Carbon footprint assessment of STELIR

A case study report

In partnership with

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About this document

This document details the findings of a carbon footprint assessment of STELIR, a large-scale blended teacher professional development programme. It summarises existing evidence on the environmental impact of different models of training, before outlining the findings of the case study and their wider implications. This report should be of interest to any stakeholder seeking to make the design and delivery of education programmes more environmentally sustainable.

Date of publication

May 2024

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Acknowledgements

We are exceptionally grateful to The British Council and the STELIR team for their invaluable support and contributions to this work.

Recommended citation

D'Rozario, J., & Barnes, K. (2024). *Carbon footprint assessment of STELIR: A case study report*. Jigsaw.

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Executive Summary

As the climate crisis becomes increasingly severe, attention is turning to how education programming could become more environmentally sustainable.

One aspect of education programming that is currently under-researched is the relative carbon footprint of face-to-face and online delivery models, a greater understanding of which could help organisations shift towards implementing increasingly sustainable programmes. This case study report examines the carbon footprint of Secondary Teachers English Language Improvement Rwanda (STELIR), a blended teacher professional programme currently being implemented by the British Council, to appraise the relative environmental impacts of different models of delivery.

Existing evidence suggests that online models of delivery are more environmentally friendly than face-to-face equivalents, in particular due to the fact that they reduce the need for travel. However, most of this evidence is not programme specific and is focused on high-income contexts (HICs), with little evidence from low- and middle-income countries (LMICs). Generating programme-specific environmental impact data from LMICs is essential to enable those working in these contexts to factor environmental sustainability into their programme decision-making.

This study outlines an exploratory methodological approach for assessing the carbon footprint of teacher professional development programmes implemented in LMICs, using STELIR as a case study. The approach involves collating specific operational data that can be combined with existing calculation tools and emissions factors to estimate the carbon footprint of different programme activities. As such, it is aimed at assessing specific programmes, a deviation from most existing methodologies and tools for carbon footprint assessments, which are focused at an organisational level.

The total estimated carbon footprint for the STELIR programme and its capital investment in hardware is 708,071 kgCO_2e. In contrast to the majority of findings in the literature, the online training component of STELIR had a higher carbon footprint than the face-to-face component, with online training constituting 48.52% of the total footprint compared to the 41.52% accounted for by in-person training. This is due to the inclusion of manufacturing emissions associated with the capital investment of new digital hardware that is purchased in order to facilitate online training. While this means the comparative findings of face-to-face and online models in this report differ from most existing studies, the inclusion of manufacturing emissions is essential to reflect the nature of education programming in LMICs specifically, where it is necessary to procure new digital hardware for implementation much more often than in HICs.

More data is needed to fully understand the significance of these case study results. The environmental impact of carbon-generating activities should be considered relative to alternatives and other impact data to better understand where opportunities to increase the environmental sustainability of programming may exist. In particular, the different benefits that can be offered by both online and face-to-face training, and their use as complementary tools, should be considered alongside environmental data when arriving at conclusions about which model of delivery is most appropriate.

It is also unclear whether the findings from this case study have wider relevance or implications for other LMICs. Therefore, it is of critical importance that LMIC-based research continues to build on this case study. When more context-specific evidence is available, decision-makers will be able to regularly and confidently determine the relative environmental impact and sustainability of different models of education delivery in LMICs.

Abbreviations and acronyms

CETT	Consultant English Teacher Trainer
CO_2e	Carbon Dioxide Equivalent (emissions)
CPD	Continued Professional Development
eTM	e-Teacher Moderators
ETT	English Teacher Trainers
FCDO	Foreign Commonwealth and Development Office
GHG	Greenhouse Gas
HCC	Humanitarian Carbon Calculator
HIC	High Income Country
LMIC	Low- and Middle-Income Country
REB	Rwanda Basic Education Board
SETT	Senior English Teacher Trainers
SBM	School-based Mentor
STELIR	Secondary Teachers English Language Improvement Rwanda
TPD	Teacher Professional Development

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1. Introduction and background

1.1 - Rationale for study

As the effects of climate change are worsening, the education sector is increasingly exploring how education programmes can both be a tool to promote environmentally sustainable and adaptive practices (such as those outlined in this FCDO position paper), and how programmes can adopt more sustainable implementation models. In line with this need to reflect on the environmental impact of education programming, the British Council is keen to explore the environmental implications of their work and how they could further promote environmentally sustainable practices.

One specific area with significant relevance to a variety of educational programmes is the relative carbon footprint of face-to-face delivery models against online or distance delivery models. However, this area is currently under-researched globally. The British Council undertakes large-scale projects focused on teacher professional development (TPD) - that offer a variety of face-to-face, online and hybrid forms of delivery. One such programme currently being implemented by the British Council under its partnership with Mastercard Foundation is the Secondary Teachers English Language Improvement Rwanda (STELIR) programme. Better understanding the relative carbon footprint of some of these approaches could help facilitate an organisational shift towards increasingly sustainable practices. The objectives of this study, as outlined in the terms of reference, are:

1. Develop an understanding of the factors that need to be considered when measuring the carbon footprint of teacher training via two modes: face-to-face and online
2. Develop a framework for measuring the impact of the two delivery modes
3. Use an existing British Council-delivered teacher development project which has a hybrid model (STELIR) to pilot the framework
4. Review the efficacy of the framework
5. Explore ways that we can reduce the carbon footprint of online training and create an action plan to achieve these
6. Identify appropriate internal and external platforms for sharing our findings to increase the sustainability of teacher development initiatives globally.

1.2 - The STELIR programme

The STELIR programme is run in partnership with the MasterCard Foundation and Rwanda Basic Education Board (REB) and aims to improve the English language proficiency of 6,000 in-service and 1,000 pre-service teachers across 14 districts in Rwanda to at least intermediate level. The three-year programme aims to increase teachers' ability to use English proficiently in their classrooms, which will contribute to the ultimate objective of improving learning opportunities for lower secondary school pupils.

At the core of STELIR's design is a three-stage language development programme (see *Figure 1* below). This is a blended English language course consisting of intensive in-person English lessons, asynchronous and synchronous online learning, and in-person continuing professional development. Teachers first undertake an Aptis English proficiency test to determine their level of English, before being offered the STELIR course at the appropriate level (A1, A2 or B1).

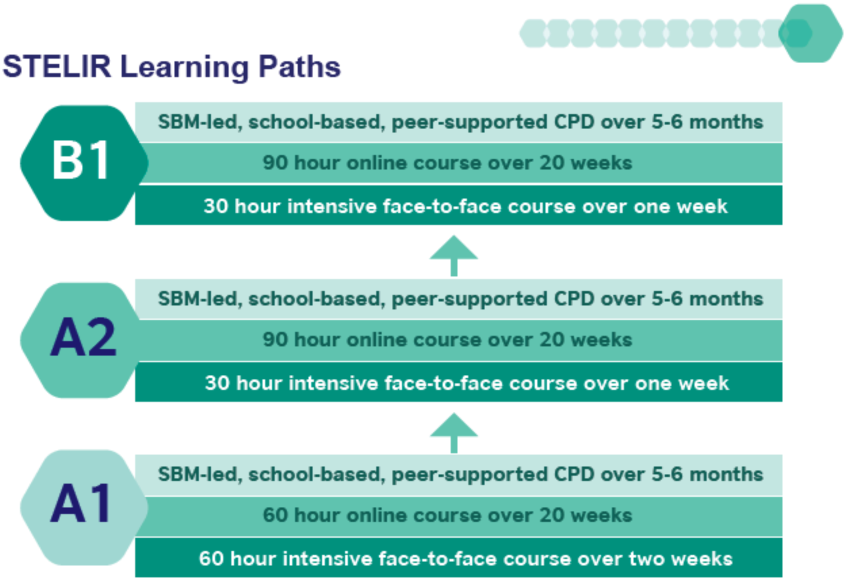

Figure 1. An overview of STELIR's three learning paths at different levels, and three stages of professional development (as shown on the STELIR website).

1.3 - Report overview

This report addresses the outlined objectives by presenting an assessment of the carbon footprint of the STELIR programme and its different modes of delivery. The report also outlines the methodological process adopted for this assessment (a framework for calculating the emissions of other TPD programmes based on this approach is discussed in more detail in a complementary report).

The report begins with a literature review of the environmental impacts of TPD as well as face-to-face and online learning, before examining the landscape of available tools and data for such assessments. An overview of the methodological process used to assess the carbon footprint of the STELIR programme is then outlined, and the results of the carbon footprint assessment are then presented. The report finishes with a discussion of the implications of the findings and methodological process for the education sector in terms of engaging with processes to better understand the environmental impact of education programming.

2. Literature review

The literature review examines existing evidence relevant to calculating and understanding the environmental impact of TPD programmes in low- and middle-income countries (LMICs).

The review is structured into four main sections:

1. Environmental impact of TPD programmes
2. Environmental impact of online and face-to-face learning modalities
3. Prioritising environmental impacts to capture within the STELIR case study
4. Effectiveness of TPD delivery modalities

2.1 - Environmental impact of TPD programmes

The literature returned no examples of work that specifically assessed the environmental impact of implementing TPD programmes. Most of the literature detailing links between the environment and TPD instead focused on how TPD programmes (usually in high-income contexts) could generate positive outcomes with regard to climate-related knowledge. For example, several studies noted that when teachers participated in professional development modules for climate education, they were themselves often highly motivated (Johnson et al., 2013) and were able to embed a deeper understanding of climate-related issues among students and instil positive attitudes towards sustainability (e.g. Drewes et al., 2017; Murphy et al. (2020)). The consensus is that high-quality TPD, focused on climate and sustainability, can be successful in delivering climate-positive outcomes amongst students and teachers.

Yet knowledge of the drivers and impacts of climate change is less relevant for students in LMIC contexts, who have little or no responsibility for causing climate change, and little agency to reduce global climate patterns through behavioural or attitudinal change. Conversely, these students are more likely to be at the forefront of experiencing some of the worst effects of climate change, meaning education around mitigating actions for climate effects that impact households and communities is likely to be particularly important. Studies from high-income counties (HICs) presented contrasting results on this issue. While some TPD courses were able to provide students with a strong understanding of mitigating actions that could be taken (e.g. Murphy et al., 2020), in cases where TPD programmes were less well designed they were less able to instigate changes in actions amongst students (e.g. Drewes et al., 2017).

A report by Rushton et al. (2023) focusing on various LMIC contexts (India, Iraq, Zambia) suggested a potential way forward for TPD to instigate actionable behaviours. For example, recognising that in Zambia TPD could be utilised to increase awareness of the impacts of climate change on local agriculture, as well as a mechanism to educate students to shift agricultural practices to mitigate these issues (Rushton et al., 2023). But most of the current evidence remains grounded in high-income contexts, and more research is needed to establish the potential of TPD to instil climate adaptive and resilient practices amongst climate-vulnerable populations in LMICs.

Examining these broader links between TPD and climate also provides useful context for assessing the carbon footprint of specific TPD programmes. TPD is seen as an imperative aspect of climate change education through its power to equip students with the knowledge to live in an increasingly climate-affected world (Rushton et al., 2023). As a result, the largest environmental benefits of TPD may result from delivering high-quality and effective TPD as opposed to implementing modalities which have the lowest carbon footprint.

2.2 - Environmental impact of online and face-to-face learning modalities

The strongest body of evidence undertaking environmental assessments of different forms of educational delivery focused on assessing the environmental impact of online modalities of teaching and learning compared to face-to-face. In particular, there has been a significant increase in literature since the onset of the Covid-19 pandemic where pivoting towards distance learning became commonplace. Almost all of the literature is focused on higher education, and assessing the environmental impact of distance and face-to-face learning opportunities at the tertiary level. While the majority of studies were focused on high-income contexts, some studies adopted a focus on LMICs incorporating a wide range of contexts, such as India (Akram et al., 2023), Turkey (Akaslan and Law, 2010), Colombia (Varón-Hoyos et al., 2021), South Africa (Brandão et al., 2015), Botswana (Modesto et al., 2019) and Indonesia (Ridhosari and Rahman, 2020).

2.2.1 - Methodological approaches used

Across the literature, there was significant variation in the approaches that were used to calculate the environmental impact of online and face-to-face learning. While some studies used pre-existing analytical tools such as a life-cycle assessment, which assesses the environmental impacts of all the inputs and outputs of a process throughout its lifecycle, (e.g. An et al., 2023) or an environmentally-extended input-output analysis, which uses consumption-based indicators (such as water usage) and financial indicators (such as raw materials purchased) to facilitate environmental accounting (e.g. Townsend and Barrett, 2015), these approaches tended to be more detailed than most studies (Filimonau et al., 2021). The approach taken for each study, in particular the approach to categorising and including different emissions, varied significantly on a contextual basis. Approaches were particularly dependent on the availability of data (e.g. Brandão et al., (2015) excluded certain categories as existing conversion factors differed significantly from the context of the study), as well as authors' own judgement around emissions that were deemed not relevant enough for inclusion, which most commonly materialised as excluding certain Scope 3 emissions (e.g. Caird et al., 2015).

This means that there was a lack of consistency in how emissions were categorised, and what drivers of emissions fell within the boundaries of assessment for each study, such as whether to include residential heating when evaluating distance learning at home (Versteijlen et al., 2017). This means that the results from studies are often not directly comparable.

Furthermore, some studies opted to focus on using reasonable estimates as opposed to exclusion where there were gaps in the data (e.g. Harlow (2016), Versteijlen et al., (2017)). Other studies did not offer detailed explanations as to how different data points were converted into carbon equivalent emissions, or how they obtained conversion figures that were used in carbon conversion calculations (e.g. Akaslan and Law (2010), Modesto et al. (2019)). All of these inconsistencies led Filimonau et al. (2021) to call for greater unity and standardisation in processes of calculating carbon footprints, in order to ensure comparability of data and facilitate the adoption of more effective methods of carbon impact assessment.

2.2.2 - Cross-study methodological consistencies

Despite these inconsistencies, there were some standardised databases and definitions of emissions that were utilised across the literature. The UK government's greenhouse gas conversion factors database was commonly cited as a key source for calculating carbon equivalent emissions (Caird et al., 2015; Filimonau et al., 2021), even when studies did not focus on the UK (Akaslan and Law, 2010), and seems to offer a comprehensive source of data for calculating the carbon footprint resulting from a wide range of inputs and activities. Additionally, most studies categorised emissions into Scopes 1, 2 and 3, using standardised definitions for each scope, even if certain emission groups were excluded contextually (see *Figure 2*).

Scope	Description	Example
Scope 1	Direct emissions from sources that are owned and controlled by the institution	Boilers, vehicles (owned by the institution)
Scope 2	Indirect emissions from the generation of the purchased electricity consumed by the institution	Purchased electricity
Scope 3	Other indirect emissions as a consequence of the activities of the institution, but occur from sources not owned or controlled by the institution	Waste, commute of students and staff, business travel, residential heating caused by studying at home

Figure 2: Definition of Scope 1, 2 and 3 emissions (taken from Versteijlen et al. (2017).

2.2.3 - Main emissions drivers from face-to-face learning

According to studies assessing face-to-face learning in higher educational institutions (particularly campus-based learning), the most significant impacts were 'Scope 3' emissions which could account for up to 80-97% of the total carbon footprint of universities (Lambrechts and Liedekerke, 2014; Versteijlen et al., 2017; Varón-Hoyos et al., 2021). In particular, emissions associated with staff and student transportation to and from campuses had a disproportionate impact, and constituted the most significant driver of carbon emissions.(Lambrechts and Liedekerke, 2014; Caird et al., 2015; Harlow, 2016; Versteijlen et al., 2017; Filimonau et al., 2021;Varón-Hoyos et al., 2021). For example at the University of Pereira in Colombia, 85.6% of Scope 3 emissions (which were 97% of total emissions) came from the travel of officials and daily commuting (Varón-Hoyos et al., 2021). The other significant drivers of carbon emissions included energy usage (Lambrechts and Liedekerke, 2014; Caird et al., 2015; Ridhosari and Rahman, 2020; Filimonau et al., 2021; Zheng et al., 2021), infrastructural development and use (Caird et al., 2015; Varón-Hoyos et al., 2021) and waste generation (Ridhosari and Rahman, 2020; Zheng et al., 2021).

2.2.4 - Main emissions drivers from online learning

With regard to online learning, it was noted that the scope 3 emissions, which are significant drivers of carbon emissions in face-to-face campus learning, could be reduced to almost zero (Filimonau et al., 2021), particularly through removing the need for daily commuting. However, it is worth noting that this conclusion was made when presenting a 'best-case' scenario (as it only included a bare minimum of at-home activities needed to make learning possible) and so may under-represent the impact of online learning (Filimonau et al., 2021). Instead, online forms of learning delivery were often associated with higher rates of energy and electricity usage being the most significant driver (e.g. Caird et al., 2015). However this notion that online learning could offer an environmentally beneficial alternative to face-to-face learning was recognised, particularly due to reduced transportation (Akaslan and Law, 2010; Versteijlen et al., 2017).

2.2.5 - Comparative environmental impacts of online and face-to-face learning

The idea that online learning is more environmentally beneficial than face-to-face alternatives was supported unanimously by studies which framed their assessments comparatively. These studies argued that utilising online learning significantly reduced the carbon footprint of teaching and learning when compared to similar face-to-face methods (Roy et al., 2007; Caird et al., 2015; Harlow, 2016; Modesto et al., 2019; Filimonau et al., 2021; Mustafa et al., 2022; Akram et al., 2023; An et al., 2023) particularly due to reductions in student travel and energy consumption. For example, Harlow (2016) found online students' total emissions were on average 72% fewer than their on-campus peers, with Caird et al. (2015) concluding that distance-based higher education models in the UK reduced the carbon footprint by 83% compared with campus-based models. The same trend was also observed in studies that specifically compared distance learning higher educational institutions to those that are campus-based (Brandão et al., 2015; Jarillo et al., 2019).

Hybrid models (incorporating both online and face-to-face learning) were also seen as leading to significant carbon reductions. An et al. (2023) demonstrated that a 46% online participation rate in workshops resulted in an 82% reduction in the carbon footprint.. Additionally, hybrid courses (where campus attendance was only part-time) reduced carbon emissions compared to full-time face-to-face courses by 61%, although this was lower than the 85% reduction resulting from entirely distance-based learning (Roy et al., 2007).

However, some authors did apply some caution to the extent to which online learning represented a more environmentally friendly alternative to face-to-face learning. Filimonau et al. (2021), while recognising a reduction in the overall carbon footprint, noted that the carbon benefits of online education can be less significant than anticipated, and blended learning may have low carbon efficiency. In addition, the use of technology in distance learning may not always be the most environmentally friendly. There are often 'rebound' effects associated with ICT-related energy consumption from online learning which has negative environmental implications (Caird et al., 2015). Additionally, e-learning offered relatively small environmental benefits compared to print-based distance learning courses due to these increased energy demands (Roy et al., 2007).

2.2.6 - Framing of findings

Several studies looked beyond just the carbon footprint of distance or face-to-face learning, and instead focused on the 'ecological footprint' (Lambrechts and Liedekerke, 2014; ; Brandão et al., 2015; Collins et al., 2018; Zheng et al., 2021; Akram et al., 2023). The ecological footprint adopted a focus on the consumption and waste of natural resources (not just greenhouse gas emissions), and so presented the findings on carbon emissions within the broader and more holistic context of the environmental impact of face-to-face and online learning.

Additionally, and perhaps more significantly, several studies also pointed to the importance of face-to-face learning in terms of delivering high-quality learning experiences and were reluctant to suggest a shift to entirely online-based forms of education due to their environmental benefits (Caird et al., 2015; Versteijlen et al., 2017; An et al., 2023; Meryem et al., 2023). Authors noted that in-person participation in learning processes should be maintained to ensure effective and high-quality learning, particularly as the social processes and effective communication which often underpin high-quality face-to-face learning experiences are not always replicable online (Versteijlen et al., 2017; An et al., 2023). Online learning was therefore not seen as something that should replace traditional face-to-face learning entirely owing to its lower carbon footprint, but instead should be promoted as a complementary learning tool to diversify learning opportunities, reduce the impact of education on the environment, and provide increased accessibility and flexibility for learning (Meryem et al., 2023).

2.3 - Prioritising environmental impacts to capture within the STELIR case study

Existing literature has pointed to four key considerations for scoping the parameters of this case study. First, the carbon footprint assessment should be tailored to the data that is available. Existing studies have used a significant variety of methodological approaches and inclusion parameters which have been heavily determined by data availability (Filimonau et al., 2021). While the methodology used in this case study was always intended to be exploratory, this suggests that a sensible focus may be to frame and present environmental impacts that TPD programmes are likely to reproduce across LMIC contexts, as opposed to developing a formulaic approach to be directly replicable. Second, scope 3 emissions are a significant contributor to carbon footprint, especially for face-to-face methods where the majority of emissions fall within scope 3 categories (e.g. Lambrechts and Liedekerke, 2014; Versteijlen et al., 2017; Varón-Hoyos et al., 2021). It is therefore imperative to include scope 3 emissions within the remit of this case study, even if using estimations. Third, the manufacturing emissions associated with new educational technologies merit inclusion. 80% of the environmental impact of handheld devices, such as tablets, result from their manufacturing and distribution (Safieddine and Nakhoul, 2016) and so it is important to capture these within carbon footprint assessments, particularly where devices are procured specifically for the purpose of delivering TPD. Lastly, obtaining accurate environmental data for the Rwandan context may be difficult. For example, the Humanitarian Carbon Calculator (which is intended for use across LMIC contexts) still relies primarily on emission factors for high-income contexts. Similar carbon footprint studies in LMIC contexts have also cited a lack of contextualised data as a significant limitation (e.g. Modesto et al., 2019). This means that this study will need to use estimations or non-contextualised data points in order to calculate emissions.

2.4 - Effectiveness of TPD delivery models

While a full review of the effectiveness of different TPD delivery modalities in LMICs is beyond the scope of this paper (see in particular Hennessy et al. (2022) and Hennessy et al. (2023) for an in-depth discussion), it is worth highlighting several key findings relating to how different TPD modalities impact the effectiveness of TPD delivery. The increasing use of technology in LMIC contexts has facilitated greater opportunities for online and distance delivery of TPD programmes. While some evidence suggests promise, results on the effectiveness of such programmes are mixed and under-researched (Hennessy et al., 2022). Yet there are clear opportunities afforded by the use of technology, for example web-based materials provide significantly greater access to teaching and learning resources, which in Rwanda was shown to increase teachers' skills and pedagogical approaches (Ndayambaje and Ngendahayo, 2014). However, some essential components of TPD often cannot be adequately replaced by technology, in particular the interpersonal dimension of teacher training and opportunities for teachers to practise learning, that are crucial to maintain its effectiveness (Hennessy et al., 2022).

Studies directly comparing face-to-face and online models of TPD have reported mixed results. Kraft et al. (2018) found similar outcomes in terms of improvements to student learning outcomes and positive changes to teachers' practices when looking at both virtual and in-person coaching. While Cilliers et al. (2022) found that both tablet-based virtual and in-person coaching were able to improve teachers' English oral language proficiency, the virtual method had a lower impact and was unable to impact reading proficiency. The authors argued this was due to the benefits of in-person contact (such as improved accountability and trust) maximising the effectiveness of the intervention (Cilliers et al., 2022). Overall, the evidence highlights a mixed picture with multiple opportunities and challenges relating to the effectiveness of online and face-to-face TPD.

Hennessy et al. (2022) suggest that in practice, the effectiveness of TPD is less dependent on its mode of delivery than other factors that impact implementation. These include macro (such as investment in education), meso (such as ICT infrastructure in schools), and micro (such as teacher motivation) level factors that influence the effectiveness of both distance and face-to-face TPD. For example, while online TPD models tend to offer flexible opportunities for participation, Widodo and Riandi (2013) found that in Indonesia, online TPD participation was significantly lower compared to in-person approaches. This was due to, in this context, low digital literacy and device accessibility being significant enough to hinder participation (Widodo and Riandi, 2013). When Hennessy et al. (2023) present a summary of characteristics that make TPD effective, none are related to mode of delivery, with the authors also recognising that these characteristics are adaptive and flexible particularly in LMIC contexts. This demonstrates that there is significant variety in terms of how different models of TPD delivery could be both effective and ineffective, depending on the context of their implementation and the quality of delivery.

3. Methodology

This section provides details of the methodological approach adopted for calculating the environmental impact of the STELIR programme.

While a high-level summary of the methods and process used can be found here, a more comprehensive description of how this approach could be used and replicated for future environmental impact calculations can be found in the calculation spreadsheet.

The research approach was divided into four phases:

1. Scoping and reviewing documentation
2. Data gathering
3. Identifying calculation tools
4. Calculating emissions

Each of these phases is described in *sections 3.1-3.4*.

3.1 - Phase 1: Scoping and reviewing documentation

To establish a basis for emissions calculations, it was important for the research team to gain a deep understanding of the STELIR programme before doing anything else - to understand its purpose, time frame, participants, and key activities. This was achieved through initial scoping discussions with the British Council team, as well as a review of available programme documents. All programme phases and activity details were entered into an activity mapping matrix.

3.2 - Phase 2: Data gathering

Based on this initial understanding of the programme, the research team made a list of all data that would be needed to calculate the emissions generated by each of its activities. This list was sent to the British Council team, and included:

- Number of participants for each phase of the programme
- Modes of transport used by participants and distances travelled
- Premises used to run the programme and their associated energy usage
- Details of accommodation and meals provided to staff and participants
- Goods and services purchased for the programme (e.g. IT equipment)

In some cases, averages and estimates had to be made. For example, as participants live in diverse locations and therefore travel varying distances using various modes of transport, the British Council team developed 'typical' journeys for different types of participants. Once received from the British Council team, all available data were added into the activity mapping matrix.

3.3 - Phase 3: Identifying calculation tools

Once it was clear which activities would need to be measured and what data was available, the research team reviewed and tested different online tools for measuring environmental impact to determine which could be used to calculate STELIR programme emissions. Tools were chosen for deeper review based on four selection criteria:

1. Being open access
2. Being designed to follow the GHG Protocol
3. Producing results in terms of carbon dioxide equivalent (CO_2e)[1]
4. Having the core aim of enabling individuals or organisations to calculate their emissions with a view to making evidence-based plans for reducing their emissions.

A summary and comparison of the three tools that were selected based on this criteria - the Humanitarian Carbon Calculator, Carbon Footprint and Our Carbon - can be found in *Table 1* on the following two pages.

Ultimately, none of the tools described below were adopted as the sole means of calculating the STELIR programme's environmental impact. This was primarily because the tools were not designed in a way that would capture all the STELIR activities for which data was available, in part because they were designed to measure the carbon footprint of either individuals or whole organisations rather than single projects.

However, a decision was made to use the same categories and emissions factors as the HCC as a starting point. The HCC provided a helpful template for organising emissions into different categories, and was the most comprehensive in terms of the types of activities and associated emissions factors that it captures. Use of the HCC was supplemented by referencing the UK Government's conversion factors 2023 and emissions factors found via Climatiq Data Explorer. This was done where the HCC did not present an emissions factor for a particular STELIR programme activity, or where a more relevant emission factor was found through the above sources.

[1] This measurement is commonly used to express a carbon footprint consisting of several greenhouse gases using a single number; the idea is to express the impact of each different greenhouse gas in terms of the amount of CO_2 that would lead to the same warming.

Tool	Emission scopes covered	Target user	Format	Date range	Free to access?	Support available	Country contextualisation	Emissions factors used	Presentation of results
The Humanitarian Carbon Calculator	1, 2, 3	Humanitarian organisations	Downloadable Excel spreadsheet	The user needs to enter annual data	Yes	Significant support material including manuals and tutorials	Yes but only for certain categories e.g. 'purchased electricity'	Various, including: - Base Carbone - ADEME - CEDA database - Ecoinvent 3.8 - GLEC framework	Detailed summary broken down by scope, category and even specific GHG. Automatically generates accompanying graphs.
Carbon Footprint	1, 2, 3	Individuals or businesses	Online form	Flexible - the user can choose to enter data for a week, month or year	Partially - free for individual carbon footprints, but calculating business and product- specific emissions requires a subscription to Sustrax MX, a premium-based carbon tracking platform	FAQ page on the website provides support by emissions category	Yes - the user can select their country to improve the accuracy of electricity emission calculations specifically, but emission factors are not available for all countries	- UK government greenhouse gas reporting: conversion factors 2023". - Defra 2017 Supply Chain factors (for individual secondary footprint) - International electricity factors	Simple summary presenting emissions for house, transport and secondary categories. Provides comparison of emissions with national and global averages.

Tool	Emission scopes covered	Target user	Format	Date range	Free to access?	Support available	Country contextualisation	Emissions factors used	Presentation of results
Our Carbon	1, 2	Small businesses	Online form	Flexible/not specified - the user enters the data for whatever period of time they have it	Yes	Downloadable user checklist and a video tutorial on the main webpage. The tool guides the user to enter data in single steps	No - only designed for UK-based businesses	- UK government greenhouse gas reporting: conversion factors 2023	Generates emissions report that can be sent via email as PDF. Breaks emissions down by scope and category.

Table 1: Comparison of online emissions calculation tools.

3.4 - Phase 4: Calculating emissions

Guided by the emissions categories used by the HCC and the UK Government conversion factors documents, the research team created a calculation spreadsheet through which to derive emissions values for different project activities. Activities were transferred from the activity mapping matrix into each emissions category tab, and columns were created in which to input the available data. Where necessary, this was converted into a different unit in order to follow the calculations and emissions factors specified by the calculation tools being used. Where exact programme data could not be provided, proxies and estimates had to be used; these were made using online searches for data from parallel contexts.

Emissions for all activities were calculated by multiplying the programme data for each activity by the emission factor identified as most closely representing that activity. For example, to calculate the emissions generated by test invigilators' journeys to and from the test centres, the total distance travelled was calculated (in km) using the average participant journeys data. This figure was then multiplied by the emissions factor identified as most closely reflecting the activity - in this case, the UK Government emissions factor for "Cars - Dual purpose 4x4 Diesel". This produced a final emissions value in $kgCO_2e$.

Finally, all emissions values were added together to produce a final figure for emissions generated across the programme. These were then separated into in-person and online stages in order to compare the emissions generated by each modality

3.5 - Limitations

It is important to be aware of several key limitations in this study, both with regard to data and methodological process:

1. There was a distinct lack of contextualised emission factors relevant to Rwanda or even LMICs more broadly. This means that calculations are likely to be situated in processes and assumptions relevant to high income country (HIC) contexts (for example, vehicle emission factors making assumptions around road quality or traffic density that generate a carbon footprint per km travelled that is more relevant to HICs).
2. There was a lack of clarity and transparency around how different organisations had calculated the emission factors used by the research team. This means it was unclear exactly what activities or processes were being accounted for within each emission factor.
3. Due to the lack of relevant data points, it was often necessary to use proxies, such as the use of an emission factor for cash assistance as a proxy for mobile money payments. Linked with the uncertainty of how emission factors have been reached, this is likely to have decreased the accuracy of calculations.
4. Programme data was not always aligned with how emission factors require data to be inputted into carbon equivalent emission conversions, such as recording the units of headphones purchased, versus the conversion requiring the total weight of headphones. This means that estimations were used to align project data to emission factors, again decreasing their accuracy (each estimation is fully outlined in the calculations spreadsheet).

5. At the time of undertaking this assessment, STELIR is only halfway through its implementation, meaning that estimates and projections (not actuals) have been used for data points for the final years of the project. Combined with the limitations of data availability and the short time span of this assessment, it is inevitable that some data points or emission-generating activities may have been missed or excluded from final calculations.
6. Due to the short time-frame of this assessment, it primarily relied on utilising primary data relating to STELIR-specific inputs and activities. The use of secondary data to map activities taking place without input from STELIR that may be relevant (such as household energy consumption for lighting rooms at home when engaging with online training) was beyond the feasibility of this case study.

Despite these limitations, the methodological process captures the most significant impacts and accounts for those with the greatest relevance to the overall carbon footprint of the programme, where data is readily available.

4. Results

This section presents the results of the carbon footprint assessment of the STELIR programme. The activities and emission categories listed are aligned to those in the activity mapping matrix, which details which particular inputs have been mapped to each programme stage. The calculations for estimating the carbon footprint of STELIR can be found in the calculations spreadsheet, which provides a full breakdown of the carbon footprint of each specific activity and input.

In the results, carbon footprint calculations are presented as the emissions of each programme-specific activity resulting from specific emission categories (see below). All results, whether aggregated or disaggregated, present a figure for emissions across the entire length of the programme. Programme activities fall into four distinct programme stages alongside a capital investment in hardware. The emissions categories that have been used in the calculations are as follows:

- **Hardware repair and manufacturing -** the emissions associated with the manufacturing of new hardware procured for the programme, including replacement devices for faulty or damaged hardware. This is presented as a 'capital investment' recognising that these devices will continue to be used beyond the lifetime of the project, but are relevant to the online components of STELIR.
- **Transportation and distribution -** the emissions associated with the movement of goods, participants and staff that are essential to the implementation of STELIR.
- **Energy usage -** the emissions associated with the electricity use at teacher training centres (TTCs) and of mobile devices (tablets, mobile phones).
- **Additional resources -** the emissions associated with the use of water at TTCs, the provision of subsistence (meals, bottled water etc.) and supplies (learning and teaching materials), and online transactions made through MTN mobile money.
- **Accommodation -** the emissions associated with the use of hotels by programme staff and dormitories by programme participants.

While the activity mapping matrix and calculation spreadsheets provide full details of each calculation, *Table 2* on the following page highlights the participant numbers that were used within calculations for each programme stage. The participant numbers used are correct as of May 2024, where 6,700 teachers were expected to be reached by the STELIR programme.

Stage	Year	Participant teachers	CETTs	ETTs	SETTs	eTMs	SBMs
Stage 1	2023	2500	8	57	8	0	0
	2024	3200	8	57	8	0	0
	2025	1000	0	57	8	0	0
Stage 2	2023	2500	0	0	0	60	0
	2024	3200	0	0	0	60	0
	2025	1000	0	0	0	60	0
Stage 3	2023	2500	0	0	0	0	936
	2024	3200	0	0	0	0	936
	2025	1000	0	0	0	0	936

Table 2: Overview of participant numbers used in carbon footprint calculations.

It should be noted that the total of 6,700 participant teachers are not all unique participants, with some participants progressing through multiple years of STELIR. Calculations are also based on the understanding that STELIR was operating in 8 districts in 2023, expanding to the full 14 districts in 2024 and 2025.

Stage	Activity	Total emissions (kgCO_2e)	
		By activity	By stage
Aptis placement testing (pre-programme)	Delivering testing (2023)	31,873	**58,376**
	Delivering testing (2024)	26,503	
Stage 1 - Intensive face-to-face training	English teacher trainer (ETT) online training	2,441	**293,990**
	On-site induction	585	
	Delivering face-to-face training	290,964	
Stage 2 - Online training	Hardware delivery	4,807	**62,600**
	e-Teacher moderator (eTM) online training	1,240	
	Delivering online training	1,142	
	Hardware return and replacement	55,411	
Stage 3 - Continuing Professional Development	School-based mentor (SBM) training	12,126	**12,126**
Hardware capital investment	Procurement and replacement	280,980	**280,980**
Total	N/A	**708,071**	

Table 3: Overview of the total carbon footprint of STELIR split by stage and activity.

Table 3 presents an overview of the total carbon footprint of the STELIR programme. In total, STELIR has a carbon footprint of 708,071 kgCO_2e, including a hardware capital investment of procuring new devices needed to operate STELIR. The Aptis placement testing, which takes place before any of the three stages of blended learning that comprise STELIR, accounts for 8.24% of the overall carbon footprint of the programme. The intensive face-to-face component (Stage 1) accounts for 41.52% of total programme emissions and represents a significant contributor to the overall carbon footprint.

The online training component (Stage 2) on its own accounts for only 8.84% of the total programme emissions. However, including the hardware capital investment that is needed to facilitate online training would mean that this stage has a slightly higher carbon footprint than face-to-face training, and would be the stage with the highest carbon footprint, representing 48.52% of total programme emissions.

The continuing professional development component (Stage 3) has a significantly lower carbon footprint by comparison to the previous two stages, constituting only 1.71% of total programme emissions. A detailed breakdown of the activities and emission categories that generate this carbon footprint at each stage of the programme is presented below, followed by a comparative analysis between the programme's stages. *Table 4* below shows the carbon footprint of each stage per participant, while *Table 5* (on the following page) provides a summary of the carbon footprint of items and activities, in order to contextualise the per participant results.

Stage	Per participant emissions (kg$C0_2$e)
Aptis placement testing (pre-programme)	8.74
Stage 1 - Intensive face-to-face training	43.88
Stage 2 - Online training	9.34
Stage 3 - Continuing Professional Development	1.81
Hardware capital investment	41.94
Total	**105.68**

Table 4: Overview of the per participant carbon footprint of STELIR split by stage.

Activity	Estimated emissions (kgCO_2e)
10 minute hot shower	2
1 serving (75g) of beef	7.7
1 hour mobile phone usage	0.17
Long-haul flight (London - New York)	900
480 km car journey	80
Fridge-Freezer A+ spec annual use	116

Table 5: A selection of carbon-generating items and activities as taken from Clever Carbon.

4.1 - Aptis placement testing

Prior to engaging with the three-stage blended learning model of STELIR, teachers are required to undertake an Aptis placement test[2] to determine which of the learning pathways they will be placed on (see *Figure 1*). The Aptis placement test takes place across the first two years of STELIR only, including 3619 participants across 8 districts in 2023 followed by 3059 participants in 6 districts in 2024. The carbon footprint associated with this process is detailed in *Figure 3* (see the following page).

The majority of emissions (71.6%) for this stage are from the transportation that teachers and invigilators use to travel to district TTCs, to undertake and oversee testing. The vast majority of the emissions categorised under 'additional resources' (19.7% of the total for this stage) are generated by MTN mobile money payments, which are made to reimburse transportation costs, further highlighting the significance of transportation in generating emissions. It is also important to highlight that while tablets are used during Aptis testing, the same tablets are used during the online training component. Therefore, all of the emissions associated with the capital investment of hardware and their manufacturing are included as part of the discussion around online training (Stage 2), as this stage encompasses the majority of their use within STELIR.

[2] The Aptis test is an assessment tool developed by the British Council to determine English language proficiency. It has five levels: A1/A2 (basic), B1/B2 (intermediate), C (proficient).

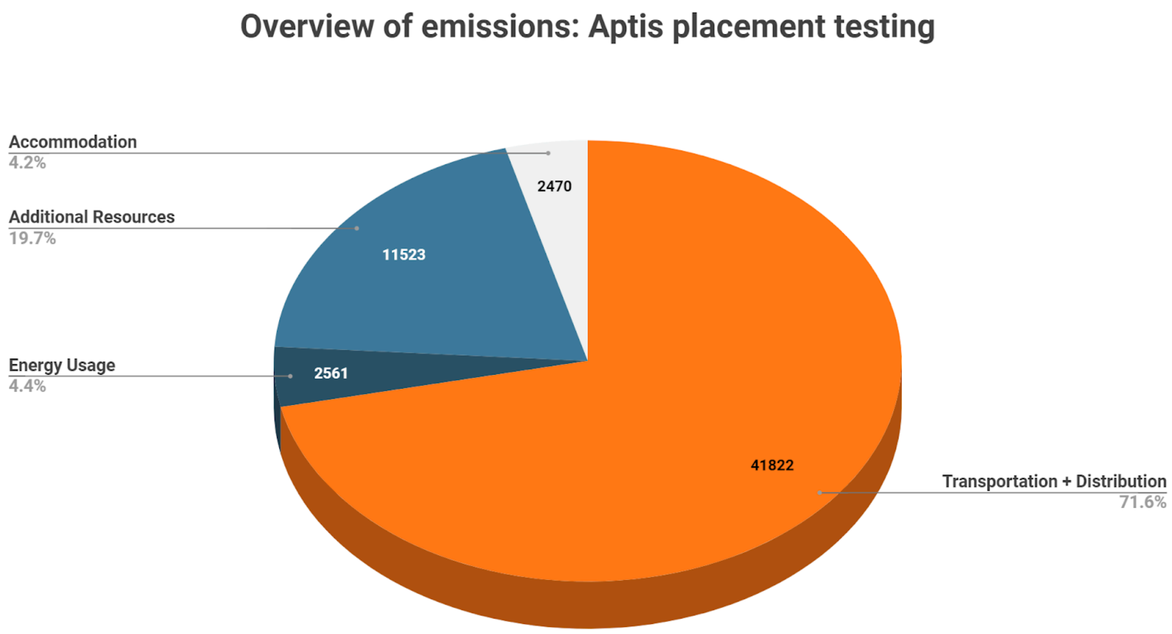

Figure 3: Overview of the carbon footprint of the Aptis placement testing stage of the STELIR programme split by emission category (showing the total emissions (kgCO_2e) for each emission category and their relative share of total emissions for the stage (%) across the entire length of STELIR).

4.2 - Stage 1: Intensive face-to-face training

During each year of STELIR, teachers undergo a stage of face-to-face intensive training, lasting for one week at the A2/B1 level and for two weeks at the A0/1 level. In each teacher training centre (TTC), intensive training lasts for two weeks (with one week courses running concurrently), meaning programme inputs and activities for face-to-face training last for a two-week duration each year. The carbon footprint associated with delivering intensive face-to-face training to 6,700 participants across the entire length of the programme is shown in *Figure 4* (on the following page).

This stage represents a significant contribution to the programme's carbon footprint. Of these emissions, the most significant contribution is from additional resources (64.7%) followed by transportation (29%). With regard to the additional resources, the vast majority of emissions are related to the provision of meals (including the fuel used to cook meals) and water, as well as MTN mobile money payments to reimburse teachers for their time spent participating in face-to-face training. A further breakdown of these additional resource emissions are provided in *Table 6* below.

Activity	Total emissions (kgC0_2e)
Water use at TTCs	874
Meal provision and waste	133,995
Cooking fuel (wood and charcoal)	23,048
Printed materials and stationary	3,802
MTN mobile money	28,558

Table 6: Additional resources from face-to-face training and their equivalent emissions.

In terms of transportation, the most significant contributions result from teachers travelling to each TTC to undertake face-to-face training, and international air travel for consultant English teacher trainers (CETTs) to support the delivery of in-person training during the first two years of the programme.

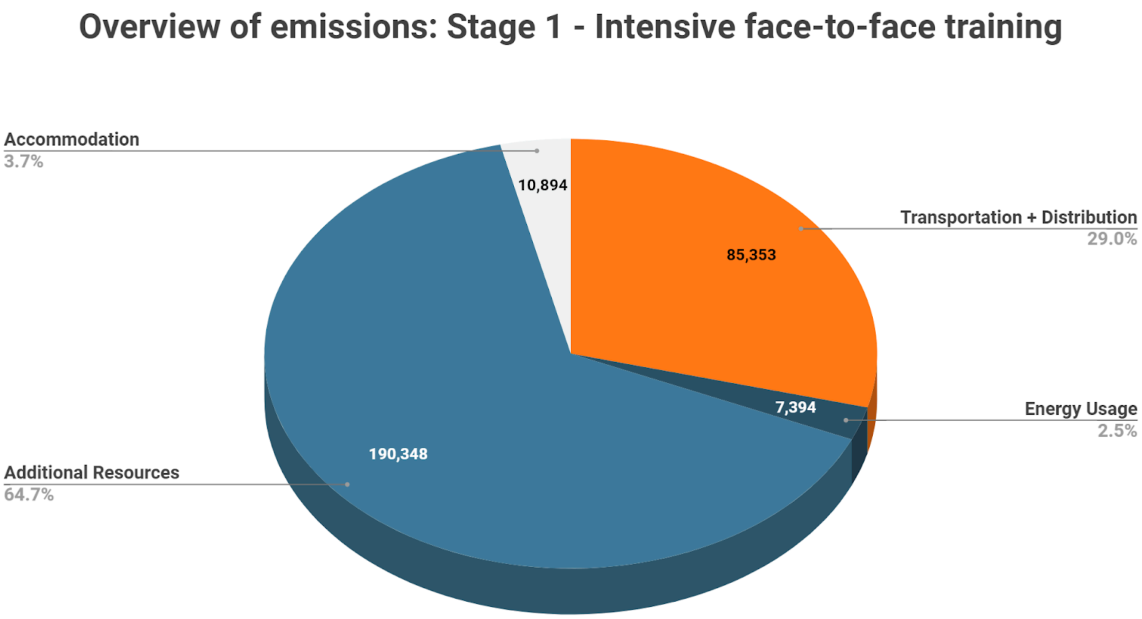

Figure 4: Overview of the carbon footprint of the intensive face-to-face training stage of the STELIR programme split by emission category (showing the total emissions (kgCO_2e) for each emission category and their relative share of total emissions for the stage (%) across the entire length of STELIR).

4.3 - Stage 2: Online training

During each year of STELIR, teachers participate in an online training component, lasting for 60 hours at the A0/1 level and 90 hours at the A2/B1 level. Each teacher is provided with a tablet in order to access the online training component. The carbon footprint associated with delivering this stage to 6,700 participants for the entire length of the programme is detailed in *Figure 5* below.

On its own, running Stage 2 online training has a carbon footprint of 62,600 kgCO_2e, representing a small contribution (8.84%) to total programme emissions. Relatively, this means Stage 2 emissions are equivalent to only 21.4% of the emissions of the face-to-face stage, a finding which is closely aligned with existing logic of online models being more environmentally friendly than face-to-face equivalents. The largest (80.1%) proportion of emissions relate to transportation and distribution, accounting for the distribution of new hardware to participants, in addition to the journeys teachers make to their district TTC in order to return hardware at the conclusion of online training.

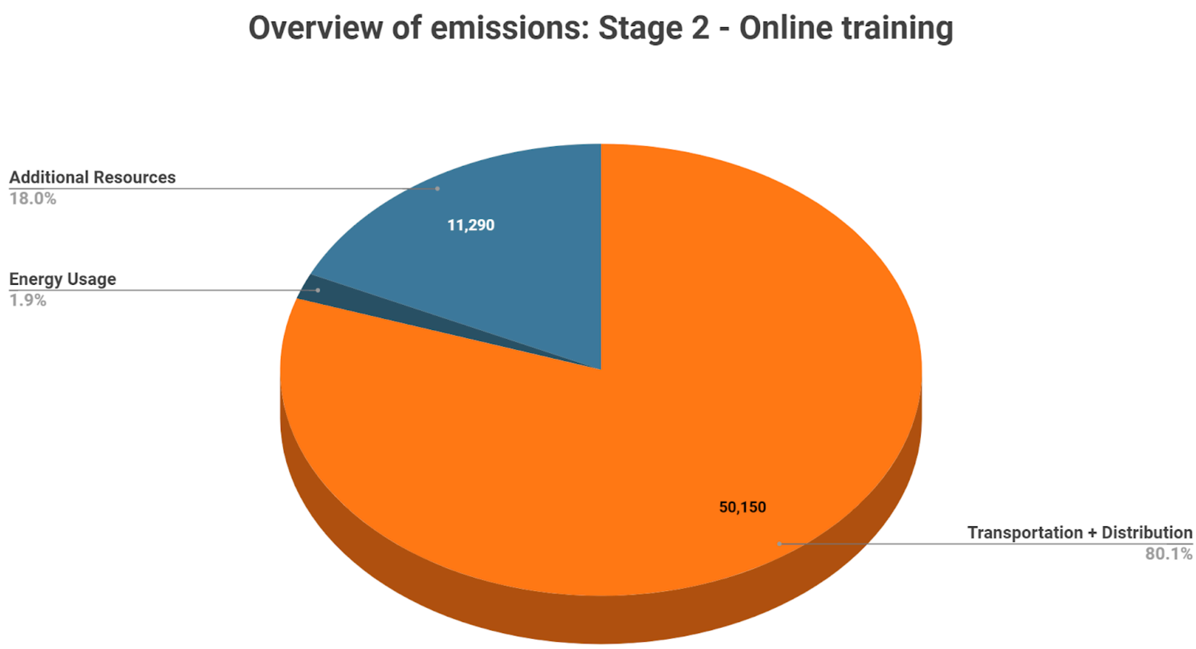

Figure 5: Overview of the carbon footprint of the online training stage of the STELIR programme split by emission category (showing the total emissions (kgCO_2e) for each emission category and their relative share of total emissions for the stage (%) across the entire length of STELIR). Note - the total emissions for energy usage not shown in the figure are 1,161kgCO_2e.

4.3.1 - Including hardware capital investment

The carbon footprint shifts dramatically when accounting for the manufacturing of new hardware that is needed to implement online training. The capital investment made by STELIR in purchasing 3,200 tablets, chargers and earphone sets, as well as any replacement items necessary, resulted in emissions of 280,980 kgCO_2e.

Adding this figure to the online training would result in emissions of 343,580 kgCO_2e, contributing nearly half (48.52%) of the total programme emissions, and would be the stage that generates the most emissions overall. The majority of these emissions (81.8%) are associated with the manufacturing of hardware, primarily tablets, that facilitate the online training. It is worth noting that this is a deviation from how most existing literature captures the carbon footprint of online learning, a full examination of which is presented below and in the discussion.

The high volume of emissions are due to the amount of hardware that is procured. Although hardware is reused each year and across programme activities (e.g. aptis placement testing), it is necessary to provide one tablet, charger and set of headphones to each participant, which in 2024 requires 3200 of each item. However, it is important to recognise that this capital investment of hardware will be used in other projects beyond the lifespan of STELIR.

This also demonstrates the significance of hardware emissions and their inclusion in shaping the results of this study. In this context, it is important to consider that education programmes that utilise technology in LMICs, like STELIR, are more likely to procure new devices in order to implement distance learning or training than programmes based in HICs where most of the existing evidence is situated. In HIC contexts, distance learning is often delivered through devices that pre-date the intervention (such as personal computers, or institutional hardware) meaning that manufacturing emissions do not fall within the inclusion parameters of their carbon footprint assessments. It is therefore important for studies from LMICs to reflect this variation in approach to technology through accounting for manufacturing emissions.

4.4 - Stage 3: Continuing professional development

After completing the online and face-to-face training components, teachers undertake five to six months of continuing professional development (CPD), led by school-based mentors (SBMs) at each school where teachers who are part of STELIR are based. The carbon footprint associated with delivering this stage to 6,700 participants across the entire length of the programme is highlighted in *Figure 6* (on the following page).

The CPD stage has the lowest carbon footprint, accounting for just 1.71% of total programme emissions. This is largely due to ongoing CPD activities being embedded within existing roles and behaviours (e.g., there is no additional travel for teachers or SBMs to take part in CPD) which significantly reduces the number of programme-specific inputs. Additionally, the total time each participant is engaged in Stage 3 training is lower than Stages 1 and 2. All of the emissions from this stage are associated with two days of training for SBMs, which takes place at district TTCs. The main contributor to emissions in Stage 3 is transportation to reach TTCs (90.3%). The provision of teaching and learning materials used in training and ongoing TPD activities, and energy consumption at TTCs also contribute to the carbon footprint.

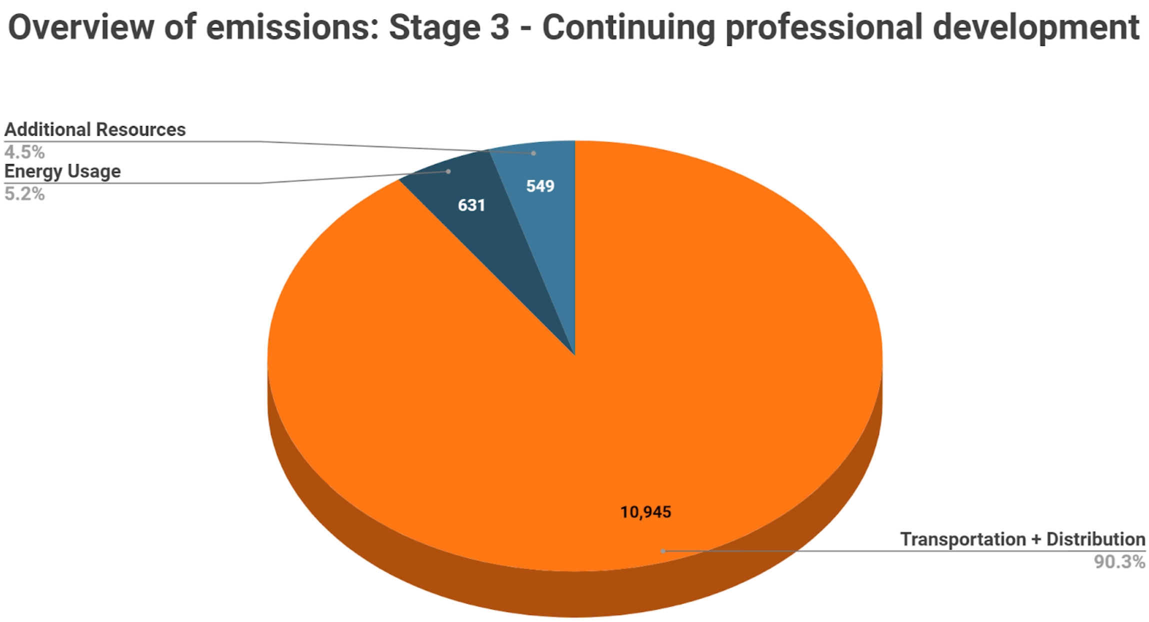

Figure 6: Overview of the carbon footprint of the continuing professional development stage of the STELIR programme split by emission category (showing the total emissions ($kgCO_2e$) for each emission category and their relative share of total emissions for the stage (%) across the whole length of STELIR).

4.5 - Comparative analysis of stages

Stage 1 (face-to-face) and Stage 2 (online) training account for 90.02% of the total carbon footprint of STELIR, when also including the capital investment of hardware. As each represents a different mode of delivery, it is worth comparing the two stages and considering how the mode of delivery impacts the carbon footprint in this context.

4.5.1 - Comparing online and face-to-face training

Comparing the online and face-to-face training components of STELIR in isolation delivers results expected in literature, that running face-to-face learning or training has a significantly greater carbon footprint relative to comparative online learning or training models (see for example Filimonau et al., 2021; Mustafa et al., 2022). However one key finding of this study - that online training has a higher carbon footprint than face-to-face training when including the impact of procuring new devices - is different from the approach and findings of most existing studies. This is due to the carbon footprint assessment for STELIR accounting for emissions associated with manufacturing new hardware (namely tablets, chargers, headphones and screen protectors).

Including these emissions as part of online training significantly increases its carbon footprint, with the manufacturing of the capital investment of hardware accounting for 81.8% of the total emissions of Stage 2. It is important to account for these manufacturing-related emissions in the context of STELIR, where new hardware is procured specifically to implement the programme. Given that 80% of the total environmental impact of tablets is accrued during manufacturing and distribution phases (Safieddine and Nakhoul, 2016), it is clear that the manufacturing of hardware should be accounted for where possible.

Furthermore, the online component of STELIR has higher than usual emissions associated with transportation when compared to other studies of online learning. This is not only due to accounting for the distribution of hardware, the inclusion of which follows the same logic as manufacturing emissions, but also due to the contextual design of the programme itself. At the end of online training, teachers are required to travel to their district TTC in order to return the hardware that is used for online learning. In effect, this means that teachers make the same journey for the online component as they do for the face-to-face component. This results in increased transportation related emissions for online training, and means that the difference in transportation emissions between face-to-face and online learning is much less than in other studies. The additional transportation emissions from face-to-face training in STELIR are almost exclusively generated by consultant-related travel, namely from international aviation and their travel within Rwanda.

Interestingly, the emissions related to energy usage are lower in online training compared to face-to-face training, which is again a deviation from much of the literature. In this context, this means that the energy used by tablets is lower than the mains and generator electricity required to operate TTCs for face-to-face training. However, it is worth noting that while household energy consumption to charge devices is included, this carbon footprint assessment does not include other energy usage indicators at a household level (e.g., the energy required to light or heat rooms in which participants are completing online training remotely) due to obtaining this kind of secondary data being beyond the feasible scope of this assessment, and so may underestimate energy consumption for the online stage. This deviation from expected results may also be due to the Rwandan context, where heating and other electricity intensive activities are much less present at an individual household level than in HIC contexts.

4.5.2 - Comparing key drivers across the whole programme

This subsection discusses the key drivers of carbon emissions across the STELIR programme beyond stages 1 and 2. The drivers discussed are:

1. Transportation related emissions
2. Accommodation and energy usage related emissions
3. Additional resource related emissions
4. Stage 3 related emissions

Transportation is a significant contributor to emissions at each stage of the programme and is responsible for 26.4% of the total carbon footprint of STELIR. As discussed above, there are potential options for reducing the carbon footprint of transportation during the online stage, although providing hardware to teachers in LMICs is more likely to necessitate a significant transport component than is suggested in the literature. Most transportation emissions at each stage are associated with participant journeys to their district TTCs, which are essential to facilitate face-to-face training and interactions. Overall, this aligns with much of the existing literature in that transportation is a significant, but necessary, aspect of delivering effective education programmes (both face-to-face and online).

However, the face-to-face stage highlights the disproportionate impact that international air travel has compared to other forms of domestic transportation. As international air travel is only undertaken by six consultant teacher trainers, reducing or removing international travel could significantly reduce transportation related emissions, without extensively altering the delivery or implementation of STELIR. For example, developing a remote alternative which allows international participation in TPD and training could reduce emissions in this context. It is worth emphasising that it is important not to interpret anything 'online' as necessarily being worse for the environment, just because in the context of STELIR the online component has a slightly higher carbon footprint in total than the face-to-face component.

Accommodation and energy usage represented a consistent but relatively low contributor to carbon emissions throughout each stage. This is perhaps most surprising for the online stage, where energy consumption may ordinarily be expected to be the most significant contributor, although in this instance this is due to certain data limitations at the household level (as discussed above). Emissions from energy usage for STELIR are also low in comparison to emissions generated by other activities, such as manufacturing of devices.

Additional resources also comprise a relatively low and consistent source of emissions across most stages, although they are a much more significant driver of face-to-face training. As discussed in the earlier results, activities accounted for under 'additional resources' include the provision of meals, the assessment of which only falls within the parameters of face-to-face training. The other 'additional resources' emissions are associated with water usage at TTCs, training materials and MTN mobile money reimbursement payments. It is worth noting that MTN mobile money payments are higher for face-to-face training (where participants are compensated for their one or two weeks of time undertaking face-to-face training, as opposed to just covering transportation costs) which further increases emissions for this stage relative to others.

Many of the emissions associated with MTN mobile money payments could also be interpreted as being related to transportation, as the payments are made to reimburse participants for their transport use. This again highlights the significance of transportation as a contributor to emissions across the programme, with its impact not being limited to transportation vehicles. But it is also important to re-emphasise the uncertainty around using an emissions factor for cash assistance as a proxy for MTN mobile money payments. This may in fact include additional activities that drive emissions, which tend to be associated with cash assistance but may not be relevant to just online transactions, overestimating the carbon contribution of mobile money payments. This underlines the importance of having contextualised emission factors and greater clarity on how they are calculated.

Stage 3 of CPD has a significantly lower carbon footprint than all of the other stages, despite being implemented over the longest period of time. This is primarily due to the CPD being implemented within existing behaviours and roles; for example, there is no need for additional transportation to a specific location for CPD as it takes place in schools where SBMs and teachers are already based as part of their regular job. It is worth noting that this may result in a slight underestimation of the carbon footprint. As this study assesses the carbon footprint of STELIR-specific activities only, regular working activities are not accounted for despite them inevitably being relevant to CPD. Taking transportation as an example, journeys between home and school are necessary for the CPD to function, but as they would take place regardless of STELIR, they are not within the parameters of this assessment. However, integrating programme activities within existing habits and behaviours more broadly is still likely to result in a lower carbon footprint overall, as there are fewer additional activities required that are likely to generate carbon emissions.

4.5.3 - Comparative impact on learning

Understanding the comparative potential carbon footprints of face-to-face and online training activities is useful for the purposes of this exercise. However, separating STELIR into its component parts is less helpful when examining its impact in terms of delivering learning outcomes. In reality, all components of STELIR are relevant to achieve any impact on learning outcomes as they are complementary elements, essential to its delivery. Therefore, it would be problematic to begin to relate specific components of STELIR, and their associated environmental data, to their impact on learning, as this would misrepresent the reality of how blended approaches to TPD impact learning in practice.

The literature also cautions against drawing strong conclusions that link different modalities, such as face-to-face and online, of TPD delivery to specific impacts on learning, particularly when integrating the use of technology (see Hennessy et al., 2022). The literature highlights that one mode of delivery of TPD,in terms of online, face-to-face or blended, is not necessarily more effective than another in LMICs, but that their effectiveness is highly contextualised and dependent upon how and where they are implemented. Therefore, strong evidence for the impact on learning outcomes delivered by STELIR is essential to fully unpack this context and understand the key factors or aspects of the programme that drive its effectiveness. This detailed understanding is essential to begin to fully and accurately explore how impact on learning may relate to environmental impact.

5. Discussion

The results and methodological process adopted by this case study have highlighted several key considerations that have implications for the broader process of engaging with environmental issues during education programming, beyond the context of the STELIR programme.

5.1 - Caution when interpreting results

It is important to recognise the limitations of this case study when considering its results, and be cautious with regard to the extent to which results should be used to alter current logic around future directions for STELIR and British Council programming more broadly. One core limitation is the narrow parameters of this assessment; it only considers STELIR specific activities and their carbon footprint as opposed to wider environmental impact data. For example, the meals that teachers would eat at home during online training are not included in the STELIR case study, yet the equivalent meals for face-to-face learning are. Other studies (e.g. Filimonau et al., 2021) that do report the equivalent meals or activities undertaken at home during online learning are therefore likely to report varying findings due to this difference in parameters.

This is not problematic or wrong, but it is a useful example to illustrate how the contextual parameters of what can be captured within a carbon footprint assessment can significantly influence results. Ultimately, this means it may be counterproductive to draw strong conclusions from a singular study, particularly when linking environmental data to decision-making processes that extend given relevant to education programming in LMICs more broadly, where the improvement of learning outcomes should arguably remain the priority objective and influence on decision-making over meeting certain environmental parameters. beyond the context of that individual programme. Results should also not be viewed as recommendations to prioritise one model of delivery over another due to their relative environmental impact, especially the effectiveness of each component of STELIR are interdependent. Given these limitations, it is important to consider any data relating to the carbon footprint of STELIR relative to other forms of impact or outcome data. This logic is particularly relevant to education programming in LMICs more broadly, where the improvement of learning outcomes should arguably remain the priority objective and influence on decision-making over meeting certain environmental parameters.

Instead, the results should be interpreted as an informative guide to provide understanding and accountability with regard to environmental impact. The results present an indicative carbon footprint for different activities and implementation models of TPD programmes in LMICs. Ultimately, once supported by additional data, this will allow environmental impact data to begin to inform decision-making with regard to programming sustainability, and be an increasing part of those discussions moving forward.

5.2 - Accounting for hardware

The results of the STELIR programme highlight the significant emissions associated with the manufacture of new devices. It is important to account for this impact, especially in LMICs where online forms of educational delivery are usually reliant on the procurement of new technologies. Yet accounting for all of the manufacturing emissions associated with each item of hardware may overestimate the carbon impact for one intervention, and underestimate it for another.

In the case of STELIR, the tablets used in the programme are later given to the Rwanda Basic Education Board (REB) to be used in additional initiatives, meaning the lifetime of each device is longer than the STELIR programme. However, 100% of the manufacturing emissions for each device have been included as a capital investment in the calculation of STELIR's carbon footprint, even though 100% of the device lifetime is not spent on the programme. This has important implications for the replicability and comparability of results. If the British Council were to implement another education programme after STELIR, and use the same devices, then the manufacturing emissions would either be zero (as they have already been accounted for in the STELIR assessment) or duplicated (captured again in their entirety), neither of which gives a truly accurate reflection of their environmental impact. Spreading emissions across the expected lifetime of a device - so for example 50% of manufacturing emissions are included if a device spends 50% of its estimated lifespan on a project - may be a way to mitigate this variance. For this study capturing all manufacturing emissions is considered a sensible starting point given the uncertainty around future device usage, however, it is important to be aware of the limitations of this approach and to recognise that the more usage data is available in future, the more accurate assessments will be.

5.3 - Implications of online learning in LMICs

The results of this case study highlight that online training or learning in LMICs may entail a more significant carbon footprint than face-to-face methods, which is a deviation from the prevailing logic espoused in most literature. As mentioned above, this is primarily due to the introduction of new hardware into online learning or training in LMIC contexts. This suggests that programme implementers could make changes to how hardware is organised and distributed at the participant level, to reduce the volume of hardware that is procured and the associated manufacturing emissions. For example, STELIR may consider implementing distance learning using existing technologies, such as mobile phones at the household level, or via device sharing, with multiple teachers at one school using a shared tablet instead of being given one each. These changes could significantly reduce the environmental impact of online learning.

However, it is important to reiterate here that these decisions should not be based primarily on environmental impact assessments. It is important to first consider how changing the arrangement of technology within an intervention could positively impact learning outcomes as the priority. Additionally, altering the design of a programme based on manufacturing emissions alone which, as explained elsewhere, could be misleading to take at face value, may not represent the best course of action. Nonetheless, any opportunities to reduce the volume of new hardware that is procured, without impacting learning, merit consideration as a potential way to reduce the environmental impact of online programming.

Additionally, evidence (see for example Hennessy et al., 2022) suggests that the utilisation or arrangement of technology is perhaps less likely to alter the impact of TPD programmes on learning outcomes when compared to other contextual factors, such as teacher motivation or accessibility of training. Well designed programmes that appropriately consider and address the multitude of factors that impact TPD may have greater scope to experiment with technological arrangements that could be more environmentally beneficial, assuming this doesn't significantly alter other factors. As more evidence on the environmental impact of TPD and other educational programmes in LMICs begins to emerge, it will be interesting to examine whether the prevailing logic around the relative environmental impacts of face-to-face and online modalities begins to change.

5.4 - Consideration of activities in isolation

There is value in considering the carbon footprint of programmes and their specific activities relative to a benchmark, rather than in isolation. Just because a programme activity has a carbon footprint, it does not necessarily mean that it has an overall negative environmental impact. In this regard, it is important to be attentive to the limited parameters of a carbon footprint assessment, in that they are solely focused on reporting the impact of programme specific inputs and activities that generate quantifiable carbon emissions. However, this provides an incomplete understanding of how a programme may deliver a 'net impact' on the environment more widely, which requires the consideration of the carbon footprint data relative to what is not implemented by a programme in order to contextualise the findings.

In particular, carbon footprint assessments are largely presented and interpreted as an 'additional impact' relative to a baseline scenario of zero emissions (i.e. the programme 'generated' a certain volume of carbon emissions). Yet to more accurately understand the extent or significance of programme-related emissions, it is important to think about their impact relative to a business-as-usual scenario if that programme were not in place, as opposed to zero. This is an important deviation from the literature that, when comparing and contrasting carbon footprints, has tended to only compare different forms of implementation, such as face-to-face and online learning.

Take two examples from the STELIR case study: the transportation and meal provision emissions of delivering Stage 1 (face-to-face training). The carbon footprint of activities to provide meals to teachers and trainers during face-to-face training is included in the carbon footprint assessment. However, these calculations do not factor in the emissions that are reduced or 'saved' from the meal that each participant would otherwise be eating in a scenario where they are not participating in face-to-face training. This means that the carbon footprint of meal provision may be misinterpreted as a significant contributor or addition to carbon emissions when considered in isolation relative to a 'zero emissions' baseline.

However, this does not account for how the provision of meals through STELIR compares to a business-as-usual scenario, which would naturally entail a level of carbon footprint. There is a logical argument to suggest that, if 200 teachers were in one TTC for face-to-face training, then centralising and providing 200 meals in one location, as opposed to 200 separate households which would be the case in the business-as-usual scenario, may actually be more efficient and environmentally beneficial if at least some of these teachers live alone. In this instance, the carbon footprint of STELIR activities that provide meals may actually be a net positive impact, relative to the alternative business-as-usual scenario, despite in isolation having a relatively high carbon footprint. While the challenge of calculating business-as-usual emissions has meant that comparing these with STELIR emissions has not been possible here, this logic suggests that an interesting long-term aim for these kinds of assessments could be for calculations to consider their impact relative to the business-as-usual scenario.

This being said, assuming a baseline scenario of zero emissions is not always flawed. Using the second example of transportation emissions for this stage of training, it is likely that these, or any equivalent, journeys to facilitate face-to-face training would not be taking place without the requirement of STELIR. In this context, comparison to a baseline scenario of zero emissions is close to the reality, as it reflects that these specific activities are truly 'additional' impacts compared to the business-as-usual scenario. In essence, this highlights the complexity of interpreting data from this carbon footprint assessment and the need to exercise caution when drawing conclusions. Moving forward, consistently comparing carbon footprints and other environmental impact data to business-as-usual scenarios would help improve understanding around where programme activities are generating significant additional negative environmental impacts, or where they may be generating positive environmental impacts. This is difficult, as this kind of nuanced and context-dependent comparative analysis inevitably relies on significantly more data being available than is the case currently.

5.5 - Significance of results for Rwanda

Rwanda's Vision 2050 outlines its commitment to sustainability, through being "a nation that has a clean and healthy environment that is resilient to climate variability and change". Central to achieving this aim is linking national strategic policy agendas across a range of sectors, including education. While Rwanda does not have a specific national policy for environmental education at the moment, the National Environment and Climate Change Policy recognises the need to integrate climate into education to continue to promote awareness of environmental issues with Rwandan citizens (GEEP, 2024).

In the context of STELIR, which is implemented in partnership with the REB, it is important to consider how results from the carbon footprint assessment could help align with these broader national-level policies. At the government level, it is clear that Rwanda is attempting to promote sustainability across multiple sectors. Presenting findings on the carbon footprint of the STELIR programme may represent a helpful data point for the Rwandan Ministry of Education, and government more broadly, to make decisions to further integrate this vision of sustainability within its education programming.

5.6 - Future study implications

Reflecting on the methodological process undertaken for this study highlights several useful findings which have broader relevance. Due to the data and methodological limitations highlighted earlier, this study is by no means claiming to be an all-encompassing assessment. But it is also worth considering the trade-off in terms of what a carbon footprint assessment of this scale can deliver versus a more comprehensive but resource-intensive carbon footprint assessment.

It could be argued that low-intensity approaches are preferable to high-intensity ones in the context of education programming. While a more intensive assessment may deliver greater accuracy in its results, a low intensity approach can still provide reasonable emission estimates, and can indicate how these are distributed across programme components and activities. The extra accuracy afforded by an intensive approach is unlikely to significantly change how decision-makers understand the overall size and distribution of emissions, and opting for a high-intensity approach may result in organisations having to divert additional resources from primary educational objectives. This case study and accompanying methodological framework can serve as an outline for a low-intensity approach to assessing environmental impact in the context of education programming in LMICs. While recognising that this is far from an exhaustive approach to capturing carbon emissions, it is hoped that it contributes to a much longer-term ambition across the education sector to engage more seriously with environmental issues.

6. Conclusion

This case study emphasises that the relationship between face-to-face and online educational activities and the environment is more complex and nuanced than is often presented.

The main finding, that online training can have a higher carbon footprint than face-to-face training, contradicts the prevailing logic that online modes of delivery have a lower environmental impact. This finding is derived from the inclusion of manufacturing emissions associated with a capital investment of digital hardware, within calculations for online learning. While removing the emissions of this capital investment would align the findings of the relative environmental impact of online and face-to-face training much more closely with existing literature, it is important to include them here as a reflection of the realities of education programming in LMICs, where the procurement of new digital hardware to facilitate implementation is more likely to be necessary than in HICs.

However, caution should be exercised when interpreting these results. While this case study report presents the estimated carbon footprint of STELIR, additional data is needed to correlate these results with both outcome data and business-as-usual scenarios in order to determine the relative significance of the environmental data for each activity. Data-related and methodological limitations also mean that there is uncertainty as to the accuracy of some calculations, and the degree of applicability and relevance of findings beyond the STELIR context. It is also imperative that further evidence begins to emerge from other LMICs before assertions around the relative environmental implications of different training delivery models in LMICs can be made.

Nonetheless, this case study represents a useful reference point for beginning to engage with the environmental impact of education programming in LMICs in a more systematic and rigorous way. This report furthers the conversation around how carbon footprint assessments could be better tailored towards measurement at the programme level, as opposed to at organisational level. The outline of this case study represents a suggestion for a relatively low-intensity approach to measuring the environmental impact of educational programming, which may be better suited to LMICs.