TOOL 2 JULY 2020

METRICS FOR ASSESSING FINANCIAL VIABILITY OF RENEWABLE ENERGY PROJECTS

COST BENEFIT ANALYSIS OF RENEWABLE ENERGY PROGRAMMES

CICSA
CLEAN CAPTIVE INSTALLATIONS FOR INDUSTRIAL CLIENTS IN SUB-SAHARA AFRICA

Frankfurt School
FS-UNEP Collaborating Centre
for Climate & Sustainable Energy Finance

UN environment programme

INTRODUCTION

This tool is published under the project titled "Clean Captive Installations for Industrial Clients in Sub-Saharan Africa" developed in four partner African countries: Ghana, Kenya, Nigeria and South Africa. This tool/ provides a general discussion on metrics used and considerations required for analysing the attractiveness of energy projects and programmes, from both the private and public perspectives.

The Project

The project aims to demonstrate the economic and financial viability of clean captive energy installations for industries and to enhance their adoption in the four partner countries and beyond to the entire continent. Captive installations refer to the energy generation technologies installed by industrial or commercial organizations on their sites. Those installations are deemed captive as the electricity produced is generated for the industrial plant's own use and sometimes for neighbouring communities. Clean captive installations refer to those installations powered by renewable sources of energy such as solar or industrial waste. Captive power plants can operate off-grid or can be connected to the grid to feed in excess generation.

Renewable energy captive installations alleviate the pressure to generate electricity from national grids and reduce industrial clients' needs to rely on private supplementary fossil-fuelled generators, which are expensive to run. These clean captive installations are frequently referred to as the second generation of renewable energy business models, as they do not rely on national governments' incentivizing policies to enhance the deployment of clean energy technologies.

The "Clean Captive Installations for industrial Clients in Sub-Sahara Africa" project will strengthen the ability of partner countries to move towards low carbon-emitting development strategies. It also contributes to several Sustainable Development Goals, including Climate Action (SDG 13), Responsible Consumption and Production (SDG 12), Affordable and Clean Energy (SDG 7) and Industry, Innovation and Infrastructure (SDG 9). The project will raise awareness among industry players, financiers and governments, and will support the dissemination of clean modern energy technology through business models tailored to the national contexts and throughout Sub-Saharan Africa.

This project is part of the International Climate Initiative (IKI) of Germany. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supports this initiative based on a decision adopted by the German Bundestag.

The implementing team of the project comprises the United Nations Environment Programme (UNEP) in partnership with its collaborating centre at Frankfurt School of Finance & Management (Frankfurt School). The project's activities fall under four components:

- Component 1: Baseline studies and awareness raising
- Component 2: Economic and financial tools and assessments
- Component 3: Realization of pilot projects in the four partner countries
- Component 4: Knowledge dissemination and outreach

The Tool

This tool falls under Component 2. Under this component, four main tools are provided as follows:

- Tool 1: "Financing guidelines and business models for solar PV Captive Systems"
- Tool 2: "Metrics for assessing financial viability of renewable energy Projects/Cost Benefit Analysis of renewable energy programmes"
- Tool 3: "User Manual for the preliminary financial model to assess the viability of solar PV captive systems for businesses"
- Tool 4: "Best Available Technology (BAT) for solar PV captive systems"

This tool complements the other tools. It provides introductory guidelines on metrics and considerations for analysing the attractiveness of individual renewable energy projects such as solar PV captive systems. It is intended also to assist stakeholders such as investors, policy makers and analysts by providing them with analytical considerations that are commonly required for a complete assessment of renewable energy investments, considering environmental and social impacts. This document presents the main issues to consider when analysing renewable energy projects and does not intend to provide an exhaustive account of all relevant considerations and metrics available for conducting a detailed economic or financial analysis.

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For more information about this document or on the *Clean Captive Installations for Industrial Clients in Sub-Sahara Africa* project, visit: www.captiverenewables-africa.org
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1. ANALYSIS FROM VARIOUS PERSPECTIVES

Electricity is a fundamental input in the production process or commercial operation. As such a country's economy as well as individual private organisation's competitiveness depend on a reliable, affordable and modern electricity source.

Electricity sources are not equal. Beyond their cost-effectiveness, each individual electricity generation project or national energy policy or programme has its own unique impacts throughout its lifecycle not only in financial terms but also, with regards to the environment and society.

Governments worldwide are increasingly addressing the climate crisis, through the implementation of mitigation and adaptation measures, an important agenda through their NDCs. The growing concern for climate change, combined with a greater access to information that countries have today, require increased precision and comprehensiveness in assessing the impact of electricity generation projects, in implementing support schemes, and in granting licenses and establishing procedures for new energy projects, including for captive energy generation systems for private industrial and commercial users. The full set of economic, social and environmental impacts should be considered when comparing between energy sources, with a more comprehensive perspective than private investment decisions have, which are often made on pure economic and financial terms.

Investors and stakeholders conduct economic and financial analyses of investments to be able to make informed decisions. Depending on the type of investment under analysis, alternative metrics are used. Additionally, each stakeholder will use a different metric depending on its own perspective. Governments, for example, typically compare and assess alternative energy generation systems by comparing the economic and social costs and benefits associated to the projects using a cost benefit analysis or the levelized cost of electricity (LCOE) metric. On the other hand, private investors, most of whom are investing to maximise profits at an equivalent level of risk, will use financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), or simple payback calculations. Typically, a private investor would use the sample financial model that has been developed under Tool 3 as part of the Clean Captive Installations project to assess the opportunity of investing in a solar PV system.

A private investor evaluates the financial profitability of a project, examining the impact of the project on its cash flows. As such, all financing costs, taxes payed and subsidies received are incorporated into the analysis. An industrial or commercial decision maker adds economic considerations such as the reliability of its electricity supply and operating risks such as the ones associated with an innovative technology. For a government, taking an economic, social and environmental perspective, the analysis would not be limited to the financial costs and benefits of the project but also include the social and environmental costs and benefits.

The table below summarizes the evaluation performed from the public and private sector point of view.

TABLE 1 ***Evaluation of projects from the public and private sector perspectives (RETD, 2011).***

Perspective	Public Sector	Private Sector
Beneficiaries	Society	Investor(s)
Timeframe	Technological lifetime[1]	Investment horizon[2]
Costs and benefits	All economic, social and environmental impacts are considered, including external and indirect impacts	Only relevant costs and benefits that directly impact cash flows are considered
Discount rate used	Social discount rate (lower than private investors' required return)	Minimum required rate of return of the investor
Relevant Metrics	Benefit to Cost Ratio NPV LCOE	IRR NPV Payback period LCOE

It should be noted that an investment may be attractive from the perspective of one stakeholder but not from the perspective of the other. That is, a given renewable energy project can be beneficial from the economic-social and environmental point of view but not profitable from a private investor perspective. Conversely, another project might be profitable for the private investor but not beneficial for society. In this sense, understanding the attractiveness of projects from a broader social perspective is very important when designing energy policies that align private investors' investment decisions with what is beneficial for society. The following section describes the most common metrics used to perform such assessments.

[1] *Longer than the investment horizon, since the public sector looks at the impact on the society until the asset cannot generate energy anymore. Usually around 30 years.*

[2] *Shorter than the technological lifetime, since the private sector's objective is to recoup their investment.*

2. RELEVANT METRICS

Depending on the point of view of the analysis and the specific project being evaluated, one metric might be more suitable than another to assess the financial, economic; social and environmental viability of a project. In general, it is advised to use different metrics to evaluate any investment. The following table summarizes the most relevant metrics and includes suggestions regarding its suitability for specific cases.

***TABLE 2** Summary of suitable metrics for evaluating energy investment projects.*

Metric	Example of questions addressed	Decision criteria	Suggested uses	Recommended perspective
NPV (Net Present Value)	(i) Which project should I invest in (from various available alternatives)? (ii) Should I invest in this project (or not)? (iii) Is this project attractive from a societal perspective?	Highest NPV	For (i) selecting investments from mutually exclusive alternatives and (ii) analyzing whether to accept or reject a single investment, as well as (iii) conducting analyses from a societal perspective	Private investor Public sector
IRR (Internal Rate of Return)	(i) Should I invest in this project? (ii) What is an acceptable return for the investment?	Highest IRR	For analyzing a single investment, and deciding whether to accept or reject it	Private investor
LCOE (Levelized Cost Of Electricity)	How do energy sources compare in terms of lifetime costs?	Lowest LCOE	For ranking and comparing energy source alternatives in terms of their costs to generate 1 kWh	Private investor Public sector
SPB (Simple Payback Period)	How long does it take to recoup this investment?	Lowest SPB	For getting a quick and simple sense of a project, without accounting for time value of money or financing	Private investor
B/C (Benefit-to-Cost Ratio)	Is this project attractive from a societal perspective?	Highest B/C	For conducting analyses from the societal perspective, where social impacts (costs and benefits) are accounted for (e.g. environmental impacts), and for ranking different projects in terms of the value they generate	Public sector

Almost all of the metrics can be used for different perspectives, as the main difference between the evaluation process from the private and the public perspective is that the latter must account for the externalities[3] (economic, social, environmental, or even ethical costs or benefits), which may be difficult to quantify. Each of the metrics is further described below.

[3] *In this case, externalities are impacts of electricity generation projects that do not have a financial effect on the owner of the plant but have a socio-economic, environmental or even ethical impact, positive or negative, on society.*

2.1 Net Present Value (NPV)

NPV considers the difference between cash outflows and cash inflows as a result of an investment, taking into consideration the time value of money. As such, a project with positive NPV is considered cost-effective and, when comparing mutually exclusive projects, the project with the highest NPV is preferred. This metric is not specific to investments in energy projects.

***EQUATION 1** NPV Calculation.*

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

***TABLE 3** NPV Nomenclature.*

NOMENCLATURE	UNIT	MEANING
NPV	Monetary Unit	Net Present Value
C_o	Monetary Unit	Initial investment
C_t	Monetary Unit	Cash flow at time t
t	Years	Timing of cash flow over project duration (T)
r	%	Annual discount rate

The most relevant variables that determine NPV are:

- Cash flows, relevant for the applicable perspective, whether private investor, public authority, electricity consumer, society, etc.
- Timing of cash flows, both outflows and inflows;
- Discount rate: the higher the discount rate, the lower the present value of the cash flows.

NPV can be used by both the public and private sectors to assess the attractiveness of projects. The former would normally consider all direct and indirect socio-economic costs and benefits - and a "social" discount rate - and the latter only the impact on its private cash flows and its own discount rate.

2.2 Internal Rate Of Return (IRR)

IRR is defined as the interest rate at which the net present value of all of the cash flows from a project or investment equal zero. As such, it allows investors to evaluate whether a single investment is attractive by comparing the resulting IRR with their minimum required rate of return, i.e. the minimum rate that specific investor would consider from an investment. This is typically a single investment evaluation metric, less relevant from a public perspective. IRR is used for any type of investment, electricity generating or not.

***EQUATION 2** IRR Calculation.*

$$0 = NPV = \sum_{t=0}^{T} \frac{C_t}{(1+IRR)^t}$$

***TABLE 4** IRR Nomenclature.*

NOMENCLATURE	UNIT	MEANING
IRR	%	Internal Rate of Return
NPV	Monetary Unit	Net Present Value
C_t	Monetary Unit	Cash flow at time t
t	Year	Timing of cash flow

The most relevant variables that determine IRR are:

- Cash flows, relevant for the applicable perspective (i.e. private investor, public authority, electricity consumer, society, etc);
- Timing of cash flows, both outflows and inflows.

2.3 Levelised Cost of Electricity (LCOE)

LCOE for an electricity-generating system is defined as the constant and theoretical cost of generating electricity, whose present value is equal to that of all the total costs associated with the system over its lifespan (Eclareon, 2013). As such, it allows for the comparison between alternative sources of electricity, such as solar PV captive systems, grid electricity and diesel generators. Thus, from the perspective of a commercial electricity consumer, LCOE includes all relevant costs that influence the decision of whether to self-generate its electricity for instance with, solar PV, or to buy electricity from the utility. The electricity generating unit that results in the lowest LCOE represents the most cost-effective alternative. Computing LCOE is also useful for ranking alternatives in terms of their costs and selecting projects to support with a limited budget.

The formula below shows the equation for LCOE from the private investor perspective including taxes which are relevant cash outflows when evaluating investments.

***EQUATION 3** LCOE Calculation.*

$$\boldsymbol{LCOE} = \frac{\boldsymbol{I} + \sum_{t=1}^{T} \frac{\boldsymbol{C_t \times (1-TR)}}{\boldsymbol{(1+r)^t}} - \sum_{t=1}^{T} \frac{\boldsymbol{DEP_t \times TR}}{\boldsymbol{(1+r)^t}}}{\sum_{t=1}^{T} \frac{\boldsymbol{E_t}}{\boldsymbol{(1+r)^t}}}$$

***TABLE 5** LCOE Nomenclature.*

NOMENCLATURE	UNIT	MEANING
LCOE	Monetary Unit/kWh	Levelized Cost of Electricity
I	Monetary Unit	Initial investment
C_t	Monetary Unit	Operation & Maintenance costs, Insurance costs and Inverter replacement costs in year t
TR	%	Corporate tax rate
r	%	Nominal discount rate (Weighted Average Cost of Capital)
DEP	Monetary Unit	Depreciation for tax purposes
T	Years	Economic lifetime of the PV system
E_t	kWh	Electricity generated in year t

The most relevant variables that determine LCOE are:

- Average PV system lifespan (T);
- Initial investment (I);
- Operations & Maintenance (O&M) costs and other operating costs (C_t);
- PV generated electricity over the system's lifespan (E_t);
- Discount rate or WACC (r);
- Depreciation (DEP);
- Corporate tax rate (TR), only applicable for tax paying entities.

From a social perspective, in addition to the elements mentioned above, the monetary value of the main externalities produced by renewable energy technologies like the solar PV technology, must be included in the LCOE calculation, such as the environmental, health benefits or those linked to the deployment of a resource-efficient, self-sufficient economy.

2.4 Simple Payback Period

The simple payback period is the time period needed to recover the project costs of a given investment. Given its simplicity - it does not account for the lifetime cash flows, risks, financing, etc. - it is normally used for quick assessments and not recommended to be used as a single metric for decision making.

***EQUATION 4** Simple Payback Period Calculation.*

$$\text{Simple payback period} = \frac{\text{Initial investment or project cost}}{\text{Yearly savings}}$$

2.5 Benefit to Cost Ratio

The Benefit-to-Cost ratio (B/C ratio) is calculated as the sum of all benefits throughout the lifetime of the considered investment divided by the sum of all associated costs, both discounted at the appropriate discount rate. Thus, it estimates the extent to which benefits of a particular investment (project, support programme, policy, etc.) exceed its costs. The benefit-to-cost ratio is calculated as illustrated below.

***EQUATION 5** Benefit-to-cost Ratio Calculation.*

$$B/C = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}}$$

***TABLE 6** B/C Nomenclature.*

NOMENCLATURE	UNIT	MEANING
B/C	-	Benefit-to-cost Ratio
T	years	Years of the analysis
t	-	year t
B	Monetary unit	Benefits in year t
C	Monetary unit	Costs in year t
r	%	Discount rate

Based on the results of the indicator, the following can be concluded:

- If the ratio is less than 1, the anticipated benefits of the investment do not cover its costs during the period of analysis;
- If the ratio is equal to 1, the benefits just cover the costs during the period of analysis;
- If the ratio is greater than 1, the benefits are greater than the costs during the period of analysis (i.e. the investment is attractive from a social perspective).

A comprehensive analysis must consider all relevant positive impacts (benefits or savings) and negative results (costs) associated to the proposed investment. For example, for a large-scale solar PV project, the analysis would include the following:

- Benefits (numerator): relevant quantifiable[4] benefits and savings as a result of the investment, e.g. energy savings as well as socio-economic and environmental benefits that can be quantified such as reduced fossil fuel imports and health benefits.
- Costs (denominator): all costs associated with the project, such as the initial investment in equipment, the installation, the costs of operation and maintenance, etc. as well as potential socio-economic costs associated with the transition to a low-carbon energy source.

While this metric can be applied to a single project evaluation, including a solar PV captive installation, it

[4] *Ideally, all benefits should be accounted for. However, the benefits associated to PV are numerous, and many are difficult to quantify (e.g. indirect benefits such as the impact on human capital and quality of life).*

can also be used for a broader investment such as a renewable energy programme or a government policy.

3. THE PUBLIC PERSPECTIVE

Quite frequently the cost-benefit analysis methodology is used to assess investments or projects that affect the nation as a whole: including public investments in renewable energy projects or investments by electric utilities that affect the public sphere (electricity consumers, taxpayers, and environment). In this sense, the Benefit-to-Cost Ratio helps determine whether an investment is attractive from a social perspective (i.e. the benefits outweigh the costs) and helps rank different projects in terms of the net benefits they generate for society. In turn, that information is very useful to develop policies that attract private investments towards projects that are beneficial from a social perspective.

Through a cost-benefit analysis that accounts for the social benefits and costs of different energy sources, policy makers can, for example, decide to eliminate fossil fuel subsidies, given the high negative externalities associated to those technologies. Likewise, a cost-benefit analysis of alternative energy sources can lead to the implementation of support schemes and policies for renewable energies (e.g. net metering, tax incentives, reduced administrative burden, licences and permits required, etc.).

However, in many countries, thorough cost-benefit analyses of energy sources are inexistent, given the difficulty to gather relevant and reliable data, among other reasons. As indicated previously, the B/C ratio accounts for all the quantifiable benefits and costs as a result of a given project or programme. The potential benefits of renewable energy projects from the public perspective not only include financial aspects but also technical aspects (e.g. impacts on the grid operator), as well as other "soft" or intangible impacts. In sum, the list of potential benefits associated to renewable energies is long, it is country-specific, and often the impacts are difficult to quantify.

As an example, the Institute for Advanced Sustainability Studies has published in 2017 a long-list of benefits, segmented by category, reproduced in the following table.

***TABLE 5** Typology of socio-economic benefits (Borbonus, 2017)*

Category of effect	Sub-category	Indicator		Examples and literature
		Physical indicator	Monetary indicator	
Direct effects/ gross effects (simple indicators)				
Environment	Reduction of local emissions (particulate matter/ PM: nitrous oxide/ NO: sulphur dioxide; non-methane volatile organic compounds	e.g. SO_2 g/ kWh	n.a	You and Xu (2010): Sathaye et al. (2011); Ma et al.(2013); Murata et al. (2016)
Access to energy	Access to modern energy services (power)	Additional consumed KWh of on-grid/ off-grid electricity; Number of households with modern energy services (e.g. connected to grid)	Willingness to pay for an additional unit of energy (e.g. price per kWh(or for access to on-grid/ off-grid electricity (cost per household)	Sagar (2005); birol (2007); Pachauri and Spreng (2011); unclear net effect: off-grid RE access versus higher energy prices; storage battery collecting systems
	Affordability of energy services (power)	Share of energy expenses in total household budget; share of energy expenses and annualised cost of end-use equipment in total household budget	Per unit cost of energy (e.g. cost per kWh)	
Macroeconomic effects	Investments	Investment in RE technologies	USD/ year	O' Sullivan et al. (2015)
	Gross jobs	Jobs in construction and O&M (fulltime equivalent/ year)	n.a	
Energy security	Resilience	Diversity of resources and technologies	n.a.	Kirchner et al. (2016)
	Reduced fossil fuels imports	Tonnes reduced	USD/ton	Öko-Institute (2015)
	Self-consumption benefits	Self-produced and consumed electricity (kWh per year)	Energy cost savings (USD per year)	Widen and Munkhammer (2013)
Distributional effects	Regional distribution	Number of regenerative electricity plants	n.a.	Planki (2913); Coon et al. (2012)
	Effects for final customers and taxpayers	Retail electricity prices	Cost per unit of energy	Pudik (2915); methodological approaches Dieckmann et al. (2016); Lutz and Breitschopf (2016)

Category of effect	Sub-category	Indicator: Physical indicator	Indicator: Monetary indicator	Examples and literature
Indirect effects/ gross effects				
Health effects	Due to lower SO_2 emissions	Avoided cases; avoided hospitalisation; restricted activity days, years lived with disability; disability-adjusted life years (DALYs); quality adjusted life years. Years of life cost	Avoidance cost approach; willingness to pay (WTP)	Sathaye et al. (2011); You & Xu (2010); Gireshop et al. (2011); Wiser et al. (2016)
	Energy poverty related			Ormandy and Ezratly (2012)
Access to energy	Productive utilisations	Value creation through productive utilisations (number of units of produced and processed products)	Revenues minus costs per unit of produced and processed products	Productive utilisations in food processing (IRENA, 2016)
Energy security	Security of energy supply	Units of avoided energy imports (e.g. oil barrels)	Cost per unit of imported energy (e.g. cost/ oil barrel) WTP for secure energy supply (e.g. cost per MWh)	Breitschopf et al. (2016); Sovacool and Mukherjee (2011); Cherp and Jewell (2014)
	Diversity and resilience	Diversification of energy mix (e.g. number of primary energy sources used)	n.a.	Johannson et al. (2012)
Macroeconomic effects	Upstream industry production	Investment in RE energy industry	USD/ year	IEA-RETD (2014); Duscha et al. (2016)
	Upstream industry jobs	Jobs (full-time equivalent/ year)	n.a.	
Distributional effects	Ownership structure or change in operator structures	Number of different owners (e.g. utility scale vs. distributed) and resulting revenues	USD/ year	Slattery et al. (2011)
Energy-related effects	Costs of additional generation and offsetting	Grid parity and fuel parity	LCOE (compared to retail price, wholesale price, fuel price)	IEA PVPS (2016); Breitschopf et al. (2010); Breitschopf et al. (2015); BWMI (2016)
	Additional grid and transaction costs	Costs per km of grid extension; cost of grid extension for lines between 50 and 100 kV	USD/ Year	Klobasa and Mast (2014) (2016)

Category of effect	Sub-category	Indicator		Examples and literature
		Physical indicator	Monetary indicator	
Induced effects				
Environment	Climate	GHG emissions per unit of GDP; avoided costs of climate change or environmental damage	Tce/ USD; CO_s price/ ton CO_2e	IRENA (2016b)
	Water	Limited or unreliable access to affordable energy necessary to extract water; reallocation of water resources from other end-users to energy; contamination of water resources due to energy extraction and transformation processes	n.a.	IRENA (2015)
Macroeconomic effects	GDP/ growth	Rate of change of real GDP as measurement of economic growth	Increase of GDP in % (e.g. constant USD in 2015 omitting purchasing power parity)	GDP is a standard unit used to compare the economic output o firrent countries
	Welfare; IREA (2016) proposes a combined indicator consisting of one economic, 2 environmental dimensions with different weightings	Consumption + future consumption as a measurement of welfare; expenditures for health and education supplement employment; annual greenhouse gas emissions in CO_2 equivalents and direct material consumption in tonnes	n.a.	UNEP (2011), IRENA (2015); Duscha et al. (2016)
	Employment	Number of employees	Net income	IRENA (2016)
	Trade with fossil fuels / electricity and with investment goods and services	Trade balance	Net exports of all goods and services, e.g. in constant USD in 2015 and as share of GDP; trade with fossil fuels in constant USD in 2015	IRENA (2014): Employment is an established indicator based on data from official statistics; Lehr et al. (2015); Ragwitz et al. (2009); Duscha et al. (2016); UNEP (2013); IRENA (2016)
Social and other effects	Participation and inclusion	Participation of stakeholder groups (especially vulnerable groups) in decision-making processes; number and distribution of distributed electricity generation NGOs; number and distribution of communities participating in RE development	n.a.	Guruswamy (2010); Sovacool and Dworkin (2014); Baker (2016)

	Minimisation of technical, financial, geopolitical of risks	Actual benefits and drawbacks of different power generation technologies, e.g. in terms of accident risk and waste streams	n.a.	McCombie and Jefferson (2016)
Distributional effects	Inequality	Effects of burdens by income groups	USD/ year	Lutz and Breitschopf (2016); Sievers and Pfaff (2016)
	Regional value creation and employment	Profit after taxes Net annual income Municipal taxes	USD/ year	Direct and indirect effects from the operating phase of installations as well as induced effects (Kosfeld et al. 2013; Hirschl et al. (2010); Hauser et al. (2015): IEA (2016)

In short, the benefits associated with solar captive PV projects are numerous, and include: energy cost savings, CO2 emission reductions, reduced pressure on current national power stations to generate electricity, increased security of stable and reliable energy for consumers, decreased dependence on fossil-fuel (gensets), benefits on welfare and health conditions (in terms of reduction of sound and air pollution), amongst others. The indirect benefits and externalities, even if difficult to quantify and to incorporate into the cost-benefit analysis, must be considered at least in a qualitative way. Externalities include for example the avoided effects as a result of electricity generation from conventional sources (e.g. air pollution, nuclear waste disposal, etc.) and the externalities and indirect impacts induced by renewable energy systems (e.g. well-being impacts, job creation, impact on exports and exports, etc.).

Given that the benefits of PV systems are country and case specific, the following table intends to highlight the main benefits (non-exhaustive list) that could be expected as a result of enhancing captive PV systems in each of the CCI focus countries: Ghana, Kenya, Nigeria, and South Africa. For more information on the situation of each country, please refer to the Country Reports available at https://www.captiverenewables-africa.org/.

***TABLE 6** Summary of benefits of Captive PV systems in CCI countries.*

	Country situation	Associated benefits of PV (non-exhaustive)
Ghana	• Severe supply challenges due to transmission constraints and gas supply risks, which leads to economic damages to C&I business, and increased use of gensets • High industrial electricity tariffs and large and increasing energy needs	• Increased energy self-sufficiency of consumers (reduced production costs and losses) • CO2 emissions reduction and contribution to the country objectives in terms of climate change mitigation
Kenya	• Electricity supply under increasing pressure, due to increasing power demand. Kenya has committed to achieving 80% of its electricity generation from renewable energy by 2030 • High electricity tariff leading several establishments to re-allocate to other countries	• Reduction of technical energy losses in the distribution grid • Demand curve flattening • Reduction of infrastructure investments needed to increase the capacity of the distribution grid • CO2 emissions reduction and contribution to the country objectives in terms of climate change mitigation • Electricity from solar may provide an affordable alternative to the high grid tariff
Nigeria	• Ageing grid infrastructure, insufficient availability of gas, poor T&D systems (i.e. insufficient supply and frequent system collapses and forced outages) • Traditional biomass (firewood and charcoal) accounts for 86% out of total energy consumption • Over 80% of the operating business own gensets	• Increased energy self-sufficiency of consumers (reduced diesel costs and production losses) • Positive health impacts and increased consumer well-being • More stable network infrastructure
South Africa	• Over 85% of the country's electricity is still generated by coal power plants • Sever load shedding were re-introduced in 2019 reaching stage 6 where blackouts occurred for 530 hours due to outdated infrastructure among other reasons	• CO2 emissions reduction and contribution to the country objectives in terms of climate change mitigation • Less pressure on the current power infrastructure

One of the main limitations of the cost benefit analysis lies with the necessary inherent quantification of the impacts – and their probability of occurring - included in the analysis. For instance, while some health benefits resulting from a renewable energy programme can be quantified, it would be very difficult to quantify the probability and impact of potential severe economic disruptions resulting from climate change. Given the difficulty to quantify many of these impacts, it is common practice to reflect ranges of impacts and perform a sensitivity analysis of the B/C ratio. This is particularly relevant when dealing with large potential impacts such as environmental benefits. Analysts turn increasingly to multi-criteria analysis which allows to consider both the monetary and non-monetary impacts of a policy against a set of objectives and measurable criteria which can be determined in a transparent and accountable way.

Lastly, it is important to note that even if the cost-benefit analysis shows that the considered investment or programme generates positive net benefits from a social perspective over a long horizon, this does not necessarily imply that those are implementable. Certain aspects such as the national legal and regulatory frameworks should also be considered and possibly eventually amended to enable deployment. In fact, in many countries for instance electricity net metering policies or feed-in tariffs are non-existent, which slows down the development of the clean captive energy market and impedes the full development of the renewable energy sector and the clean energy transition. For example, a given government may assess the B/C of solar PV captive systems from a broad social perspective and conclude that supporting those investments would be attractive for the country. Subsequently, the government should conduct an analysis of those projects from the private investor perspective to assess whether in practice these projects are profitable per se or require governmental intervention, not necessarily financial support.

4. CONCLUSION

The project "Clean Captive Installations for Industrial Clients in Sub-Saharan Africa" aims to demonstrate the economic and financial viability of clean captive energy installations for industries to enhance their adoption. Given the importance of incorporating costs and benefits in evaluating those installations, this document provides a general discussion on such considerations from the private and public perspectives.

With the growing climate change crisis, there is a greater need for policy makers to accurately assess the impacts of electricity generation projects and appropriately implement the right support schemes, licenses and regulatory processes for such projects. When comparing among various energy sources and trying to promote the "right" energy source, full consideration should be given to a complete set of social impacts (to the extent possible), including social and environmental externalities that affect society as a whole in the longer term rather than just financial profitability, as well as to direct private sector funding towards the "right" investments.

In this sense, understanding the attractiveness of projects and programmes from a social perspective is very important when developing policies that align the private investors' investment decisions with what is beneficial for society.

The benefits associated to solar captive PV projects are numerous, and include: energy cost savings, CO_2 emission reductions, reduced pressure on current national power stations to generate electricity, increased security of stable and reliable energy for consumers, decreased dependence on fossil-fuel (gensets), benefits on welfare and health conditions (in terms of reduction of sound and air pollution), amongst others. Many of the aforementioned social impacts are hard to quantify. It is therefore common practice to perform a sensitivity analysis on the analytical results.

Finally, it is pertinent to note that cost-benefit analysis should not be done on a stand-alone basis, i.e. certain projects may result in a positive benefit/cost ratio from a social perspective over the long-term, however due to legal and regulatory impediments, may not be financially/economically feasible. It is therefore best to conduct cost-benefit analysis from a social perspective whilst simultaneously conducting a financial analysis from an investor perspective in order to decide on the best renewable energy project or programme and attract adequate private sector funding.

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For more information

CLEAN CAPTIVE INSTALLATIONS FOR INDUSTRIAL CLIENTS IN SUB-SAHARA AFRICA

Visit the project website
www.captiverenewables-africa.org

ABOUT THE UNITED NATIONS ENVIRONMENT PROGRAMME

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system, and serves as an authoritative advocate for the global environment. Our mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

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