MERIDIAN ECONOMICS
NAVIGATING COMPLEXITY

SCOPING STUDY ON ELECTRICITY EMISSION FACTORS AND ENVIRONMENTAL ATTRIBUTES

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ABSTRACT

This report examines how South Africa can credibly account for the greenhouse gas emissions and environmental attributes of its electricity sector. It explores the interaction between electricity emission factors, energy attribute certificates (EACs) and carbon offsets, and outlines the institutional, data and policy requirements for robust tracking systems. The study provides a foundation for aligning South Africa's evolving power market with international best practice in emissions reporting and environmental integrity.

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ACRONYMS

CBAM	Carbon Border Adjustment Mechanism
CDM	Clean Development Mechanism
COAS	Carbon Offset Administration System
DEE	Department of Electricity and Energy
DFFE	Department of Forestry, Fisheries and the Environment
DGGEF	Domestic Generation Grid Emission Factor
DLGEF	Distribution Losses Grid Emission Factor
EAC	Energy attribute certificate
GEF	Grid emission factor
GHG	Greenhouse gas
GO	Guarantee of Origin
GRMEF	Grid residual mix emission factor
IPP	Independent power producer
ITMO	Internationally Transferred Mitigation Outcome
kWh	Kilowatt-hour
MW	Megawatt
MWh	Megawatt-hour
NDC	Nationally Determined Contribution
NERSA	National Energy Regulator of South Africa
NGGEF	National Generation Grid Emission Factor
PPA	Power purchase agreement
REC	Renewable Energy Certificate
RECSA	Renewable Energy Certificates South Africa
RPS	Renewable portfolio standard
tCO_2e	Tonnes of carbon dioxide equivalent
TLGEF	Transmission Losses Grid Emission Factor
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme

GLOSSARY

The way in which terms are used varies in the literature, adding to confusion on an already complex topic. The working definitions captured below and used throughout the document are the outcome of a study of this literature and its application to the South African context.

Bundled EACs: Certificates that are sold or transferred together with the physical electricity they represent, often in the form of a PPA.

Carbon offsets: Carbon offsets are tradable credits that represent a reduction, avoidance, or removal of GHGs (measured in tCO_2e) that can be used to offset emissions made elsewhere.

Compliance market: A regulated system in which electricity suppliers or large consumers are required to obtain and retire EACs to demonstrate that a specified share of the electricity they sell or use comes from renewable sources. Also applies to systems related to legal requirements for reductions in GHG emissions.

EAC scheme: The organised system through which EACs are issued, tracked, traded and eventually retired. Examples include the Renewable Energy Certificate (REC) scheme in the US, the Guarantees of Origin (GO) scheme in the EU and the global International Renewable Energy Certificate (I-REC) scheme.

EAC standard: The set of rules and requirements that govern how an EAC scheme operates, ensuring that certificates are credible, transparent, and not double counted.

Electricity emission factor: The GHG emissions (usually CO_2-equivalent) associated with a unit of electricity, expressed for example as tCO_2e/MWh.

Environmental attributes: Characteristics of energy sources and other activities that define specific environmental or sustainability aspects of those sources and activities.

Energy attribute certificates (EACs): Tradable instruments that represent the environmental attributes of a unit of electricity (typically 1 Megawatt hour (MWh)) and include information such as the source, location, and date/time of generation.

Grid emission factor (GEF): The GHG emissions (usually CO_2-equivalent) produced per unit of electricity consumed from a power grid. The GEF may be calculated in different ways in different jurisdictions or for different applications.

Grid residual mix emission factor (GRMEF): An adjusted grid emission factor for application to null power that accounts for the removal of electrons and emission benefits associated with retired EACs, leaving behind electrons associated with unspecified environmental attributes, including those of fossil power.

Null power: Electricity stripped of its environmental attributes once the associated EACs or carbon offsets have been sold separately.

Retired EAC: An EAC that has been cancelled in a registry, also referred to as a cancelled EAC.

Unbundled EACs: Certificates that are separated from their underlying power and sold on their own.

Unspecified environmental attributes: Environmental attributes that have not yet been formally specified through the issuance of EACs. In the literature these environmental attributes are sometimes referred to as ‘untracked’.

1 INTRODUCTION

The accurate accounting of greenhouse gas (GHG) emissions associated with electricity supply and consumption is increasingly being required both globally and in South Africa, for a wide range of applications including:

- **Policymaking and tracking of policy implementation at the national and sub-national level:** Examples include establishment and tracking of decarbonisation policies that target a decline in electricity emissions, and assessing the emissions reductions achieved by mitigation policies that drive electricity use efficiency.
- **Compliance with mandatory reporting and targets:** Emissions accounting is increasingly being required through international policies and regulations, such as the European Union's Carbon Border Adjustment Mechanism (CBAM). The first phase of the CBAM will require reporting of electricity-related emissions associated with two products (cement and fertilisers), but the scope is likely to grow in future. It is possible that domestic renewable energy targets at the national, regional or local level could be mandated in South Africa in future, as has been done in other jurisdictions.
- **Voluntary entity-level reporting:** Private sector companies and governments, including sub-national governments, are under pressure to track and mitigate GHG emissions, including those associated with electricity demand. Entities are also signing up to voluntary targets and reporting frameworks such as the RE100 and REN21.

Accurate accounting for electricity-related emissions requires quantification and attribution of not only the quantum of the emissions associated with each unit of electricity (electricity emission factors), but also any claims made to the "greenness" or so-called environmental attributes of electricity generated from lower emissions sources. There are two ways in which electricity sector environmental attributes can be claimed: as energy attribute certificates (EACs) and carbon offsets.

Whilst electricity emission factors and claims to environmental attributes are used for different purposes with different procedures, there are important overlaps between them which can impact their integrity. Failing to accurately and transparently track, attribute, and incorporate environmental attributes into electricity emission factors poses several significant risks. These include:

- **Double counting and greenwashing:** Without robust tracking, there is potential for multiple entities to claim the same renewable energy or emissions reduction, undermining the credibility of emissions reporting and enabling greenwashing.
- **Market distortion and reduced investment:** Poorly designed and implemented environmental attribute systems can erode trust among buyers and investors, while failing to reward renewable generators appropriately. This can weaken incentives for new clean energy projects and slow the growth of a credible low-carbon electricity market.
- **Export penalties and trade barriers:** Inaccurate or unverifiable environmental attribute claims can lead to higher effective carbon costs under mechanisms like the EU's CBAM, harming export competitiveness.
- **Risk of private sector capture of public environmental value:** In the absence of clear policy on how the value of environmental attributes linked to electricity supplied to the public grid should be assigned, private entities

could lock in contracts that capture this value for their own benefit.

- **Poor information for domestic climate policymaking:** Weak environmental attribute tracking makes it difficult for all tiers of government to understand the emissions dynamics of the power sector and to develop appropriate policy responses.

This study scopes the topic of electricity environmental attributes and electricity emission factors and their current and future interactions, in the current South African context, as well as exploring the data, systems and institutional structures required to support robust and credible tracking, reporting and policy.

South Africa is currently seeing a shift away from the dominance of Eskom's coal-fired power stations towards increasing generation of electricity from clean sources owned by private players. The country is also transitioning from a monopolistic centralised electricity system towards a competitive, multi-market structure where electricity can be freely traded on an open wholesale market. Both of these factors increase the complexities in the electricity environmental attribute space and the calculation of accurate emission factors.

2 ELECTRICITY ENVIRONMENTAL ATTRIBUTES

While electricity generated from fossil fuels and renewable sources is physically indistinguishable, the method of generation has markedly different environmental consequences. Environmental attributes provide a means of capturing this distinction by describing how each unit of electricity was produced and its impact on the environment. These attributes may include factors such as water use, land disturbance, and air pollution. However, for the purposes of this report, the focus is on environmental attributes related specifically to GHG emissions.

These environmental attributes of electricity can be captured and specified through two main instruments: (1) EACs, or (2) carbon offsets. EACs certify the source of a unit of electricity, enabling consumers to make credible claims about renewable or low-carbon electricity use[1]. Carbon offsets, on the other hand, represent verified reductions or removals of a quantified amount of GHG emissions. Together, these mechanisms form the foundation for recognising, transferring, and accounting for claims to the environmental benefits associated with different sources of electricity.

The relationship between different types of electricity environmental attributes is provided in Figure 1.

Definitions

Environmental attributes: "characteristics of energy sources and other activities that define specific environmental or sustainability aspects of those sources and activities"[2].

Energy attribute certificates (EACs): Tradable certificates that represent the environmental attributes of a unit of electricity (typically 1 Megawatt hour (MWh)) and include information such as the source, location, and date/time of generation.

Carbon offsets: Carbon offsets are tradable credits that represent a reduction, avoidance, or removal of GHGs (measured in tCO_2e) that can be used to offset emissions made elsewhere, both in voluntary and compliance markets.

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[1] While EACs are most commonly associated with renewable energy, they can also be issued for electricity generated from nuclear, gas, and even coal-fired power – for example, through the I-TRACK(e) product code. However, such applications remain limited and are not widely used globally.

[2] Clean Energy Institute (2022). https://cleanenergy.uci.edu/PDF_White_Papers/Environmental_Attribute_Credits_Analysis_of_Program_Design_Features_and_Impacts_091523.pdf

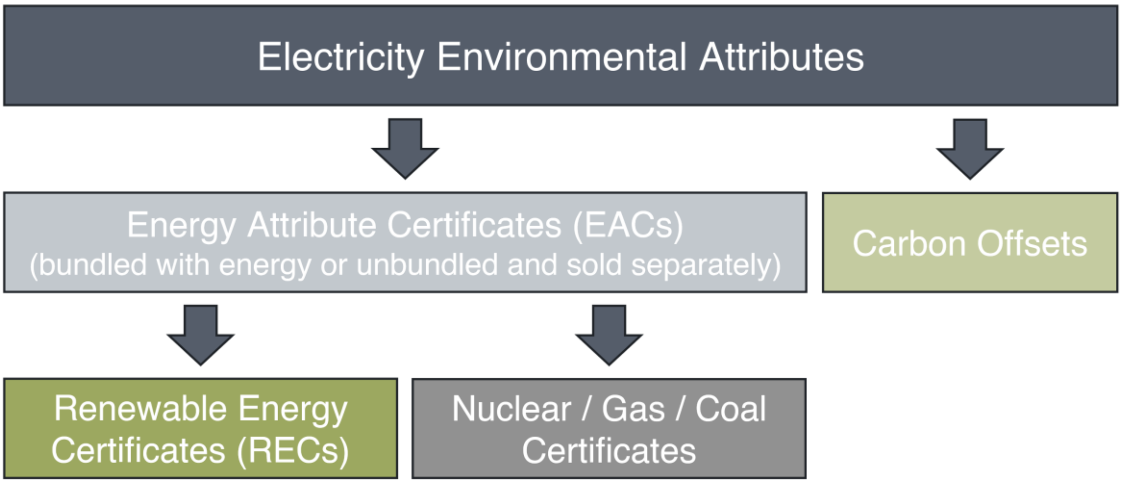

Figure 1: Typology of electricity environmental attributes

2.1 ENERGY ATTRIBUTE CERTIFICATES (EACS)

Energy attribute certificates (EACs) are tradeable certificates that represent information on the generation characteristics of a unit of electricity (typically 1 MWh hour). They include information such as the source, location, and date/time of generation. By specifying this information, EACs provide proof that a certain amount of electricity was produced from a particular source, such as renewables[3], allowing consumers to claim ownership of the environmental benefits of a specific power source, even though the physical electricity they use is drawn from the grid where electrons are indistinguishable.

2.1.1 EAC LIFECYCLE

There are three main phases to an EAC's lifecycle, as demonstrated in Figure 2:

- Issuance: An accredited electricity generator produces a MWh of renewable electricity and provides the necessary generation data to the EAC issuing body. A unique EAC is then created in the registry and issued to the generator. Verification of this data by a third-party verifier may be required prior to issuance.
- Transfers and trading: The EAC can be transferred and traded between accounts, either directly from the generator to the end-user, or via intermediaries such as traders/brokers. The registry logs each transfer in a transparent ownership chain.
- Retirement: The end-user retires the EAC to claim the green benefits. At this point, the EAC is cancelled from the registry and thereby removed from circulation.

[3] *EACs do not account for transmission and distribution losses. These are accounted for separately as Scope 3 emissions.*

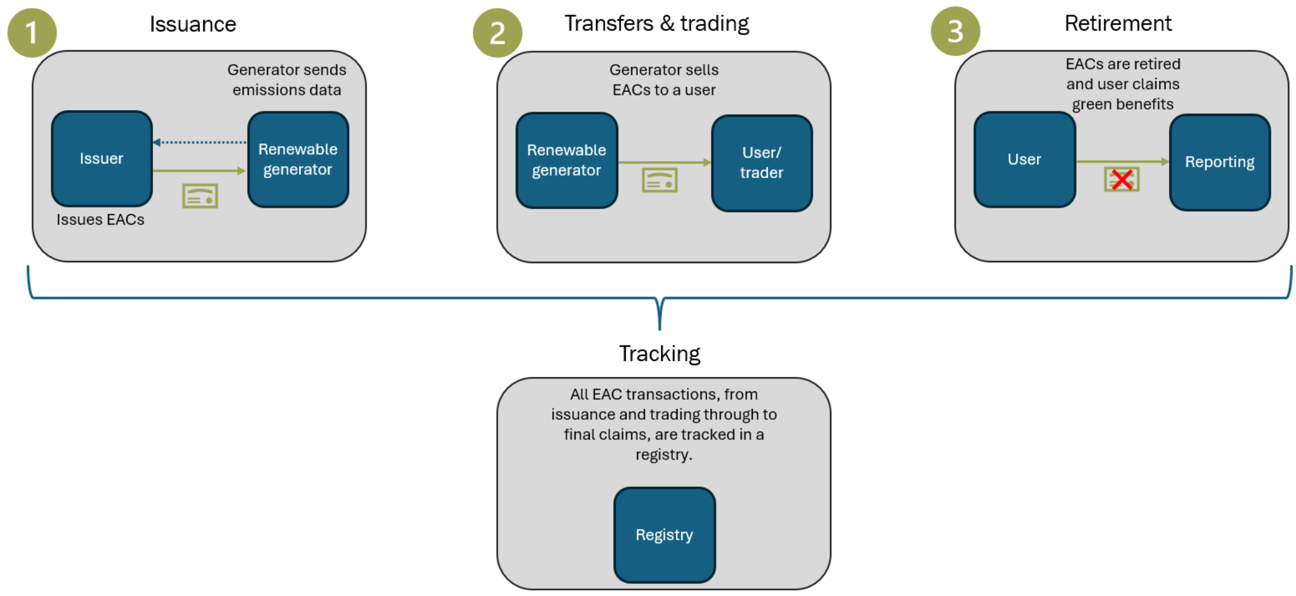

Figure 2: EAC Lifecycle

2.1.2 EAC SCHEMES, STANDARDS AND ISSUING BODIES

EACs are managed under different schemes and standards, and can be applied in compliance markets to meet regulatory obligations or in voluntary markets to support reporting and disclosure.

<u>Definitions</u>

EAC scheme: The organised system through which EACs are issued, tracked, traded and eventually retired. Examples include the Renewable Energy Certificate (REC) scheme in the US, the Guarantees of Origin (GO) scheme in the EU and the global International Renewable Energy Certificate (I-REC) scheme.

EAC standard: The set of rules and requirements that govern how a particular EAC scheme operates, ensuring that certificates are credible, transparent, and not double counted.

Compliance markets are created by law and are designed to help meet renewable energy or emissions reduction goals. For example, in the US, RECs are the accounting tool used by electricity suppliers to demonstrate compliance with state-level Renewable Portfolio Standards, which require a certain proportion of power to come from renewable sources. In Europe, GOs and their UK equivalent, Renewable Energy Guarantees of Origin (REGOs), operate under legislation but function mainly as disclosure instruments, certifying to end-consumers the renewable content of electricity supply.

Alongside these legally mandated systems, voluntary EAC markets have emerged to meet the reporting needs of businesses and institutions. In these markets, EACs are purchased and retired to make claims about renewable electricity consumption. I-REC is one of the most prominent voluntary schemes, providing a common system for tracking renewable electricity that is used in multiple countries around the world.

Each EAC scheme has an issuing body which is the designated authority responsible for issuing EACs and overseeing their integrity. This includes verifying generation data, creating certificates, and monitoring their lifecycle. The issuer also typically manages the registry, a centralised electronic platform where the issuance, transfer, and retirement of EACs are recorded. Registries ensure transparency by providing an auditable chain of ownership and safeguarding against double counting.

2.1.3 TYPES OF EACS

EACs can be sold together with their associated electricity in a bundled Power Purchase Agreement (PPA), or unbundled and sold separately from the underlying power.

Definitions

Bundled EACs: Certificates that are sold or transferred together with the physical electricity they represent, often in the form of a PPA.

Unbundled EACs: Certificates that are separated from their underlying power and sold on their own.

Bundled EACs

A straightforward example of bundled EACs is a PPA where a renewable energy project sells its electricity and the EACs issued for that same generation to a contracted offtaker.

One benefit of purchasing EACs together with their underlying electricity is that renewable generation is automatically time-matched with consumption periods, meaning the buyer's load can be demonstrably matched to specific clean energy output when it is produced (see Box 1). This enhances the credibility of reporting of emissions.

Another advantage of bundled EACs in a PPA is that they secure a fixed price for both electricity and the associated EACs, offering an effective hedge against volatility in both electron and EAC markets. By ensuring long-term revenue certainty, they also play a critical role in enabling the financing and construction of new renewable energy projects. However, given the large energy volumes and long-term financial commitments involved, bundled EACs are generally accessible only to organisations with large and predictable electricity demand. Smaller consumers often find it difficult to commit to the contract sizes and durations (typically 10 to 20 years) that such agreements require.

Box 1: EAC vintage and time-matching

The vintage of an EAC is the period (usually the year) when the renewable electricity was generated and the certificate issued. The GHG Protocol Scope 2 Guidance (see Box 3) includes vintage as one of its criteria for determining the credibility of EACs by ensuring that the generation of EACs "occurs close in time to the reporting period for which the certificates (or emissions) are claimed" (WRI, 2015). Using older vintage certificates (typically more than a year) is seen as less credible, since it weakens the link between generation and consumption.

The idea of time-matching builds on this by seeking alignment not only on an annual basis, but hourly or sub-hourly. This is more accurate because electricity generation and demand vary within hours, days and seasons, meaning annual matching can mask mismatches.

As the renewable-energy market has matured, expectations have shifted towards greater temporal precision. Time matching is currently being actively debated in the development of the GHG Protocol Scope 2 Guidance Update anticipated in 2027, as stakeholders push for:

- More granular and accurate reporting;
- Incentives for energy storage and flexible demand;
- Updates to standards like the GHG Protocol; and
- Greater transparency and integrity in corporate renewables claims.

Unbundled EACs

Unbundled EACs are purchased separately from electricity and can be acquired independently of who supplies the buyer's actual electricity. This provides more flexibility as consumers of all sizes can purchase EACs without a long-term contract for energy.

One limitation is that because unbundled EACs are detached from actual electricity, they do not necessarily ensure that a buyer's demand is met with renewable energy generated at the same time or location. This separation has led to concerns about credibility compared to bundled

EACs. In response, there is a growing movement toward hourly matching of unbundled EACs – often referred to as 24/7 Carbon-Free Energy (NESO, 2025). This approach aims to ensure that at every hour of the day, for every location, the electricity a company uses is matched with renewable output feeding the grid at that same hour.

The separation of EACs from their underlying electricity adds an additional layer of complexity to electricity emissions reporting as adjustments need to be made to account for the fact that the underlying power is now stripped of its EACs and so can no longer be considered zero or low emissions. The adjustment is typically done using a 'residual mix factor' which is discussed further in Section 3.3 below.

2.2 CARBON OFFSETS

Carbon offsets originated under the Kyoto Protocol of the United Nations Framework Convention on Climate Change. Carbon offsets are fundamentally different instruments from EACs, due to how they are specified (See Box 2 below). EACs represent the generation of 1 MWh of electricity from a particular carrier, while carbon offsets represent 1 tonne of CO_2e reduced, avoided or removed from the atmosphere. As internationally tradeable instruments on both compliance and voluntary markets, carbon offset principles and systems are now relatively well developed, with many established standards, issuing bodies, compliance schemes and trading registries. Some of the better known include Verra, Clean Development Mechanism (CDM) and Gold Standard.

Carbon offsets used for transfer under international compliance markets are called Internationally Transferred Mitigation Outcomes (ITMOs), and are governed by the rules of Article 6 of the Paris Agreement. Carbon offsets generated for domestic compliance schemes are subject to the particular rules of the scheme, but often these utilise the standards and infrastructures of the international markets.

Whilst carbon offsets and EACs are different in terms of how they are calculated and used, it is important to recognise that an environmental attribute cannot be specified simultaneously as an EAC and a carbon offset. This is to avoid double counting of the same environmental attribute for different purposes. All credible offset and EAC standards require that the instruments generated cannot be double counted through generation in another offset or EAC scheme.

Box 2: Carbon offsets - baseline and credit instruments

Electricity carbon offsets are generated by demonstrating that an electricity project avoids emissions that would have arisen in the project's absence. To do this, a baseline future emissions trajectory is established, together with a project trajectory which has lower emissions. The difference between the two becomes the potential number of offset credits that the project can issue over time.

As its name suggests, a carbon offset is used to 'offset' emissions occurring elsewhere, relying on the concept of 'additionality' to ensure its environmental integrity. To meet additionality requirements, individual project developers must demonstrate that the project would not have occurred in the absence of the carbon offset mechanism. Once a project is registered under a carbon offset standard, it can generate carbon offset credits for a pre-specified period of time.

3 ELECTRICITY EMISSION FACTORS

An electricity emission factor represents the emissions per unit of electricity, usually expressed in tonnes of carbon dioxide equivalents (tCO_2e) per MWh. Different electricity emission factors are required for different purposes. The use case will determine what emissions and units of electricity are included and excluded from the calculation of the factor.

Definition

Electricity emission factor: The GHG emissions (usually CO_2-equivalent) associated with a unit of electricity, expressed for example as tonnes CO_{2e}/MWh.

Electricity emission factors are calculated based on claims (or lack thereof) to the environmental attributes associated with the associated electrons. Box 3 discusses the reporting requirements under the GHG Protocol, the current best practice in electricity emissions reporting.

Box 3: Greenhouse Gas Protocol Scope 2 Guidance

The GHG Protocol was established as a joint initiative between the World Resources Institute and World Business Council on Sustainable Development to provide standardised frameworks for GHG emissions accounting and reporting, which have become the most widely used reporting frameworks globally.

The first publication was the Corporate Standard, focusing on company-level reporting. Since then a number of further guidance documents have been developed, including the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), the Scope 3 Standard and the Policy and Action Standard. Of relevance here is the GHG Protocol Scope 2 Guidance, which focuses on emissions associated with generation of acquired and consumed electricity, steam, heat, or cooling (collectively referred to as "electricity" in the standard) (WRI, 2015). These emissions are known as Scope 2 emissions, as opposed to Scope 1 emissions which are the direct emissions from a company or community's own operations. Emissions associated with electricity lost during Transmission and Distribution are classified as Scope 3 or value chain emissions, and are not included in Scope 2 reporting.

The Scope 2 Guidance was developed in response to the need to standardise on a number of the topics covered thus far in this current study, including calculation of grid factors to determine emissions associated with electricity use; accounting for bundled and unbundled attribute purchases; and the implications of individual entities claiming green power attributes for other electricity consumers.

The Guidance provides two distinct methods for Scope 2 accounting:

- **Location-based reporting** which reflects the average emissions intensity of grids on which energy consumption occurs (using mostly grid-average emission factor data). Location-based reporting does not consider any contractual arrangements for the trading of EACs or carbon offsets.
- **Market-based reporting** which reflects the emissions associated with electricity that consumers have intentionally chosen. It thus includes consideration of all contractual instruments for purchase of energy attributes. To allow for market-based reporting, individual electricity suppliers (IPPs, retailers, traders etc) are required to provide the information associated with their electricity supplied to their customers. Any remaining electricity is allocated a residual grid factor (GRMEF), with the residual factor reflecting an adjustment for sales of attributes. The residual grid factor is discussed further in Section 3.3 and the Appendix.

The Protocol requires that "companies with any operations in markets providing product or supplier-specific data in the form of contractual instruments" must report emissions using both approaches. However, if companies only have operations in markets without product or supplier-specific data, then only one scope 2 result shall be reported, based on the location-based method.

An update to the Scope 2 Guidance is in preparation, anticipated for release in late 2027. It is likely that this update will address the issue of time-matching (see Box 1), which is largely absent from the existing Guidance.

3.1 GRID EMISSION FACTORS

Different grid emission factors (GEFs) are defined, and are used for location-based reporting or policy purposes.

Grid generation emission factors refer to electricity generated from all grid connected sources. There may be a variety of GEFs calculated for a country or region, varying in terms of how the grid boundaries are set.

Between net electricity generation (after allowing for internal consumption by the generator) and consumption, electrons are lost in the processes of transmission and distribution. The MWh generated will always be more than the MWh consumed on a grid. Transmission and Distribution grid loss factors account for these losses at the Transmission and Distribution levels respectively.

3.2 SUPPLIER EMISSION FACTORS

Unlike a centralised system where location-based emission factors are broadly representative of all power consumed on the grid, in a competitive electricity market, consumers will increasingly require retailers and traders to specify a supplier emission factor for reporting purposes. The difference between location-based grid generation emission factors and market-based supplier emission factors is represented graphically in Figure 3.

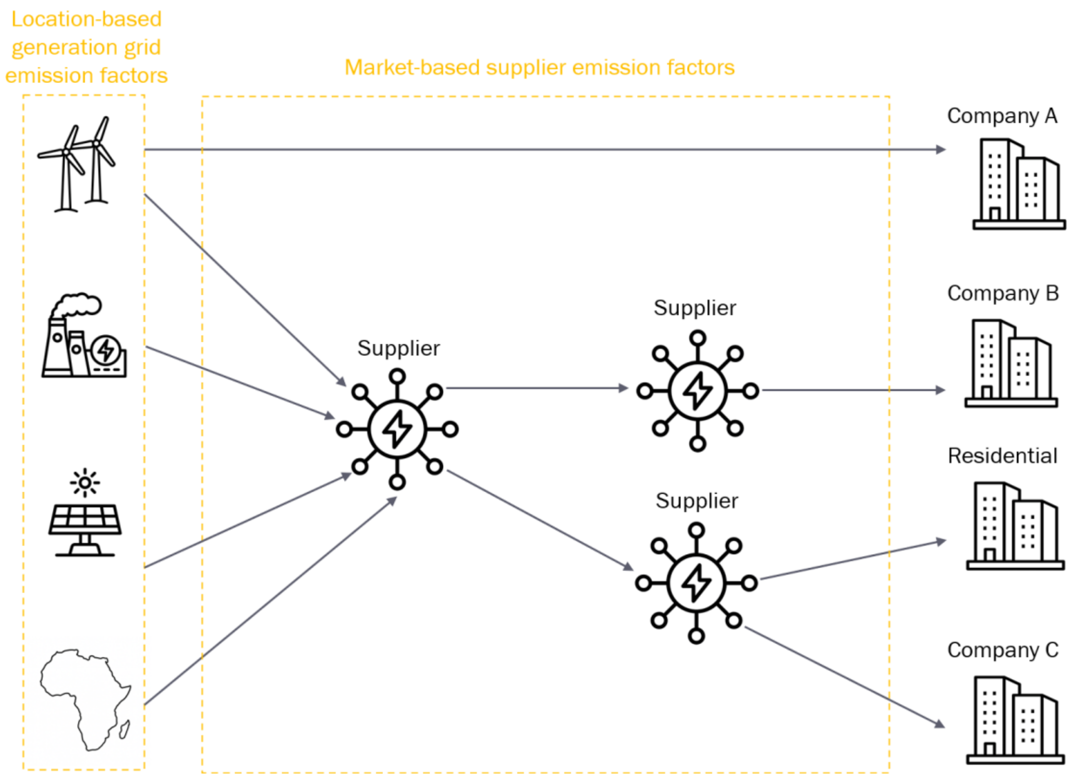

Figure 3: Generation grid emission factors and supplier emission factors

Each supplier emission factor will be derived from the supplier's specific portfolio of power purchase and environmental attribute contracting arrangements, depicted in Figure 4. Environmental attribute contracting arrangements can include: bundled EACs; unbundled EACs; renewable or fossil power where the environmental attributes remain unspecified (i.e. no EACs or carbon credits have been issued); and 'null' power, which refers to electricity that has been stripped of its environmental attributes and sold separately.

End-users then apply these supplier-specific factors, together with any EACs they have contracted, to calculate and report their electricity emissions.

Accurate calculations of supplier emission factors rely on credible EAC tracking and reporting. If environmental attributes are claimed both by the entity retiring an EAC and by other users of grid electricity, the same environmental benefit is effectively counted twice.

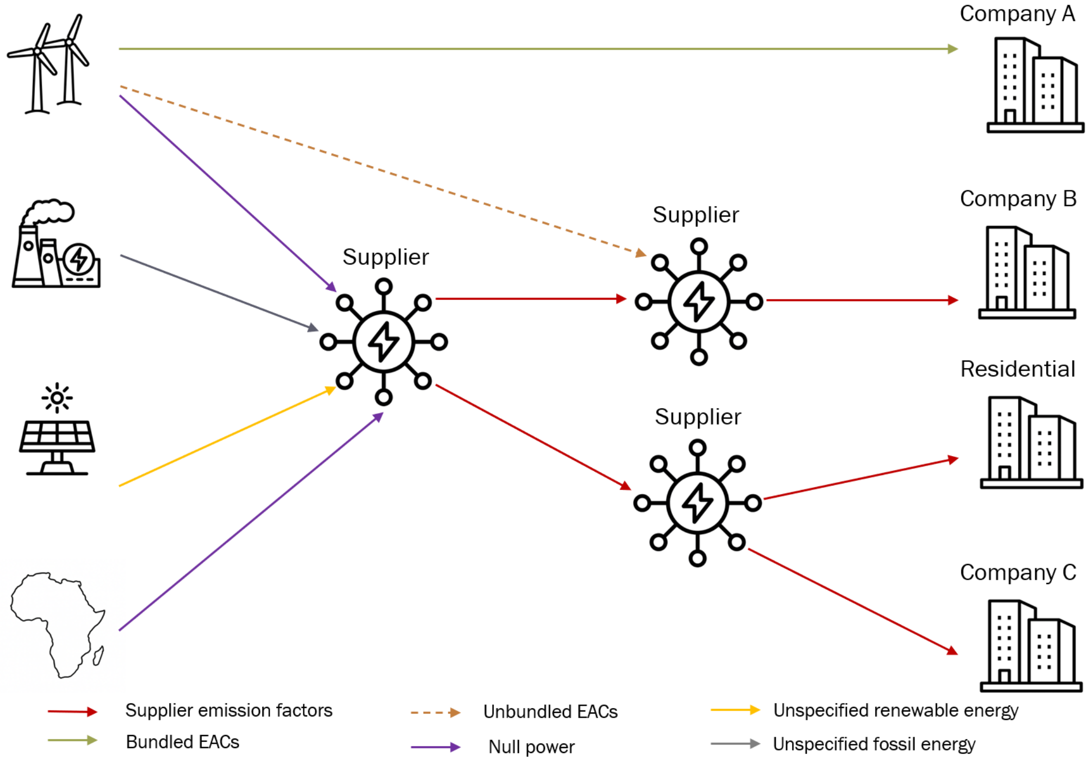

Figure 4: Supplier factors must account for various power purchase and environmental attribute contracting arrangements

3.3 NULL POWER AND THE GRID RESIDUAL MIX

When an EAC is unbundled or a carbon credit is issued, the environmental attributes can no longer be associated with the underlying electricity. This results in an accounting challenge: what emission factor should be used for these 'null' electrons?

Definitions

Null power: Electricity stripped of its environmental attributes once the associated EACs or carbon offsets have been sold separately.

Grid residual mix emission factor (GRMEF): An adjusted grid emission factor for application to null power that accounts for the removal of electrons and emissions benefits associated with retired EACs, leaving behind electrons associated with unspecified environmental attributes, including those of fossil power.

A grid residual mix emission factor (GRMEF) provides an adjusted emission factor that accounts for emissions benefits associated with retired EACs and carbon offsets, leaving behind electrons associated with unspecified environmental attributes, including those of fossil power. Because claimed EACs and carbon offsets are most likely to be associated with renewable generation, the residual mix will have a higher emission factor than the grid generation emission factor. A worked example of how to calculate the GRMEF can be found in the Appendix.

4 ENVIRONMENTAL ATTRIBUTES AND ELECTRICITY EMISSION FACTORS IN SOUTH AFRICA

4.1 EACS

South Africa's EAC market is currently characterised by two primary voluntary schemes: the national zaRECs system, administered by the Renewable Energy Certificates South Africa (RECSA) association based on the European EECS specifications, and the global I-REC standard, for which the Green Certificate Company (GCC) acts as the issuer. While these schemes are well-functioning and adhere to international standards, their impact on the domestic electricity market to date has been limited (Eskom, 2023).

A major constraint to the development of the domestic EAC market is that existing certificates do not cover generation from power plants enrolled in the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). EACs were not issued for this power, and ownership of the underlying environmental attributes remains uncertain. As a result, the domestic EAC market is substantially smaller than it otherwise might be if the legal ownership of these green attributes was clarified. Despite this limitation, the market has seen positive developments, including a clear growth trend in certificate issuance, with increasing demand now driven primarily by large corporations adhering to RE100 and Carbon Disclosure Project reporting standards (Eskom, 2023).

There is also the potential for issuing nuclear EACs associated with Koeberg's production, which Eskom is currently considering.

Ultimately, because the South African grid is interconnected with the South African Power Pool (SAPP), environmental attributes associated with the SAPP region will need to be accounted for. Given the size of the SAPP versus the South African grid, this is not a pressing near-term issue. However, the status of Cahora Bassa's EACs does require clarification to ensure the appropriate emission factors are being attached to electrons imported from Mozambique.

While time-matching is nascent, zaRECs have partnered with GAE Connect to offer time-stamped RECs that enable hourly matching.

4.2 CARBON OFFSETS

Carbon offset credits in South Africa are used for compliance with the South African carbon tax, or by domestic or international buyers for voluntary offsetting or international compliance schemes under Article 6 of the Paris Agreement to which South Africa is a signatory.

The National Treasury is responsible for establishing the rules of the domestic carbon tax offset system (National Treasury, 2019). Treasury has identified the CDM, Gold Standard and Verra standards as eligible for use under the carbon tax. These standards all have international registries. The international sale of carbon offsets is governed by Article 6 of the Paris Agreement. The Department of Forestry, Fisheries and the Environment (DFFE) Focal Point is anticipated to be involved in issuing approval letters required for Article 6 projects[4]. The standards used by both require that double counting of environmental attributes is not allowed.

Offsets used for voluntary offset purposes are subject to the credibility requirements of the particular user, with many requiring issuance by an established and credible standard, tracked in a reputable registry, with a commitment to non-double counting. South Africa has only one domestic voluntary offset standard, Credible Carbon.

Under most international carbon standards, renewable energy projects are no longer eligible to generate carbon offsets, given that they are commercially viable even in the absence of revenues from sale of carbon offsets. This means that they typically cannot meet the requirement of 'additionality' – which refers to an offset project needing to demonstrate that it would not have achieved the emissions reductions in the absence of carbon revenue. However, the South African carbon tax rules allow the generation of carbon offsets from renewable energy projects with a capacity of up to 30 MW and with a cost greater than R1,09/kWh (National Treasury, 2025).

Carbon offset project approval and registry functionality was initially established by the Department of Mineral Resources and Energy for the approval of CDM projects, and is now under the Department of Energy and Electricity (DEE). The DEE's Designated National Authority (DNA) runs the Carbon Offset Administration System (COAS)[5], which currently acts as a registry for carbon tax offsets and is anticipated to expand to manage South African Mitigation Outcomes under Article 6 (DFFE, 2024a). Carbon offsets developed for the voluntary market do not have to register with the COAS, but as long as they utilise credible standards, these offsets will be tracked in the registries of the standard under which they are developed.

4.3 ELECTRICITY EMISSION FACTORS

In 2024 the Minister of Forestry, Fisheries and Environment published the country's first official electricity emission factors report for 2021 (DFFE, 2024b), with subsequent publications for 2022 and 2023 (DFFE, 2024c, 2025). The reports include two grid generation emission factors:

- The **Domestic Generation Grid Emission Factor (DGGEF),** which represents the GHG emissions per unit of electricity generated within South Africa. It does not consider whether the electricity is exported or consumed domestically, and it excludes auxiliary consumption related to electricity generation and electricity generated for own use. Wheeling not intended for sale or distribution on the grid is excluded, although private wheeling agreements are included in the GEF.
- The **National Generation Grid Emission Factor (NGGEF)** which includes electricity generated within South Africa and its associated emissions, and imported electricity along with its associated GHG emissions. This factor thus represents the emissions associated with end-user electricity consumption from the grid.

The boundaries of these factors are shown schematically in Figure 5. The report also presents separate transmission and distribution loss emission factors, known as the TLGEF and DLGEF respectively.

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[4] *Under the United Nations Framework Convention on Climate Change (UNFCCC), a focal point is an officially designated individual or institution that serves as the primary liaison between a country and the UNFCCC Secretariat.*
[5] https://carbon.energy.gov.za/Home.aspx

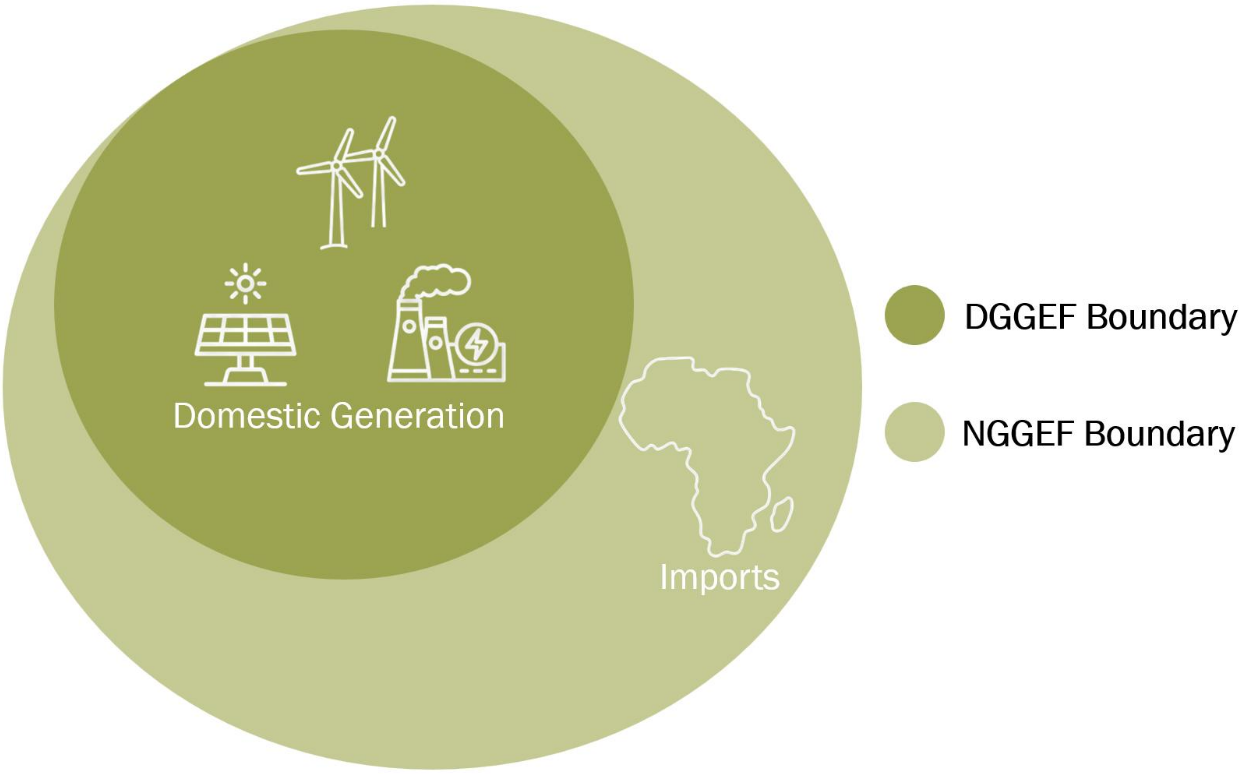

Figure 5: Domestic Generation Grid Emission Factor (DGGEF) and National Generation Grid Emission Factor (NGGEF) boundaries

Box 4: What constitutes the "grid" for location-based reporting in South Africa?

For location-based reporting, the GHG Protocol provides some guidance on how the boundary is drawn around the grid. It states:

"The most appropriate spatial boundaries for emission factors serving the location-based method are those that approximate regions of energy distribution and use, such as balancing areas. All generation and emissions data within this boundary should be aggregated and any net physical energy imports/exports and their related emissions should be taken into account. For multi-country regions with frequent and significant exchanges of energy throughout a year (as measured by percent of that country's total generation), a multi-country regional grid average may be a better estimate than a production-only national emission factor without energy imports/exports adjustments.

South Africa is a part of the Southern African Power Pool (SAPP), both importing and exporting power from neighbouring countries. Imports and exports each represent a few percent of total generation. The location-based emission factor best suited to South Africa could either be the SAPP grid emission factor, or the NGGEF. **Given the relatively small imports and exports together with limited data availability on SAPP EACs, the NGGEF could be considered appropriate for use at present.**

DFFE suggests that the DGGEF is "most useful for DFFE in the development of policy and international reporting purposes. This factor is also useful for other government departments such as the Department of Mineral Resources and Energy." However, no further details are provided as to how it is used. The NGGEF is identified to be "most useful to electricity consumers, especially those that need to conduct corporate reporting of GHG emissions or those that need to report on Scope 2 emissions", and has effectively represented the location-based emission factor and supplier emission factor to date. **Importantly, neither the DGGEF nor the NGGEF take EAC retirements into account and are therefore not appropriate for market-based reporting under the GHG Protocol.**

In compiling the DFFE emission factors, domestic electricity generation data for both emitting and non-emitting facilities was sourced from the National Energy Regulator South Africa (NERSA), which collects electricity generation information from all licensed electricity producers in the country. Data on electricity imports and exports was provided by Eskom.

Emissions from domestic electricity production were sourced from the SA GHG Emissions Reporting System (SAGERS), which requires reporting under the National GHG Emissions Reporting Regulations for facilities exceeding the capacity threshold. Data for installations below the 10 MW threshold were obtained from NERSA.

Emissions associated with imported electricity were calculated using the approved Standardised Baseline: Grid Emission Factor for the Southern African Power Pool (SAPP)[6].

In addition to the DFFE publication, Eskom publishes two emission factors for determining the "environmental implications of using or saving electricity." The first is calculated based on Eskom's total electricity sales, which is the total available for distribution including purchases from IPPs, imports and wheeling less losses through Transmission and Distribution and from theft, own internal use and wheeling.

The second considers only Eskom's generation across different sources, but excludes electricity consumed by Eskom itself. It thus excludes other generation in the country and imports.

At present, South Africa does not publish a GRMEF for use in market-based reporting.

4.4 POWER MARKET REFORM

South Africa's electricity sector has historically been structured around a vertically integrated monopoly, Eskom. Under this centralised structure, consumers had very little choice over their supplier, with their power coming either directly from Eskom or via their municipality (which in turn bought power in bulk from Eskom). The lack of differentiation between suppliers meant that the location-based GEF was an appropriate metric for consumers reporting on their Scope 2 emissions.

South Africa's electricity sector is undergoing fundamental electricity market reforms with the introduction of the South African Wholesale Electricity Market (SAWEM) scheduled for April 2026. On the supply side, this will provide an open market platform whereby power producers compete to provide power into the market at regular trading intervals in addition to bilateral contracting for power outside of the market. On the demand side, the range of suppliers available to consumers will increase substantially. Incremental reforms, such as the lifting of the licensing requirement for generators in 2023, have already expanded the range of supply options available, primarily for large commercial and industrial consumers on Eskom networks.

As market reforms advance, end-users will gain greater choice over their electricity sources. Each supplier – whether Eskom, an IPP, the SAWEM, a trader, or a municipality – will need to develop supplier-specific emission factors that account for their share of EACs and carbon offsets. Figure 6 illustrates the evolving South African power market in terms of supplier emission factors.

[6] *This is also used for CDM projects.*

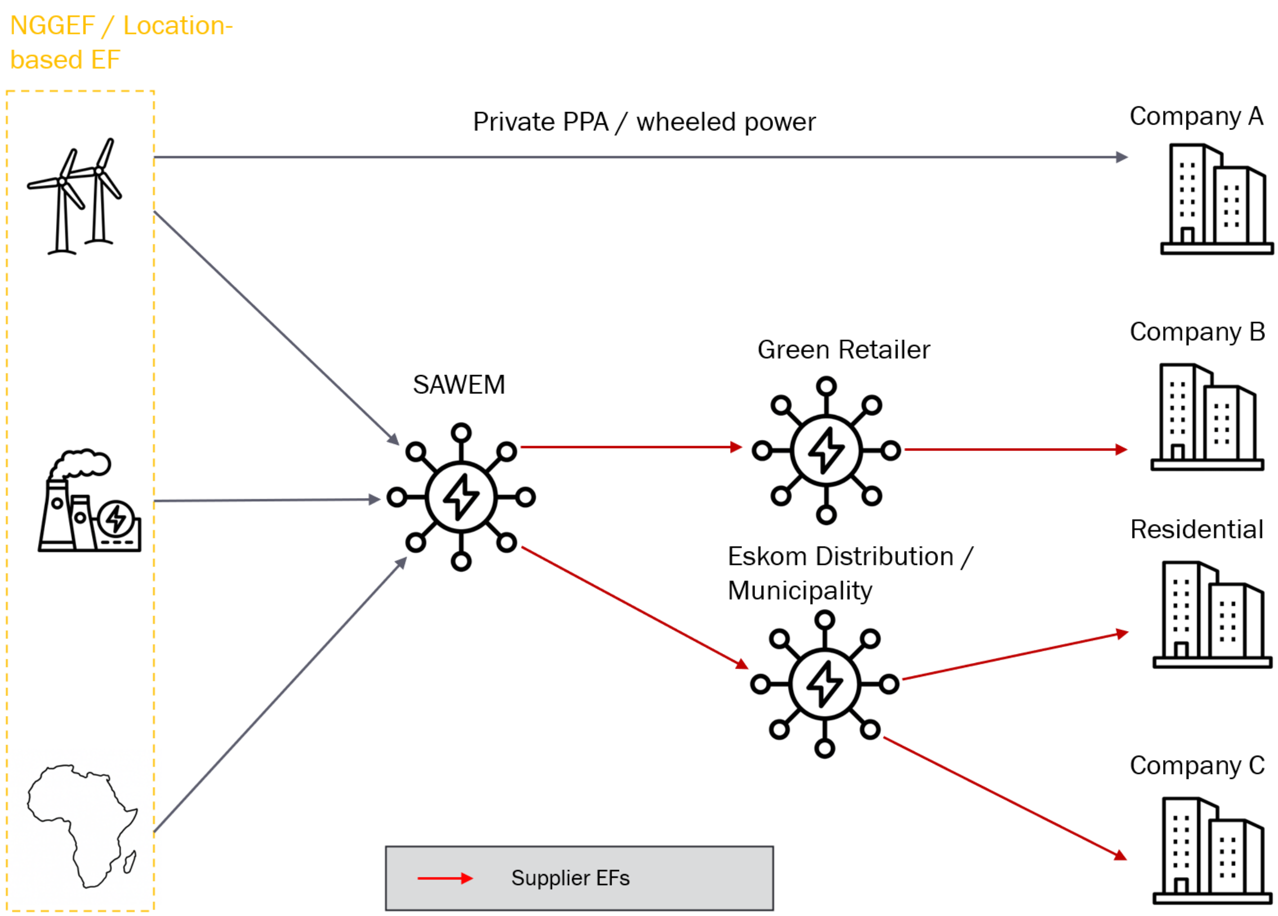

Figure 6: Emission factors required in the evolving South African market.

5 REQUIREMENTS FOR TRACKING ENVIRONMENTAL ATTRIBUTES IN SOUTH AFRICA

The evolution of mitigation policymaking, compliance requirements and voluntary reporting in South Africa indicates that robust and credible electricity emission factors supported by credible EAC tracking are increasingly being required. In particular, the retirement of emissions attributes associated with grid-tied electricity needs to be credibly evidenced to calculate the GRMEF and validate Scope 2 emissions reporting claims.

The power market reform underway in South Africa also implies changes to the institutional landscape that affects the sources and flows of data. It may be that institutions other than the DFFE, who currently publish grid emission factors, are better positioned to collate and/or publish emission factors for policy, compliance and reporting use.

5.1 ELECTRICITY EMISSION FACTORS AND ENVIRONMENTAL ATTRIBUTE TRACKING STATUS

Table 1 presents an overview of existing and future electricity emission factors and EAC tracking systems categorised by use, with red font indicating where factors and systems need to be created or updated.

	Electricity emission factor	EAC / carbon offsets
Policymaking and tracking of policy implementation	DGGEF, TLGEF, DLGEF	COAS and Art 6 registry
Compliance with mandatory and voluntary reporting and targets	NGGEF, TLGEF, DLGEF, GRMEF, Supplier EFs.	COAS and Art 6 Registry Credible EAC tracking

Table 1 Emission factors and EAC tracking systems and requirements in South Africa

5.2 OVERARCHING REQUIREMENTS FOR ROBUST ELECTRICITY ENVIRONMENTAL ATTRIBUTE TRACKING SYSTEMS

Five overarching issues are identified as needing to be resolved for building robust electricity EA systems in South Africa.

5.2.1 CLARIFICATION ON OWNERSHIP OF PUBLIC EACS

There are various concerns surrounding ownership of public EACs, be those generated by Eskom (e.g. nuclear), or those where the power is publicly procured, for example under the REIPPPP. Clarification is required as to whether public EACs should be retained by Government / Eskom to ensure the environmental benefits flow to all consumers of public electricity, or whether the utility should be allowed to sell these EACs separately to raise revenue to support its own operations. This also requires consideration of relevant policies, such as the carbon tax.

5.2.2 POLICY MANDATES AND LEGISLATIVE CAPABILITIES

Historically, rules for environmental attribute compliance schemes (carbon tax and Article 6) have been set by National Treasury and DFFE respectively, whilst the management of systems (COAS) has fallen to the Energy department. A decision now needs to be made as to which government entity is most appropriately mandated and legislatively equipped to govern and implement EAC systems within the country.

5.2.3 SCARCE RESOURCES AND PRIORITISATION

Resources are required to develop new systems and so Government will need to decide what it should prioritise, and what can initially be left to the private sector to address. The following are recommended as Government's primary responsibilities, in order of priority:

- NGGEF; DGGEF; TLGEF; DLGEF; GRMEF
- Public supplier factors
- Approval of eligible EAC Standards and EAC registries.

5.2.4 A STRATEGIC VIEW OF THE ROLE OF ENVIRONMENTAL ATTRIBUTES IN THE ENERGY TRANSITION

As the energy transition progresses, electricity environmental attributes will likely become sought after commodities for a period of time. This may have implications for SAWEM, the functioning of the carbon tax in the electricity sector and Eskom and Municipalities' financial viability. It is possible that environmental attribute value could exceed that of the underlying electrons during certain seasons, times of the day and/or transition phases. South Africa has not established mandatory compliance schemes associated with renewable energy. Other countries have done this effectively, and this policy instrument should be considered at the national, regional and local levels as part of the policy suite supporting the energy transition.

5.2.5 ANTICIPATING FUTURE DEVELOPMENTS

Three anticipated future needs for environmental attribute tracking and reporting systems in the country are identified:

1. More granular time matching of EACs
2. A distinction between the EFs of sub-grids such as provincial or municipal networks may be required
3. The possibility of future domestic regulatory schemes being established at national, provincial or municipal levels.

Recommendation:

Tracking, reporting and realising value from electricity environmental attributes is a cross-cutting issue involving a range of institutions and stakeholders. It is therefore recommended that an inter-departmental government working group be established to engage with the issues above. This group should at minimum include DFFE, DEE, and National Treasury. The working group will need to engage with Eskom, the NTCSA, Municipalities, EAC sector players, Industry and others as the issues above are deliberated. However, it is important that a distinction is maintained between Government and market players (primarily generators and suppliers) in conducting this work.

5.3 SPECIFIC REQUIREMENTS

Beyond these overarching considerations, South Africa has some more detailed electricity emission factor and environmental attribute reporting and tracking requirements. These are identified in Table 2. In the table, a distinction is made between governance responsibility, compilation of the information, and the source of the data.

	Governance responsibility	Information compilation	Data sources
Electricity emission factors			
NGGEF (GHG Protocol location-based factor), DGGEF	Current: DFFE *Future: DFFE (or an alternative public body aligned with governance mandates and procedures.)*	Current: DFFE *Future: The System Operator in the NTCSA would be well placed to publish the factors, if provision is made for market bids to include emissions data. Doing so would enable the System Operator to publish hourly NGGEFs in the future, should these be required.*	Current: NERSA, SAGERS, Eskom Transmission and the SAPP. *Future: Generator Bids to the System Operator, including SAPP.*
Grid residual mix emission factor (GRMEF)	Current: None *Future: To support reporting for both compliance and voluntary schemes, it is recommended that a GRMEF be added to the suite of publicly reported*	Current: None *Future: System Operator or DFFE*	Current: None *Future: Generator bids to the System Operator, including SAPP. Details of retired environmental attributes obtained from registries.*

	electricity emission factors.		
Supplier emission factors	Current: Eskom, some others. *Future: Suppliers will construct and publicise their own emission factors initially. Over time, this may require guidance / standardisation or regulation, at least for public suppliers.*		
Distribution and transmission grid loss factors	Current: DFFE *Future: DFFE (or an alternative public body aligned with governance mandates and procedures.)*	Current: Eskom Distribution and Transmission *Future: No change*	Current: Eskom Distribution and Transmission *Future: Municipalities and private Transmission / supply entities could also be considered here?*
Environmental attribute tracking infrastructure			
RECs, nuclear and gas attributes	Current: None *Future: DFFE (or an alternative public body aligned with governance mandates and procedures, potentially even a multi-departmental entity) to approve standards.*	Current: I-REC, ZAREC, I-TRACK(E) *Future: Given the ongoing expansion of standards and registries in the environmental attribute space, the simplest point of measurement may be when the electricity is injected to the grid, which is determined by the System Operator.*	Current: I-REC / ZAREC / I-TRACK(E) registries *Future: Generator bids to the System Operator, potentially including SAPP region.*
Carbon offsets	Current: NT (carbon tax) and DFFE (Art 6) list of approved standards. *Future: No change*	Current: COAS (DEE) *Future: No change*	Current: International registries *Future: No change*

Table 2 Electricity emission factor and environmental attribute reporting and tracking requirements in South Africa

6 APPENDIX

To prevent double counting of environmental attributes, a grid residual mix emission factor is calculated. This factor is applied to electricity from which the environmental attributes have been removed, commonly referred to as 'Null Power'.

While the GHG Protocol Scope 2 Guidance states that null power should be assigned the GRMEF, it does not provide a methodology for calculating it[7]. Additional guidance on this calculation has been provided by the Clean Energy Accounting Project (CEAP, 2024), using the formula:

$$\mathrm{GRMEF} = \frac{(\mathrm{E_T} - \mathrm{E_R})}{(\mathrm{MWh_T} - \mathrm{MWh_R})}$$

Where:

E_T	=	Total emissions on grid
E_R	=	Emissions associated with retired environmental attributes of electricity. If the retired attributes are associated with renewables, then $E_R = 0$.
MWh_T	=	Total MWh on the grid
MWh_R	=	Total MWh associated with the retired attributes

The variables are illustrated in Figure 7 below.

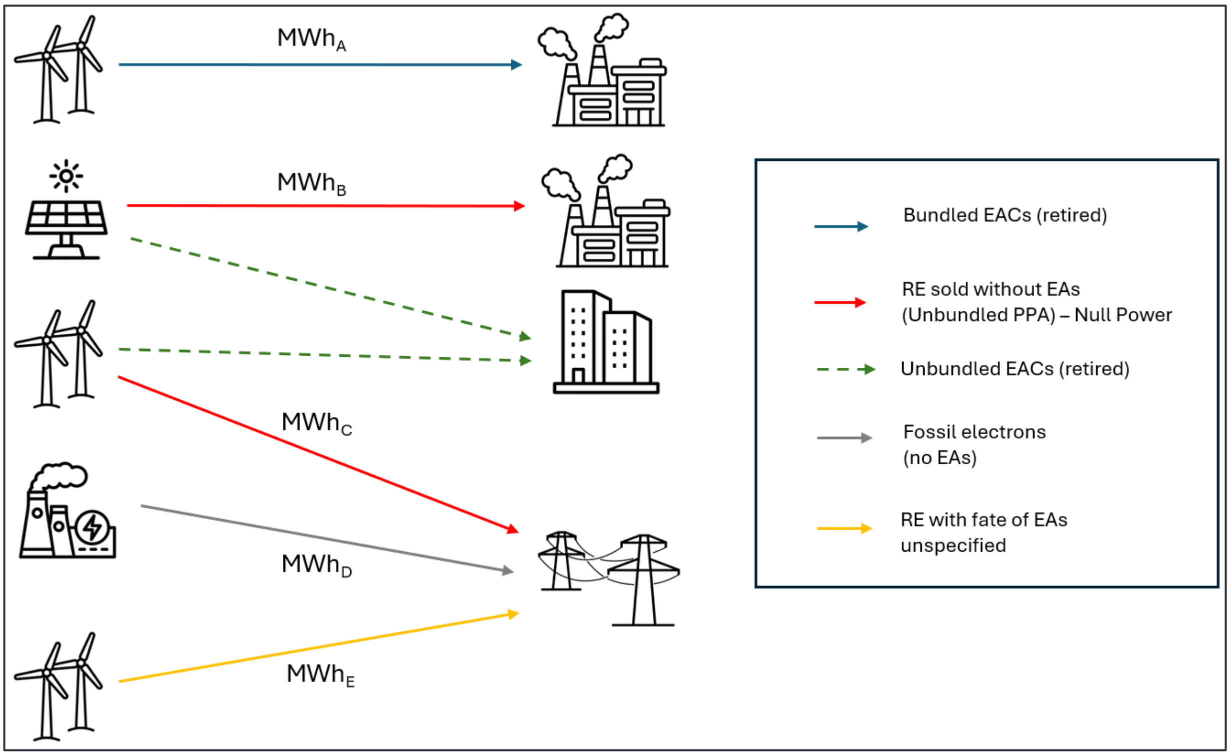

Figure 7: Various power and environmental attribute contracting arrangements

[7] *Note: The GHG Protocol Scope 2 Guidance is currently being revised. This calculation reflects the authors' best understanding at present, but it may change once the updated guidance is released.*

Here:

$MWh_T = MWh_A + MWh_B + MWh_C + MWh_D + MWh_E$

$MWh_R = MWh_A + MWh_B + MWh_C$

E_T = Emissions from the fossil generating plant

A stylised example is as follows:

Generating facility	MWh	Emissions tCO_2e
A	60,000	0
B	40,000	0
C	50,000	0
D	5,000,000	4,860,000
E	80,000	0

$$\mathrm{GRMEF} = \frac{4{,}860{,}000}{(5{,}230{,}000 - 150{,}000)}$$
$$= 0.96\ t/MWh$$

This factor is applied to any null power on the grid.

Note: A different methodology is used to calculate the residual grid factor where a Renewable Portfolio Standard (RPS) or Clean Energy Standard (CES) is in place, which is not relevant in South Africa at present.

7 REFERENCE LIST

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