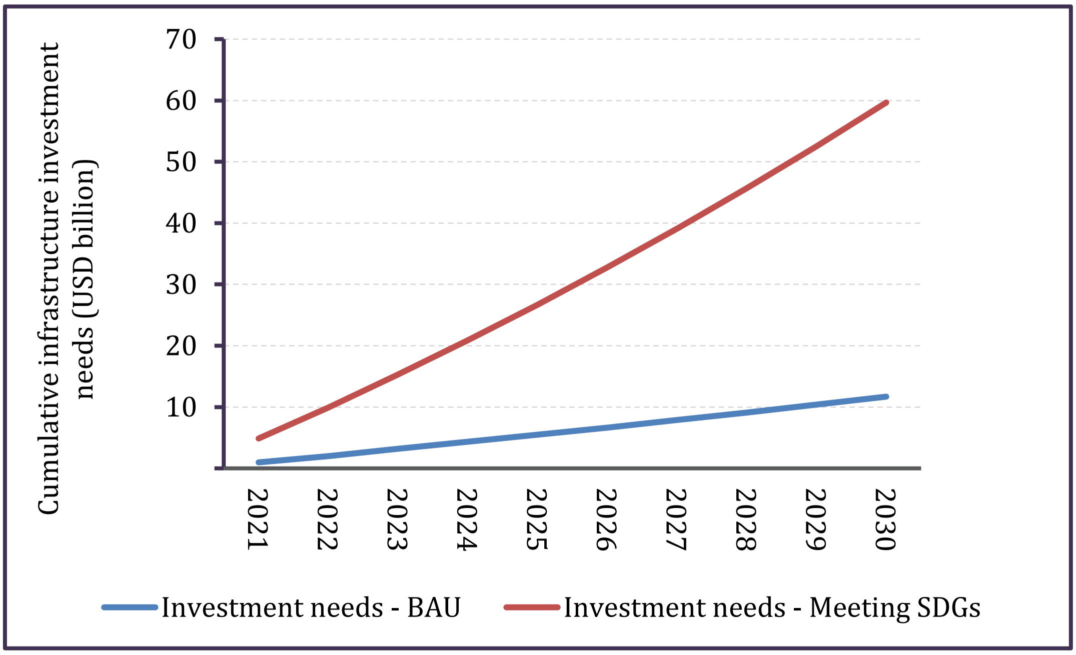
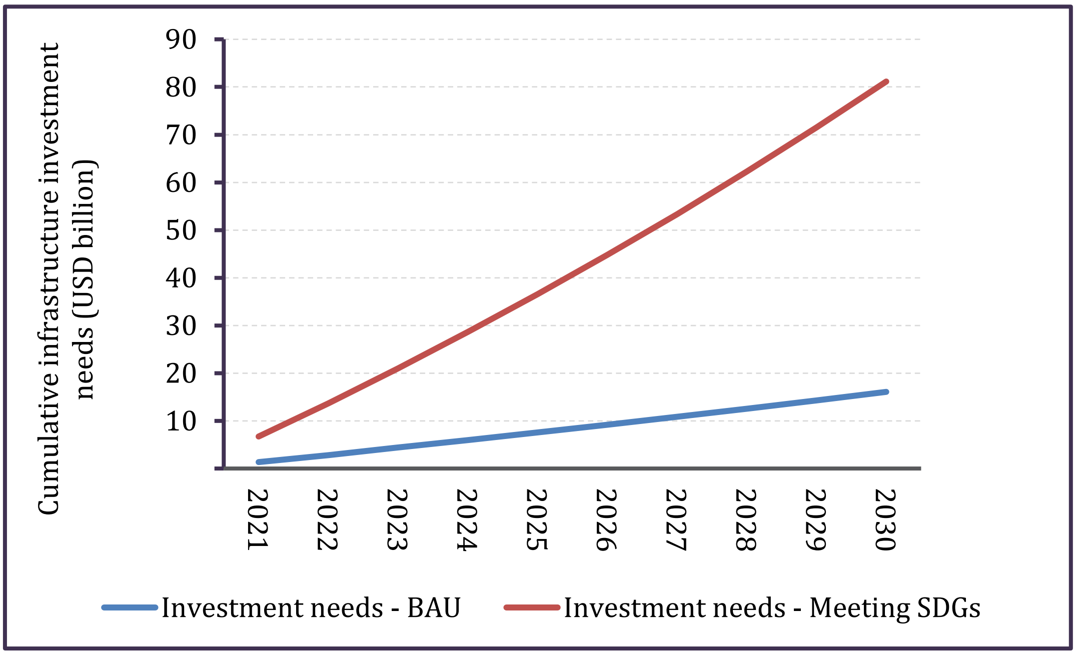



Figure 13: Senegal - Comparison Between The Cumulative Infrastructure Investment Need In the BAU And Meeting The SDGs Scenarios (High Unit Costs)



### 5.4 Infrastructure investment gap in each country under consideration

We conclude by setting the size of the infrastructure investment gap in the countries under consideration from 2021 to 2030. In **Figure 14** to **Figure 17**, we set out, for each country under consideration, the cumulative infrastructure investment gap (i.e., the difference between the assessment of infrastructure investment spend in Scenario 2 and Scenario 1) with reference to both the high and the low end of infrastructure investment costs. The cumulative infrastructure investment gap in the countries under review is as follows:

- **Côte d'Ivoire**: The cumulative infrastructure investment gap ranges from USD 57.6 (low end of unit costs) to 73.8 billion (high end of unit costs);
- **Ghana**: The cumulative infrastructure investment gap ranges from USD 40.4 to 51.3 billion;
- **Nigeria**: The cumulative infrastructure investment gap ranges from USD 432.8 to 557.3 billion;
- **Senegal**: The cumulative infrastructure investment gap ranges from USD 48.0 to 65.1 billion.

**Figure 14: Côte d'Ivoire – Cumulative Infrastructure Investment Gap (High vs Low Unit Costs)**

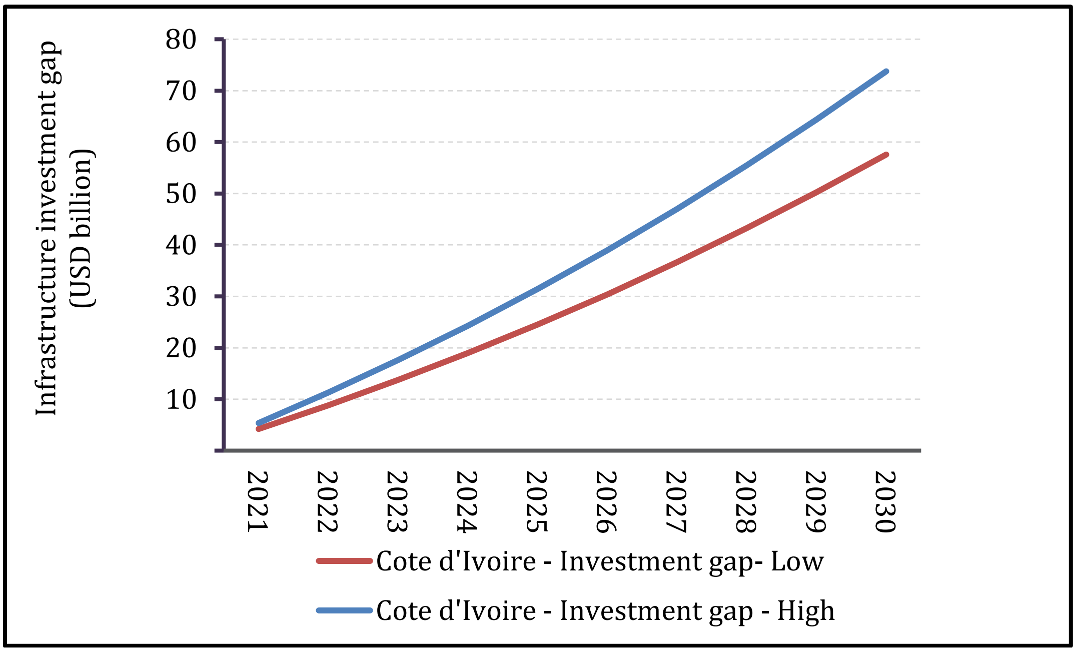



**Figure 15: Ghana – Cumulative Infrastructure Investment Gap (High vs Low Unit Costs)**

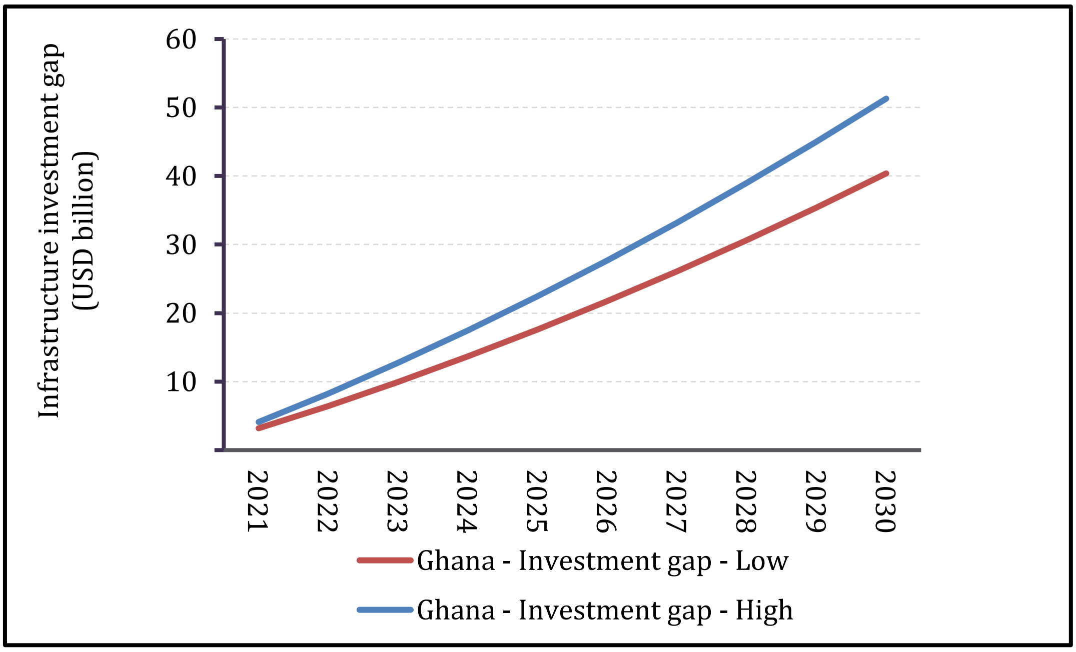


**Figure 16: Nigeria – Cumulative Infrastructure Investment Gap (High vs Low Unit Costs)**

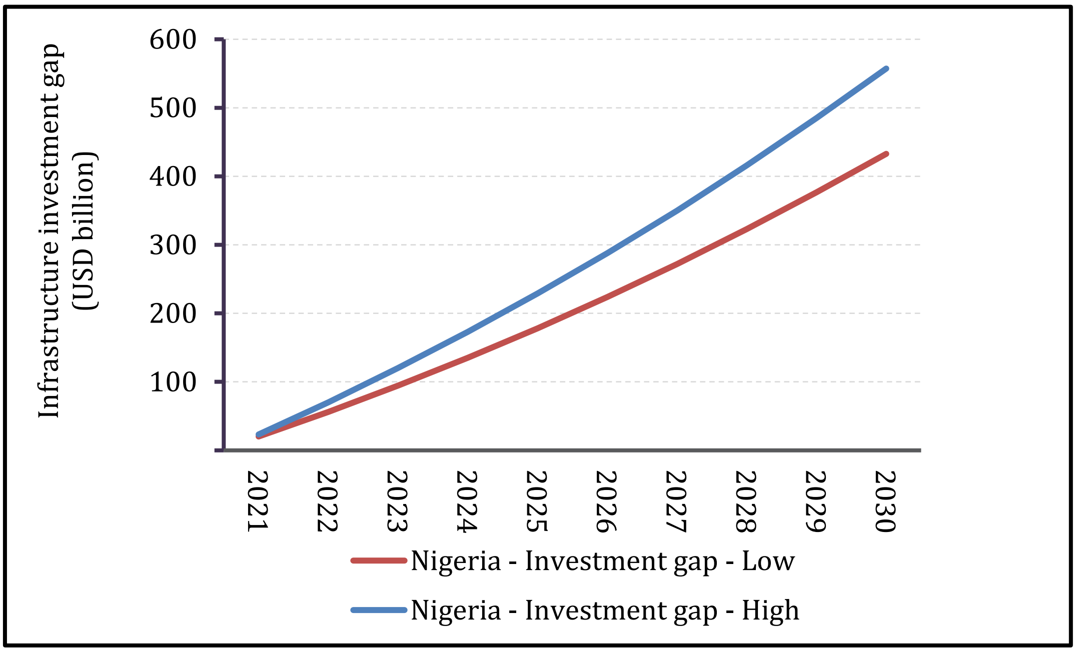
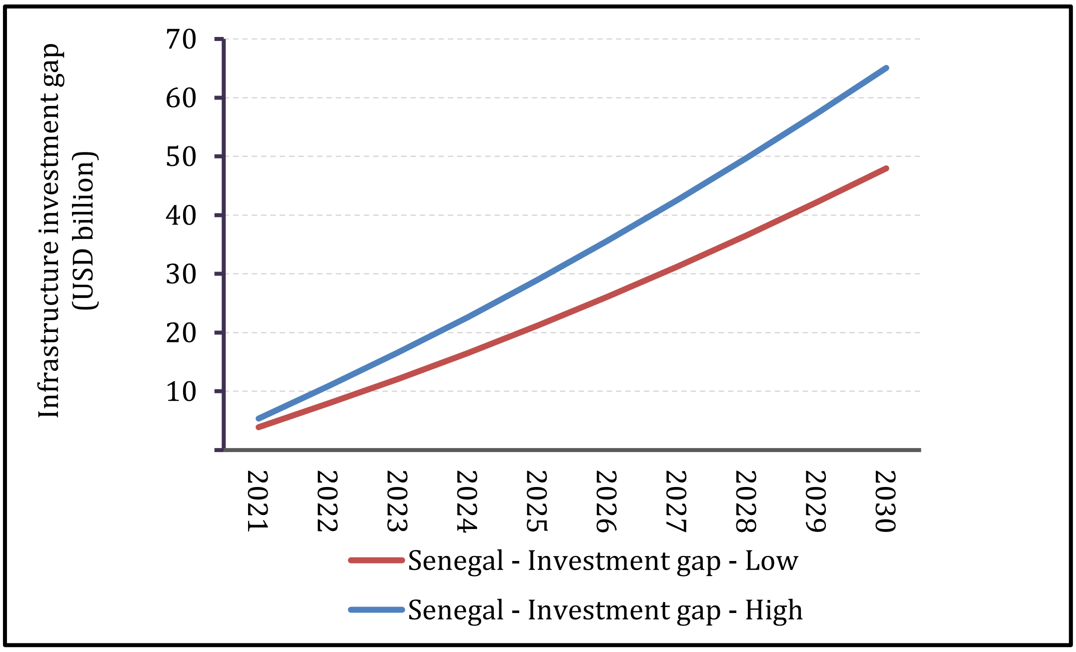



**Figure 17: Senegal – Cumulative Infrastructure Investment Gap (High vs Low Unit Costs)**



### 6. Conclusion

This analysis has proven that infrastructure investment is expensive. However, investments in infrastructure assets are a prerequisite for economic growth and development. As evidenced from Table 12 and the figures provided in Section 5.4, the countries under consideration face a substantial infrastructure gap which needs to be filled. **The question is how?**

**Table 12: Average annual infrastructure financing gap in the countries under consideration**

| Country | Infrastructure financing gap (USD billion) |
|---|---|
| Côte d'Ivoire | 5.8 - 7.4 |
| Ghana | 4.0 - 5.1 |
| Nigeria | 43.3 - 55.7 |
| Senegal | 4.8 - 6.5 |

*Note: Numbers have been rounded.*

COVID-19 has placed additional financial constraints on African countries and has resulted in reduced economic activity. Infrastructure investments will induce economic growth, create jobs, and will enable countries and their citizens to prosper. International organisations, multinational and regional development banks, national governments, and civil society organisations must put the spotlight on the issue of development finance and advocate for more funds to be allocated to infrastructure projects that will foster sustainable development and inclusive growth for all.

**Table 13: Countries DSA Classification and infrastructure gap (cumulative and annual)**

| Country | IMF/World Bank DSA Classification | Cumulative Infrastructure Gap (USD Billion) | Annual Infrastructure financing gap (USD Billion) |
|---|---|---|---|
| Côte d'Ivoire | Moderate Risk | 57.6 – 73.8 | 5.8 - 7.4 |
| Ghana | High Risk | 40.4 – 51.3 | 4.0 - 5.1 |
| Nigeria | N/A | 432.8 – 557.3 | 43.3 - 55.7 |
| Senegal | Moderate Risk | 48.0 – 65.1 | 4.8 - 6.5 |

As aforementioned, the current DSA is inherently problematic as it i) provides a negative signal to investors and ii) ignores the positive side of debt. Under the DSA, Ghana is currently classified as a country in high risk of debt distress, while Senegal and Côte d'Ivoire are classified as countries in moderate risk of debt distress. Subsequently, their "African Risk Premium" is higher, and their access to international capital markets becomes both more costly, and more constrained, making the ability to address these infrastructure gaps more challenging.

The efforts made by all countries to meet the UN SDGs is *contingent* on their ability to secure affordable financing. Therefore, the ability to address infrastructure gaps and meet the UN SDGs is hindered by the existing DSA which ignores the positive side of debt, being the debt can be used to finance investments in productive infrastructure assets. As our analysis highlights, infrastructure investment is expensive, but nevertheless a prerequisite for sustainable development, which is severely hindered by the DSA which urgently needs revision to enable African countries to address these gaps and their citizens to prosper.

### 6.1 Acknowledgements

Development Reimagined would like to give special thanks to Dibekulu Mulu, Orestis Kotronis, Sophia Kladaki and David Tinashe Nyagweta for diligently conducting the extensive research and forecasting analysis as well as Hannah Ryder for her overall stewardship.

# APPENDICES

## A1. Data collection and data cleaning methodology

Our dataset is organized in the form of a balanced panel of yearly observations from 2005 to 2020. We have collated data from various sources. For all the dependent (i.e., infrastructure) variables except for road and electricity, the data is obtained from the World Bank World Development Indicators Database. The data for electricity and road network comes from the US Energy Information Administration Agency and the Africa Development Indicator database (provided by the World Bank), respectively. For some sectors that are included in our analysis, data available from the afore mentioned sources was not complete either for some of the countries and/or for part of the historic period. In this case, the data has been completed to the extent possible from other sources such as ministries of the countries under consideration, private infrastructure databases, research firms, and international agencies such as the WHO and the UNICEF.

However, it has not been made possible to fill in all missing observations. For this reason, we have used the linear interpolation methodology for the remaining missing observations.

For the independent variables, the World Bank World Development Indicator database provides a complete dataset for the entire historic period as far as the independent variables are concerned. Our forecasting approach in the current trend scenario involves the use of projections of the independent variables up to 2030. Our information sources were as follows:

1. The projected data for GDP per capita for the countries under consideration was found from the US Department of Agriculture and Economic Research Service International Macroeconomic Dataset;
2. Population density and urbanisation projection data are taken from the World Bank Population Estimates and Projections Database; and
3. The agriculture and manufacturing share of GDP over the forecast period are assumed to be constant to their respective most recent (historic period) values (i.e., the 2020 values) due to the unavailability of projection data. This methodology is consistent with what other researchers have done in the past to address this issue.

## A2. STATA and econometric analysis

In the current trend scenario, we have used a panel data analysis framework to estimate the regression coefficients in the historical period (2005 to 2020). Panel regression analysis can be conducted using different techniques such as (i) pooled Ordinary Least Squares; (ii) fixed-effects; and (iii) random effects. All the previous studies we have reviewed have relied on the fixed-effects regression technique to estimate investment financing needs. We have also relied on the fixed-effect technique in our assessment. The fixed-effect model helps to control country-specific parameters that consistently affect infrastructure stock overtime but for some reason cannot be controlled by the independent variables.[30] It ensures that the impact of country-specific variations in infrastructure stock is controlled.

As discussed, our analysis covers ten infrastructure sectors. Below we set out the econometric model used for our forecast. For sector, the model is estimated separately but under similar control variables.

$$I^{s}_{it} = \beta_0 + \beta_1 I^{s}_{it-1} + \beta_2 Y_{it} + \beta_3 AGR_{it} + \beta_4 MAN_{it} + \beta_5 URB_{it} + \beta_6 POPDEN_{it} + \delta_i D_i + \epsilon_{it}$$

(Equation 6)

$I_{it}$ is physical stock of infrastructure investment in country i at year t. $I_{it-1}$ is the lagged physical stock of infrastructure investment of country i. $Y_{it}$ is the GDP per capita of country i at year t. $A_{it}$ is the agriculture share of GDP of country i at year t. $M_{it}$ is the manufacturing share of GDP of country i at year t. $U_{it}$ is the urbanisation rate of country i at year t. $P_{it}$ is the population density of country i at year t. $D_i$ is the dummy variable for country i. Finally, $\varepsilon_{it}$ is the error term. All the continuous variables are in natural logarithm form to linearise the model.

[30] Global Infrastructure Hub & Oxford Economics (2017). Global Infrastructure Outlook: Infrastructure Investment Needs 50 Countries, 7 sectors to 2040.

## A2.1 Regression output and DO File

### Table 13: Regression output

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | lnroad | lnrail | lnairport | lnport | lnelectricit | lnwater | lnsanitatio | lnmobile | lntelepho | lnbroad |
| lnroad_lag | -.038 | | | | | | | | | |
| | (.178) | | | | | | | | | |
| lngdppercapita | .249 | -.085*** | 1.964* | -.048 | .173 | -.004** | -.02* | .179 | .492 | 1.815** |
| | (.155) | (.026) | (1.083) | (.614) | (.142) | (.002) | (.011) | (.117) | (.461) | (.823) |
| lnagriculture | .123 | .009 | -.63 | -.554 | -.024 | .008*** | .014** | .118 | .006 | 2.085*** |
| | (.103) | (.013) | (.724) | (.426) | (.073) | (.001) | (.005) | (.071) | (.242) | (.531) |
| lnmanufacture | -.114 | .013 | -.274 | -.613* | .001 | -.001 | -.004 | .021 | .139 | .411 |
| | (.083) | (.01) | (.559) | (.315) | (.057) | (.001) | (.004) | (.057) | (.188) | (.398) |
| lnpop_density | -.16*** | 0 | -.088 | .005 | -.001 | .001* | .002 | .002 | -.238** | .276 |
| | (.057) | (.005) | (.302) | (.173) | (.031) | (0) | (.002) | (.03) | (.111) | (.213) |
| lnurbanization | .216 | .263*** | -3.424 | 2.792* | .04 | .003 | .079*** | .327 | -2.031 | -1.493 |
| | (.367) | (.064) | (2.41) | (1.535) | (.266) | (.005) | (.021) | (.316) | (1.649) | (1.76) |
| Ghana_dummy | .273*** | .28** | .645 | -.222 | .157** | .044*** | -.03** | -.025 | .319 | -.29 |
| | (.078) | (.139) | (.481) | (.275) | (.075) | (.001) | (.013) | (.049) | (.198) | (.342) |
| Nigeria_dummy | -.186** | .336** | -.405 | -.611* | -.085 | .001 | -.006 | -.163*** | -.396 | -2.545*** |
| | (.082) | (.14) | (.576) | (.343) | (.074) | (.001) | (.005) | (.058) | (.427) | (.49) |
| Senegal_dummy | -1.022*** | .346** | .538 | .338 | .054 | .045*** | -.009** | .061 | .063 | 1.424*** |
| | (.186) | (.164) | (.515) | (.292) | (.061) | (.002) | (.004) | (.066) | (.191) | (.484) |
| lnrail_lag | | .57*** | | | | | | | | |
| | | (.198) | | | | | | | | |
| lnairport_lag | | | .617*** | | | | | | | |
| | | | (.101) | | | | | | | |
| lnport_lag | | | | .578*** | | | | | | |
| | | | | (.112) | | | | | | |
| lnelectricity_lag | | | | | .791*** | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (.112) | | | | | |
| lnwater_lag | | | | | | .974*** | | | | |
| | | | | | | (.002) | | | | |
| lnsanitation_lag | | | | | | | .964*** | | | |
| | | | | | | | (.011) | | | |
| lnmobile_lag | | | | | | | | .717*** | | |
| | | | | | | | | (.029) | | |
| lntelephone_lag | | | | | | | | | .843*** | |
| | | | | | | | | | (.107) | |
| lnbroadband_lag | | | | | | | | | | .401*** |
| | | | | | | | | | | (.076) |
| _cons | 3.674*** | -.138 | 1.54 | -6.956 | -1.907 | .091*** | -.048 | -1.639 | 4.87 | -16.752** |
| | (1.062) | (.143) | (6.959) | (4.199) | (1.528) | (.012) | (.081) | (1.239) | (4.006) | (6.698) |

*Standard errors are in parentheses*

**** p<.01, ** p<.05, * p<.1*

## A3. Financial overview of the countries under consideration

### A3.1 Ghana

Classified as a middle-income country, Ghana is the second-largest economy in the West African region with a population of over 26 million people and a GDP of USD 72.35 billion. According to the AfDB, Ghana's GDP growth declined from 6.5% in 2019 to 1.7% in 2020, largely driven by the COVID-19 health crisis and the worldwide slump in oil prices.[31] Growth is expected to increase to 4% in 2021 driven by investments in the construction and manufacturing sectors alongside favourable prices in the gold and cocoa sectors.

Although Ghana is considered one of Africa's leading and most stable economies, with a positive economic outlook there are still challenges for sustained growth, especially when it comes to meeting its SDGs by 2030. Ghana has a significant infrastructure financing gap of USD 0.4 billion within an estimated infrastructure spend of USD 2.3 billion most significantly spent in the energy and water sector.[32] Although access to electricity is relatively high at 83.5% across Ghana, just under 30% of the rural population does not have access to electricity and significant under-pricing has led to spending inefficiencies.[33] Based on the estimates of GIH, Ghana's economy will need a total investment equal to USD 168 billion between 2016 and 2040 to fill its investment needs and meet the sustainable development goals up to 2030.[34]

### A3.2 Côte d'Ivoire

Since the return of political stability in 2012, Côte d'Ivoire has enjoyed consistent and high economic growth, having averaged an 8% economic growth rate per year. With a population of over 24 million people and a GDP of USD 58.5 billion, Côte d'Ivoire is classified as a lower-middle-income country, with the third-largest economy in West Africa, behind Nigeria and Ghana. It is also the dominant economy in the eight-country West African Economic and Monetary Union customs and currency union. According to the AfDB, in 2020, Côte d'Ivoire's GDP rose by 1.8%, a 4.6% decline from 2019 growth levels of 6.4%. In 2021, the AfDB estimates that GDP will rebound to 6.2%, further increasing to 6.5% in 2022.

The government is preparing a new National Development Plan (2021- 2025) which aims at improving the diversification of the economy, boosting domestic value-added content in commodity exports, and addressing structural bottlenecks from infrastructure gaps and weaknesses in human capital. Côte d'Ivoire's "Vision 2040" which defines the long-term vision

[31] African Development Bank, (2021). Ghana Economic Outlook. Accessed: March 29th, 2022.
[32] World Bank, (2011). A conventional perspective. Accessed: March 29th, 2022.
[33] World Bank, (2022). Access to electricity, rural (% of rural population) – Ghana. Accessed: March 29th, 2022.
[34] GIH, (2022). Infrastructure investment at current trends and need. Accessed: March 29th, 2022.

of the country, focuses on several areas of development, including transforming Côte d'Ivoire into an industrial, technological, agricultural, and financial power. For the SDGs to be attainable, Côte d'Ivoire must address the remaining financing gaps which impede its structural transformation and overall development. According to the GIH, the economy of Côte d'Ivoire will need a total investment equal to USD 117 billion between 2016 and 2040 to fill its investment needs and meet the sustainable development goals up to 2030.[35]

### A3.3 Nigeria

Nigeria is an economic powerhouse within West Africa and a vital player in the global economy. In 2013, the Nigerian economy represented roughly 55% of West Africa's GDP based on the purchasing power of the fifteen member countries of the Economic Community of West African States (ECOWAS).[36] Despite its economic significance in the West Africa region, Nigeria faces numerous socioeconomic challenges that impede its growth and its effort to attain the SDGs. As an example, 44% of the population lacks access to electricity, 49% of the population lacks access to drinking water, and 39% of the population lacks internet access.

The aforementioned statistics become more significant when taking into consideration the significant investment gaps faced by the Nigerian economy. According to GIH, Nigeria faces an investment gap[37] of USD 221 billion, including USD 84 billion for road infrastructure, USD 61 billion for energy infrastructure and USD 47 billion for telecommunications infrastructure.[38] According to the GIH, the Nigerian economy will need a total investment equal to USD 1.1 trillion between 2016 and 2040 to fill its investment needs and fulfil the SDGs up to 2030. Contrary to the estimates provided by the GIH, the Nigerian government has published its National Integrated Infrastructure Master plan, stating that to meet its infrastructure needs, the country requires approximately USD 2.3 trillion between 2014 and 2030.[39]

### A3.4 Senegal

Senegal is a growing economy with a significant impact on the rest of the West African Region. The country's coastal location close to European markets gives Senegal a competitive advantage alongside its political stability and investment in the private sector. According to the AfDB, Senegal's GDP growth declined from 5.3% in 2019 to 0.7% in 2020, largely driven by the COVID-19 health crisis and the worldwide slowdown in tourism, trade, and investment.

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[35] GIH, (2022). Infrastructure investment at current trends and need. Accessed: March 29th, 2022.
[36] African Development Bank, (2013). *Country Strategy Paper 2013-2017*.
[37] For a definition of investment gap see the relevant definitions in Appendix 5 of this annex.
[38] Global Infrastructure Outlook, (2017). Infrastructure investment at current trends and need. Accessed: February 17th, 2022.
[39] Federal Republic of Nigeria, (2015). *National Integrated Infrastructure Master Plan*.

Growth is expected to increase to 5.1% in 2021 driven by the resumption of global growth, public investments, and the growth of Senegal's hydrocarbon sector. Through the Plan Senegal Emergent, since 2014, Senegal has aligned its economic priorities with the UN SDGs and key drivers of economic growth. To meet the SDGs and fulfil its investment gap, GIH has estimated that Senegal will need a total investment equal to USD 94 billion between 2016 and 2040.[40]

[40] Global Infrastructure Outlook, (2017). Infrastructure investment at current trends and need. Accessed: February 17th, 2022.

## A4. Glossary

**Table 14: Glossary of terms used throughout this annex**

| | |
|---|---|
| ADB | Asian Development Bank |
| AfDB | African Development Bank |
| AU | African Union |
| BAU | Business As Usual |
| BEA | U.S. Bureau of Economic Analysis |
| Convergence club | Term used to refer collectively to China, Chile, Colombia, Costa Rica, Malaysia, Mexico, Thailand, and Turkey |
| Countries under consideration | Term used to refer collectively to Côte d'Ivoire, Ghana, Nigeria, and Senegal |
| DSA | Debt Sustainability Assessment |
| DR | Development Reimagined |
| ECOWAS | Economic Community of West Africa |
| GDP | Gross Domestic Product |
| GH¢ | Ghanaian cedi |
| GIH | Global Infrastructure Hub |
| IAS | International Accounting Standards |
| IFRS | International Financial Reporting Standards |
| IMF | International Monetary Fund |
| IRENA | International Renewable Energy Association |
| km | Kilometre |
| KW | Kilowatt |
| MW | Megawatt |
| ₦ | Nigerian naira |
| OECD | Organisation for Economic Cooperation and Development |

| | |
|---|---|
| SDGs | Sustainable Development Goals |
| TEU | Twenty Foot Equivalent Unit |
| UEL | Useful Economic Life |
| UN | United Nations |
| USD | United States Dollars |

### A5. Defined terms

**Current investment trend** are baseline forecasts of infrastructure investment under the assumption that countries continue to invest in line with current trends, with growth occurring only in response to changes in each country's economic and demographic fundamentals. Current investment trends are assessed in the Current trend scenario in our modelling.

**Investment needs** as defined by the GIH is the investment that would occur if countries were to match the performance of their best performing peers, after controlling for differences in the characteristics of each country.

**Investment gap** is the difference between current investment trends and investment needs. In our analysis current investment trends are the ones calculated in Scenario 1 and investment needs the ones assessed in Scenario 2.