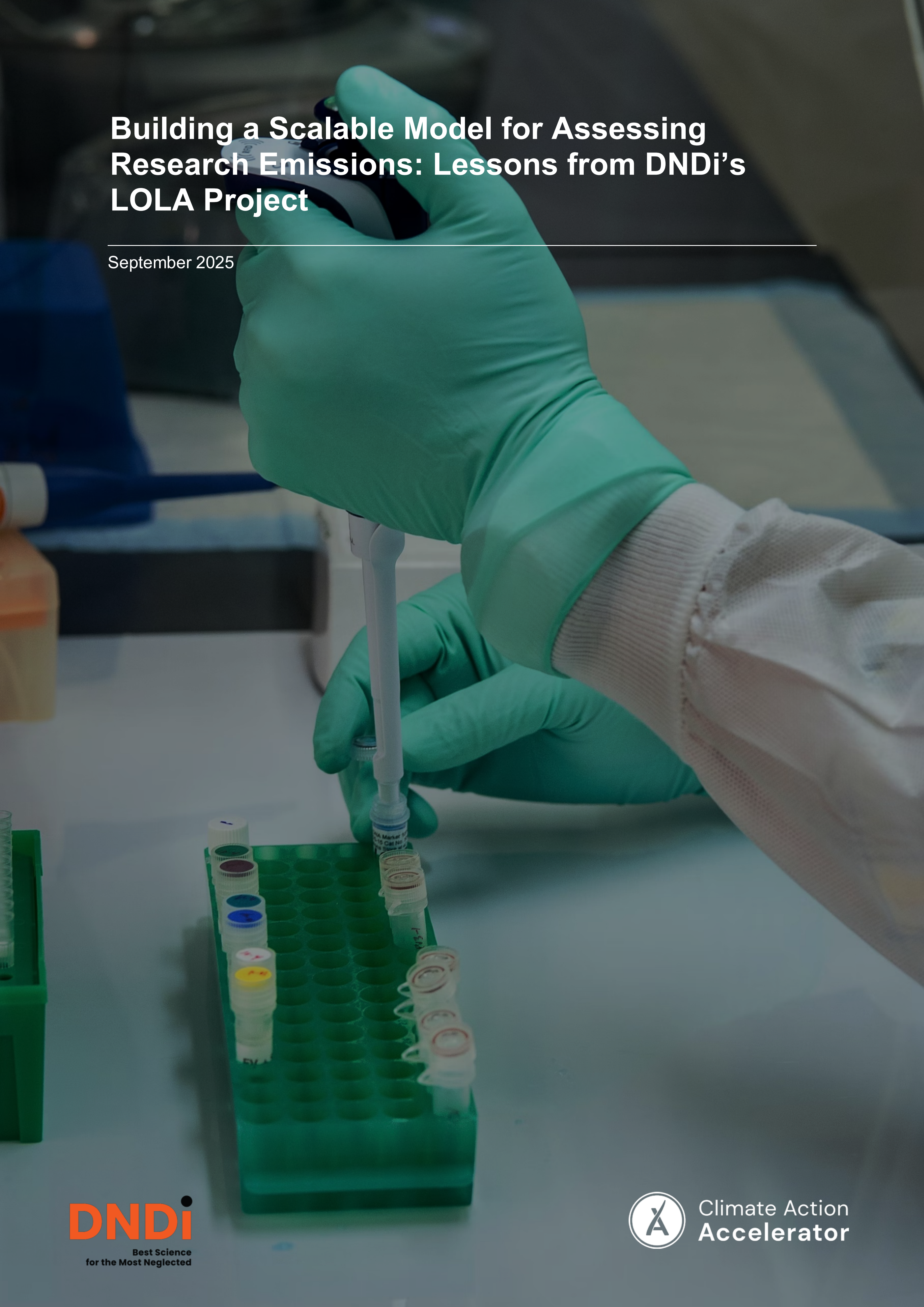

Building a Scalable Model for Assessing Research Emissions: Lessons from DNDi's LOLA Project

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DNDi
Best Science
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TITLE	Building a Scalable Model for Assessing Research Emissions: Lessons from DNDi's LOLA Project
ABSTRACT	This report presents a simplified Life Cycle Carbon Assessment of "LOLA" (Lead Optimization Latin America), an early-stage drug discovery research project led by DNDi and conducted in Brazil. Unlike industrial activities with significant material flows, early-stage research projects are predominantly intellectual in nature and at a small scale. They are, therefore, often overlooked in conventional environmental accounting. Using data from 2023 and a functional phase-based approach, this study estimates the total greenhouse gas emissions of the project at approximately 25 tCO_2e over a 12-month period. The primary sources of emissions are energy consumption (48%) and commuting (20%), followed by material inputs, travel, and data management usage. Despite relying on assumptions due to limited primary data, this analysis demonstrates that even research activities with low material intensity carry a measurable environmental footprint. More importantly, it provides a replicable framework for identifying actionable levers such as energy efficiency improvements and low-carbon mobility strategies. While not a full ISO-compliant life cycle assessment, the methodology offers operational insights and strategic value for DNDi and other public interest research actors seeking to make their R&D portfolios sustainable. This case study illustrates the importance of developing tailored tools for decarbonising the knowledge economy, especially in under-resourced or distributed research contexts.
KEY WORDS	Life Cycle Assessment, Research sustainability, Global health, Climate impact, Carbon footprint, Early-stage R&D, Low-carbon research, DNDi, Environmental accountability
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1. Foreword

This report presents an initial assessment of the carbon emissions associated with the Lead Optimization Latin America (LOLA) research project, a "hit to lead" initiative led by the Drugs for Neglected Diseases initiative (DNDi) based in Brazil. DNDi is a not-for-profit research and development organisation that addresses the needs of vulnerable populations by developing treatments for neglected diseases. The study, which leverages data collected in 2023, aims to provide a deep dive into estimating the project's potential CO_2 emissions. This work has been conducted by the Climate Action Accelerator (CAA), a non-profit initiative that partners with organisations to catalyse emissions reductions and promote sustainable transformations. Together, in collaboration with DNDi, we have undertaken this analysis to better understand the environmental footprint of early-stage research activities[1]. While the analysis follows the broad principles of a life cycle assessment (LCA), it is important to note that it does not meet the rigorous standards typically expected of a formal LCA. Due to the limited availability of data, numerous assumptions and estimations were made to approximate figures, which inherently limits the precision of the results. Nevertheless, this assessment provides valuable insights and serves as a starting point for understanding the environmental impact of research projects within the health sector. The primary aim of this work is to provide operational insights into the distribution and magnitude of carbon impacts within research projects, enabling a clearer understanding of where emissions are concentrated. Ultimately, the findings from this assessment can be used to define a generalised model that could be extrapolated to DNDi's wider discovery portfolio. This approach allows for a more nuanced estimation of the carbon footprint of research activities compared to the purely financial-based methods that have been predominantly used to date. By developing a more refined understanding of these impacts, this report seeks to support DNDi in integrating sustainability considerations into their research strategy and decision-making processes.

2. Presentation of the LOLA project

The LOLA project is an initiative spearheaded by DNDi to bolster research on neglected diseases in Latin America, with a focus on Chagas disease and leishmaniasis. By fostering collaboration between local and international researchers, the project leverages regional expertise and infrastructure to advance the development of new treatments. This study takes place in Brazilian laboratories where the facilities are not exclusively dedicated to this project. The liaison between the LOLA project and these laboratories was maintained by Luiza Cruz, Discovery Manager at DNDi Latin America. The following graphic illustrates the key elementary processes involved in the LOLA project. This visual representation provides a simplified overview of the various stages in the drug discovery pipeline.

[1] (The Climate Action Accelerator & DNDi, 2023)

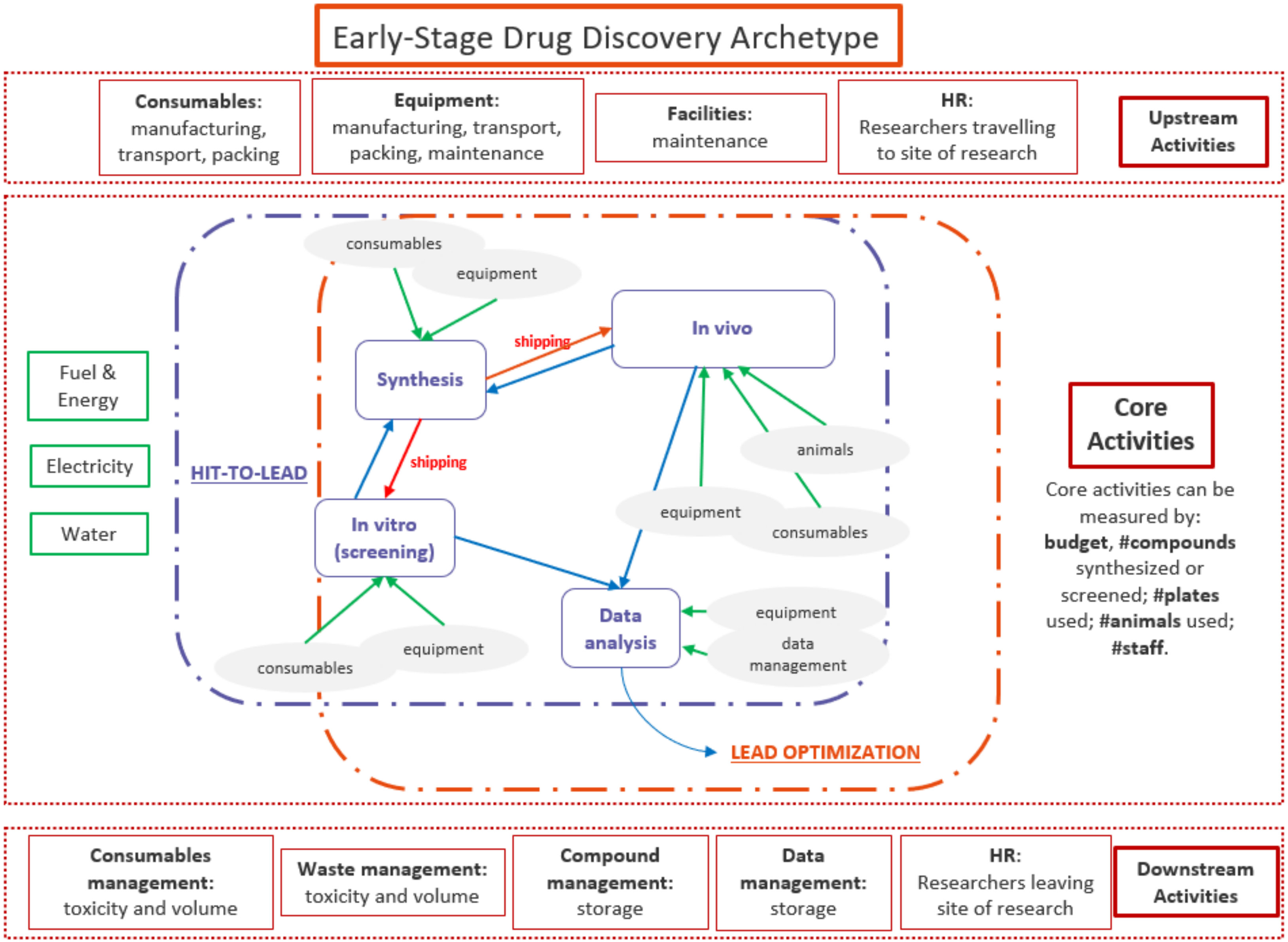

Figure 1: Process mapping of LOLA project (H2L)

3. Impact assessment approach

The impact analysis for the LOLA project is structured into several sections, reflecting the different stages of a typical "hit to lead" research project. The assessment considers all LOLA project activities in 2023 and focuses on five main phases: (1) the synthesis phase, where chemical compounds are produced; (2) the outbound transportation phase, during which synthesised products are shipped to external laboratories; (3) the in vitro testing phase; (4) the in vivo testing phase; and (5) a transversal phase that encompasses activities such as conference travel, data management, and laboratory waste management. This structure aims to provide a clear view of how emissions are distributed across each research stage.

3.1. Synthesis

During the synthesis phase, five main sources of carbon emissions have been identified. The first source relates to the procurement of raw materials, followed by emissions from the transportation of these materials to the research facilities. The third source is energy consumption within the research offices, while the fourth is linked to researchers' commuting. The final source of emissions is attributed to liquid waste generated during synthesis activities. Some potential emissions, such as greenhouse gas releases during chemical reactions or from capital goods (e.g., computers, office supplies), have not been included due to a lack of data. However, we have estimated that their impact is negligible.

3.1.1 Raw materials

Approximately 1 000 kg of raw materials were purchased for use during the synthesis phase, according to the information given on solvent waste. Given that the project involves organic chemistry, it was assumed that these 1 000 kg correspond to the following chemicals: 300 kg of ethanol, 600 kg of hydrochloric acid, and 100 kg of sodium sulfate. Although many other chemicals may have been used, these specific compounds are representative of the complexity and density of the main research products.

The environmental impact of these raw materials was estimated using emission factors from the ecoinvent 3.10 database[2].

Item	Quantity	Unit	Impact Factor	Source
Ethanol, C2H6O5	300	Kg	ethanol, without water, in 99.7% solution state, from ethylene, GLO	ecoinvent 3.10
Sodium sulfate Na2SO4	100	Kg	sodium sulfate, anhydrite, GLO	ecoinvent 3.10
Hydrochloric acid, HCl	600	Kg	hydrochloric acid, without water, in 30% solution state, GLO	ecoinvent 3.10

GLO: Geography code that stands for Global, representing the average production of a product across the world

[2] (Wernet et al., 2016)

The climate change impact of the raw materials was estimated at 1 154 kgCO_2e. Due to ecoinvent licensing restrictions, a breakdown of the detailed results cannot be shared within this document.

3.1.2 Transportation

Two transport scenarios were developed to evaluate the carbon emissions related to raw material deliveries. For the local transportation scenario, it was assumed that 85 out of the 97 shipments were sourced within Brazil. An average truck transportation distance of 120 km was considered, reflecting the typical proximity of suppliers to the project's location.

For the international transportation scenario, it was assumed that 12 shipments came from Europe or North America. This scenario included a 10 000 km distance by air and an additional 80 km by truck (40 km at each end, between suppliers or destination and the airports).

These scenarios were multiplied by the total weight of 1 000 kg of materials to yield 115 t.km by truck and 1 237 t.km by air.

These two scenarios give a reasonable approximation of the transport routes, given the uncertainties surrounding the exact origins of some of the shipments. All calculations were performed using relevant ecoinvent 3.10 emission factors[3].

Item	Quantity	Unit	Impact Factor	Source
Airplane transportation	1 237	t.km	transport, freight, aircraft, belly-freight, long haul, GLO	ecoinvent 3.10
Truck transportation	115	t.km	transport, freight, lorry, unspecified, GLO	ecoinvent 3.10

GLO: General Load Operator

The climate change impact of the transportation for the raw materials was estimated at 1 069 kgCO_2e. This value represents the emissions resulting from both local and international transport scenarios, considering the specific distances and shipment weights detailed earlier. Due to ecoinvent licensing restrictions, a breakdown of the detailed results cannot be shared within this document.

3.1.3 Energy

To estimate the energy impacts of the synthesis phase, it was assumed that energy consumption was exclusively linked to office activities, as the scale of the synthesis work did not necessitate dedicated equipment with exceptional energy requirements. Without exact consumption data, the estimations are based on the average annual electricity consumption per employee in the services sector, as provided by an Odyssee-Mure[4] study. Given the climatic similarities[5], Cyprus' average consumption of 6 017 kWh/Full-Time Equivalents (FTE)

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[3] (Wernet et al., 2016)
[4] (*Energy Consumption per Employee in EU Countries | ODYSSEE-MURE*, n.d.)
[5] (*World Bank Climate Change Knowledge Portal*, n.d.-b)

in 2021 was used as a proxy for São Paulo's conditions. With four FTEs dedicated to the synthesis phase, the total estimated energy consumption amounted to 24 068 kWh.

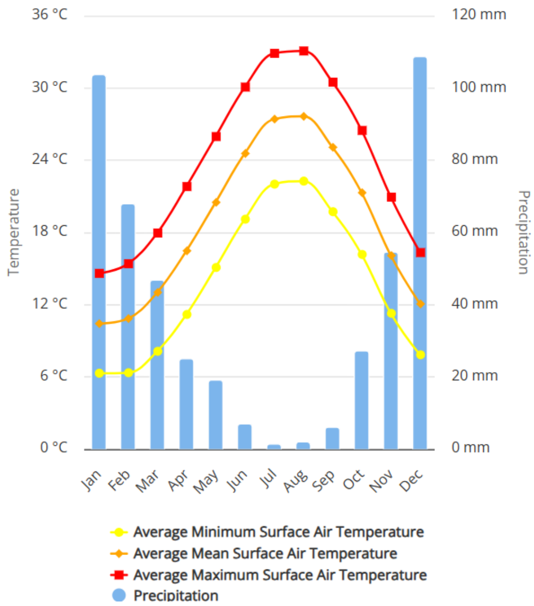


Figure 2: Monthly Climatology of Average Minimum Surface Air Temperature, Average Mean Surface Air Temperature, Average Maximum Air Temperature & Precipitation 1991-2020; Cyprus; World Bank Climate Change Knowledge Portal

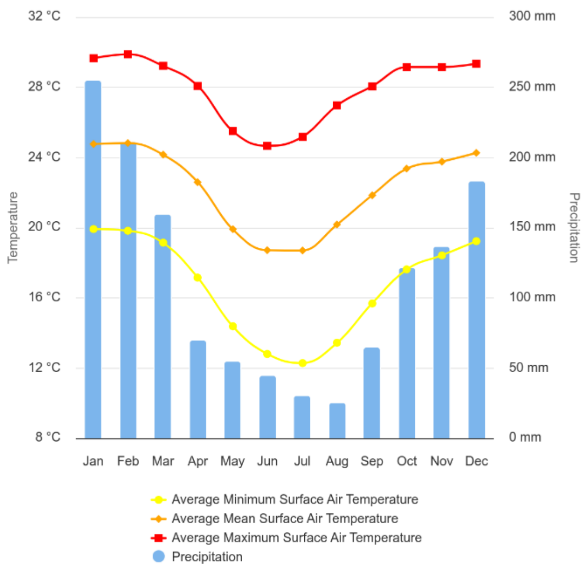


Figure 3: Monthly Climatology of Average Minimum Surface Air Temperature, Average Mean Surface Air Temperature, Average Maximum Air Temperature & Precipitation 1991-2022; Sao Paulo, Brazil; World Bank Climate Change Knowledge Portal

Although the seasons differ significantly between São Paulo and Cyprus, as displayed in Figures 2 and 3, with São Paulo characterised by a hot and humid climate while Cyprus experiences hot and dry summers and cold, dry winters, the energy needs for heating and cooling in these climates appear to be somewhat equivalent. In São Paulo, the high humidity levels necessitate significant energy consumption for cooling, especially during the summer months. Conversely, in Cyprus, while the summers demand substantial energy for cooling due to high temperatures, the colder winter months require heating, contributing to an estimated comparable overall energy demand.

Item	Quantity	Unit	Impact Factor	Source
kWh, Brazil	24 068	kWh	electricity, low voltage, BR	ecoinvent 3.10

The climate change impact associated with energy consumption for the synthesis phase was estimated at 5 939 kgCO_2e. Due to ecoinvent licensing restrictions, a breakdown of the detailed results cannot be shared within this document.

3.1.4. Commuting

Four full-time employees worked on the project in 2023. Assuming an effective working year of 220 days with work conducted entirely on-site, this resulted in 440 round trips between home and the laboratory. In the context of São Paulo, an average distance of 5 kilometers was estimated for these trips. Given Brazil's socioeconomic situation, it was hypothesised that 70% of the distance was travelled by private car, 15% by public transport (likely bus), and 15% via light transport, such as walking or cycling. It is important to note that these commuting assumptions are intuitive and have not been verified with the LOLA project teams. Therefore, the results derived from these estimations should be interpreted with caution, as they may not accurately reflect the actual commuting patterns of the project staff.

Based on these assumptions, a total distance of 6 160 km was travelled by car, 1 320 km by bus, and 1 320 km by walking or cycling in 2023.

Item	Quantity	Unit	Impact Factor	Source
kilometers, private car	6 160	km	transport, passenger car, RoW	ecoinvent 3.10
kilometers, local bus	1 320	km	transport, regular bus, RoW	ecoinvent 3.10
kilometers, bike	1 320	km	negligible[6]	

RoW: Rest of the World

This commuting analysis lead to an estimated climate change impact of 2 431 kgCO_2e. Due to ecoinvent licensing restrictions, a breakdown of the detailed results cannot be shared within this document.

3.1.5 Waste

It was reported that approximately 1 000 kg of liquid waste were generated from the synthesis activities. In the absence of a specific impact factor for pharmaceutical waste water treatment, the factor from oil refinery wastewater treatment was chosen, which has the highest TOC (Total Organic Carbon) rate of 10,783 kg/m³. TOC is a measure of the organic compounds present in water, indicating the potential for environmental impact due to the presence of pollutants. This choice assumes that the solvents used in the synthesis process could yield similar environmental impacts.

Item	Quantity	Unit	Impact Factor	Source
Wastewater	1 000	Kg	treatment of wastewater from vegetable oil refinery, wastewater treatment, GLO	ecoinvent 3.10

GLO: General Load Operator

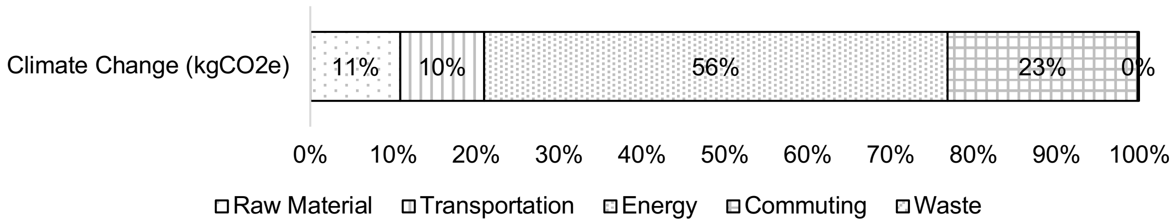
The analysis of liquid waste generated from the synthesis activities leads to an estimated climate change impact of 21 kgCO_2e.

3.1.6 Total for synthesis

The synthesis phase was estimated to have a total climate change impact of 10 615 kgCO_2e, primarily driven by energy consumption, which accounts for 56% of the total emissions. Commuting contributes 23%, while raw materials represent 11%. 10% is attributed to transport, and the impact of waste is less than 1%. This distribution is not surprising, as early-stage

[6] The order of magnitude for 1 km of cycling is 10^{-3} kgCO_2e, compared to 10^{-1} for other means of transport. Therefore, the impact of cycling is negligible.

research activities tend to be less material intensive. The value chain of these processes relies heavily on the knowledge and expertise of researchers, making emissions related to employee



activities and energy consumption for standard working conditions and commuting naturally the largest contributors.

3.2. Transportation

After the synthesis phase, the synthesised compounds are shipped to laboratories for initial testing phases, including in vitro and *in vivo* assessments. These shipments are made both locally and internationally, depending on the location of the partner laboratories.

For the LOLA project, it was reported that a total of 12 shipments were made: eight at the regional level and four internationally. To estimate the associated impacts, the following assumptions were made: regional shipments were conducted within a 200 km radius by truck. Considering a detour factor of 1.33 for this mode of transport, it was assumed that 8 kg of materials were transported over 266 km, resulting in 2.13 t.km. For international shipments, a 10 000 km radius was used, with a detour factor of 1.15, indicating that 4 kg were transported over 11 500 km, equating to 46 t.km.

Item	Quantity	Unit	Impact Factor	Source
Airplane transportation	46	t.km	transport, freight, aircraft, belly-freight, long haul, GLO	ecoinvent 3.10
Truck transportation	2,13	t.km	transport, freight, lorry, unspecified, GLO	ecoinvent 3.10

GLO: General Load Operator

The transport impact was estimated to be 39 $kgCO_2e$, which is relatively low. This is mainly because most shipments were conducted at the regional level and involved small volumes. Although some compounds may have required more complex logistics, such as cold chain transportation, the overall magnitude was expected to remain similar. Given that emissions from synthesis activities are approximately 100 times higher, further investigation into transport impacts was not deemed necessary for this stage of the analysis.

3.3. In vitro

The in vitro testing phase involves performing preliminary analyses on the synthesised compounds to evaluate their potential biological activity. This is achieved by conducting experiments in controlled environments, such as petri dishes or test tubes, using cultured cells or biochemical assays. These tests help determine the efficacy, toxicity, and mechanism of action of the compounds before moving on to more complex stages, like in vivo testing. While this phase does not require significant material inputs, since the compounds are already synthesised, it consumes substantial energy due to the use of specialised analytical equipment. Consequently, the main sources of emissions for this phase include the energy consumption of the site and equipment, as well as laboratory technicians' commuting.

3.3.1. Energy

To estimate energy consumption for the in vitro phase, the same approach as for the synthesis phase was adopted, by using a per-employee ratio. Specifically, the Cyprus average of 6 017 kWh/year/FTE was used, as explained in section 3.1.3, and multiplied by the number of FTEs dedicated to in vitro studies, which was three. Additionally, the energy consumption of a High-Performance Liquid Chromatography (HLPC) and Liquid Chromatography-Mass Spectrometry (LC-MS) machine was included. HLPC and LC-MS are advanced analytical tools used to separate, identify, and quantify compounds in complex mixtures. The equipment, which operated for 500 hours according to the data provided, has an estimated power consumption of 2 kW, adding up to 1 000 kWh. This brings the total energy consumption for the in vitro phase in 2023 to 19 051 kWh.

Item	Quantity	Unit	Impact Factor	Source
kWh, Brazil	19 051	kWh	electricity, low voltage, BR	ecoinvent 3.10

This brings the energy-related climate change impact of the in vitro phase to 4 701 kgCO_2e.

3.3.2. Commuting

For emissions due to commuting, the same assumptions as used for the synthesis phase were applied. A daily commute of 5 km between home and the laboratory was assumed, with an effective working year of 220 days, resulting in 440 commutes. With 70% of these trips by car, 15% by bus, and 15% by walking or cycling, this corresponded to an annual travel distance of 4 620 km by car, 990 km by bus, and 990 km by foot or bicycle.

Item	Quantity	Unit	Impact Factor	Source
kilometers, private car	4 620	km	transport, passenger car, RoW	ecoinvent 3.10
kilometers, local bus	990	km	transport, regular bus, RoW	ecoinvent 3.10
kilometers, bike	990	km	negligible[7]	

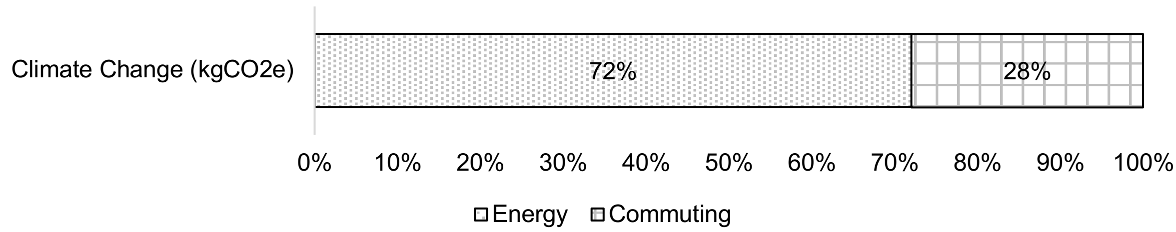
RoW: Rest of the World

[7] The order of magnitude for 1 km of cycling is 10^{-3} kgCO_2e, compared to 10^{-1} for other means of transport. Therefore, the impact of cycling is negligible.

This analysis of commuting results in an estimated climate change impact of 1 824 $kgCO_2e$ for the in vitro phase. Similar to the synthesis phase, the emissions are driven primarily by car use, which represents the largest share of the distance travelled.

3.3.3. Total for in vitro

The total climate change impact of the in vitro phase was estimated at 6 525 $kgCO_2e$. The majority of these emissions (72%) were attributed to energy consumption, which was largely driven by general laboratory operations and the use of analytical equipment. The remaining 28% resulted from commuting-related emissions, reflecting the travel of laboratory personnel to and from the research facility.



3.4. In vivo

The in vivo testing phase involves evaluating the synthesised compounds in animal models, typically mice, to assess the safety and efficacy of the compounds in more complex biological systems. This phase is crucial for providing data that cannot be obtained from in vitro experiments. The main sources of emissions for this phase include energy consumption for laboratory operations, commuting of personnel, and the purchase of laboratory animals.

The consumption related to the maintenance and care of the animals has been excluded from the analysis, as the energy used for lighting, ventilation, and temperature control is already accounted for in the overall laboratory energy consumption, included in the Energy estimation bellow. Additionally, the environmental impact of feeding the animals has been considered negligible given the small scale of the project. Consequently, the only material-related impact included for this phase is the purchase of the laboratory animals themselves.

3.4.1. Energy

For this phase, it was reported that one FTE was dedicated to in vivo testing in 2023. We used the same energy consumption assumptions as for the other phases (6 017 kWh/year/FTE) and also included the energy used by a laboratory imaging device, estimated to consume 1 500 W and operated for 500 hours throughout the year according to information shared, resulting in an additional 750 kWh. Consequently, the total energy consumption for this part of the project amounted to 6 767 kWh.

Item	Quantity	Unit	Impact Factor	Source
kWh, Brazil	6 767	kWh	electricity, low voltage, BR	ecoinvent 3.10

The energy-related climate change impact of the in vivo phase is 1 670 kgCO_2e.

3.4.2. Inputs

While laboratory animals were treated as material inputs in this carbon assessment, for the sake of methodological consistency with other emission sources, it is essential to acknowledge that mice are living beings. Their inclusion in the emissions calculation reflects only their material and financial footprint and does not diminish their ethical status or biological complexity. The broader ethical implications of animal research, while important, lie outside the scope of this environmental analysis.

In the in vivo testing phase, it was reported that 220 mice were used. Since there was no direct emission factor available for this specific research-related item, a financial emission factor from Labo1.5[8] was used instead. This collective of researchers has developed a tool to estimate the carbon footprint of French research laboratories, including financial-based emission factors for specific research items such as laboratory animals. For mice, they use the category mice & maintained mouse strains ("*souris et lignées entretenues de souris*") which corresponded to 0.35 kgCO_2e/euro spent.

Based on the information provided by the LOLA project, which indicated the use of 220 mice, the financial expenses were estimated by considering an average price of 20 € per mouse. This price falls within a reasonable range, as confirmed by publicly available data, such as the service fee list from the University of Adelaide[9]. With this cost assumption, the expenditure on mice totals approximately 4 400 €, leading to an estimated impact of 7 kgCO_2e per mouse

item	quantity	unit	impact factor	source
Mice, EURO	4 400	EURO	souris et lignées entretenues de souris	Labo 1.5

The impact of acquiring mice for *in vivo* testing is therefore estimated at 1 540 kgCO_2e, based on the assumptions detailed previously.

3.4.3. Commuting

For the commuting aspect of the in vivo phase, the same assumptions as before were applied to one FTE. Although it may not be realistic for a single individual to travel 70% by car, 15% by bus, and 15% by light transport, this statistical approach allowed us to maintain a consistent scenario across all commuting analyses. Consequently, this resulted in 1 540 km by car, 330 km by bus, and 330 km by light transport (walking or cycling) for the year.

Item	Quantity	Unit	Impact Factor	Source
kilometers, private car	1 540	km	transport, passenger car, RoW	ecoinvent 3.10
kilometers, local bus	330	km	transport, regular bus, RoW	ecoinvent 3.10

[8] (Aumont et al., 2022)
[9] (*Laboratory Animal Services*, n.d.)

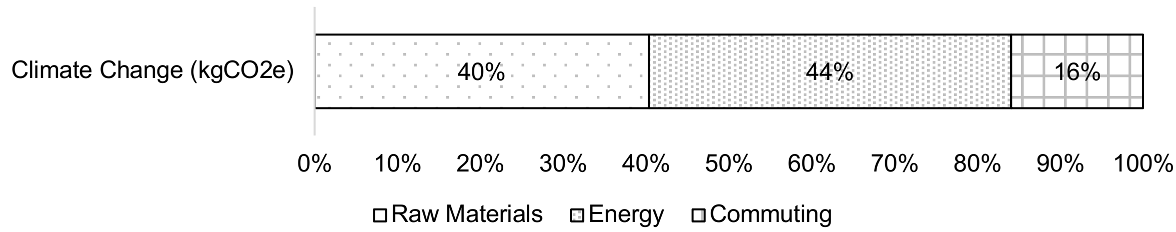
Item	Quantity	Unit	Impact Factor	Source
kilometers, bike	330	km	negligible[10]	

RoW: Rest of the World

This commuting analysis resulted in an estimated climate change impact of 608 $kgCO_2e$ for the in vivo phase.

3.4.4. Total for in vivo

In total, the in vivo phase had an impact of 3 818 $kgCO_2e$. Of this impact, 40% was attributed to the acquisition of laboratory animals, 44% to energy consumed on-site, and 16% to the transportation of laboratory personnel. This distribution highlights the significant role that both energy usage and animal procurement play in contributing to the overall climate change impact of the in vivo testing phase of the project.



3.5. Transversal

The transversal phase encompassed activities related to the project as a whole rather than to specific phases. It included the waste generated from research activities at various stages, the emissions from travel for presentations (such as conferences and seminars), and the environmental impact of data storage on research servers. These factors collectively contributed to the overall climate impact of the project.

3.5.1. Waste

It was determined that the project generated approximately 600 kg of solid waste, a figure that was used in the calculations. Liquid chemical waste had already been included in the synthesis phase. The emission factor for "Solid Waste, Refuse, Commercial and Industrial Waste" was employed, as it is considered appropriate for this context.

[10] The order of magnitude for 1 km of cycling is 10^{-3} $kgCO_2e$, compared to 10^{-1} for other means of transport. Therefore, the impact of cycling is negligible.

Item	Quantity	Unit	Impact Factor	Source
Solid Waste	0,6	tons	Solid Waste, Refuse, Commercial and Industrial Waste, GLO	ecoinvent 3.10

GLO: General Load Operator

The total impact of solid waste was estimated at 1 511 kgCO_2e.

3.5.2. Travel

For travel-related emissions, it was estimated that project researchers participated in four events annually, one international event lasting three days, occurring within a radius of 5 000 km, resulting in 10 000 km of travel and three nights of hotel stays. Additionally, three regional events were attended by researchers, estimated to take place within a 1 000 km radius and lasting four days, totalling 6 000 km and 12 nights of hotel stays. These assumptions for international travels are conservative, considering the research team is frugal on travels. Emissions from hotel stays were estimated using a DEFRA[11] emission factor due to the lack of a relevant factor in ecoinvent.

Item	Quantity	Unit	Impact Factor	Source
kilometers, Airplane	16 000	km	transport, passenger aircraft, all distances to generic market for transport, passenger aircraft, unspecified, GLO	ecoinvent 3.10
Hotel night	15	nights	Hotel night, average	DEFRA 2023

GLO: General Load Operator

The travel-related activities for the seven FTEs resulted in a cumulative climate change impact of 2 486 kgCO_2e. This does not include travel of DNDi staff connected to LOLA project for program management activities (outside the LOLA LCA boundary and captured in the DNDi "office" footprint).

3.5.3. Data management

For the data storage analysis, it was estimated that 1 000 gigabytes of information needed to be stored throughout the year. The impact of this storage was assessed through energy consumption. According to the Cloud Carbon Footprint methodology[12], storing 1 terabyte on SSD (Solid State Drive) requires approximately 1.2 Wh per terabyte per hour. Consequently, storing 1 000 GB for one-year results in an energy consumption of 10.5 kWh. Infrastructure-related emissions are considered negligible according to the same source. The analysis utilises US electricity emission factors, reflecting the significant presence of IT companies and data storage facilities in this region.

Item	Quantity	Unit	Impact Factor	Source

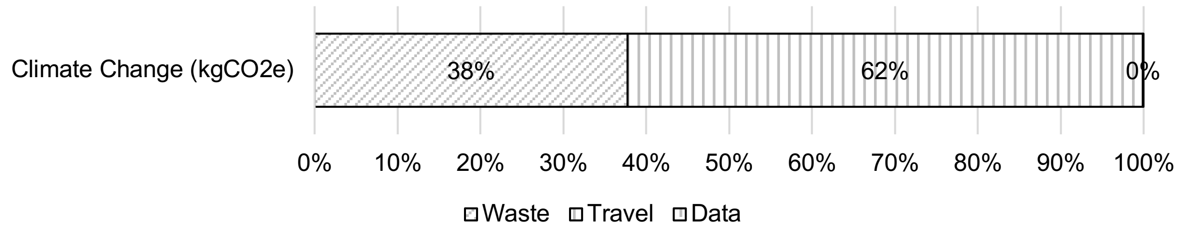
[11] (Department for Energy Security and Net Zero, 2023)
[12] (*Methodology | Cloud Carbon Footprint*, n.d.)

kWh, US	10,5	kWh	electricity, low voltage, US	ecoinvent 3.10

The impact of data management was estimated at 5 $kgCO_2e$. Several approximations were made in this analysis. In addition to the emissions from passive storage, there was also the energy consumed for actively exchanging information, which could significantly increase overall emissions. However, it must be emphasised that the impact of these tools was relatively small compared to the overall emissions associated with the rest of the project.

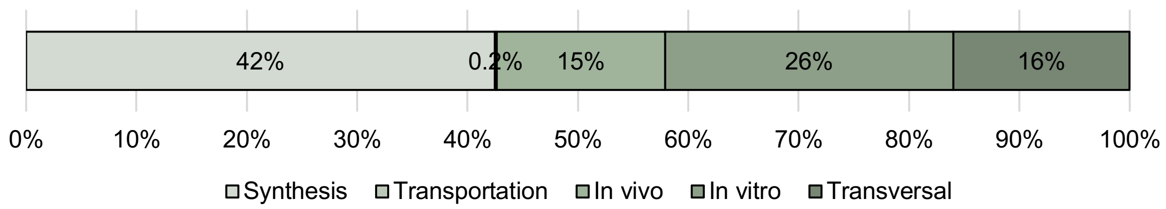
3.5.4. Total for transversal

In total, the emissions from the transversal activities amounted to 4 002 $kgCO_2e$, with a significant impact from travel accounting for 62% of the total. The remaining 38% was attributed to waste generation.

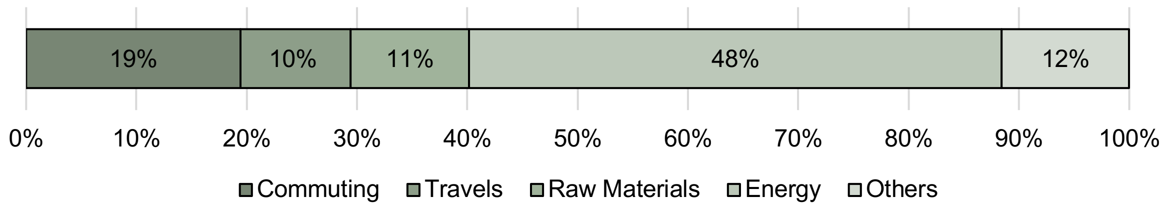


4. Results

Overall, the LOLA project was estimated to have an impact of approximately 25,0 tCO_2e. According to the breakdown, 42% of the emissions were attributed to the synthesis phase, while the in vivo and in vitro phases accounted for 15% and 26%, respectively, and 16% came from transversal activities. The synthesis phase logically had the greatest emissions due to its higher consumption of both human and material resources.



An alternative approach is to examine emissions by source rather than by phase. In this case, it becomes evident that the most significant factor was energy consumption, which was responsible for 48% of the total emissions. Then followed commuting, accounting for nearly 20% of the emissions, while material purchases contributed around 11%, and travel accounted for 10%.



The results of the LOLA project are in line with the order of magnitude of the financial emission factors associated with this type of activity. It is noteworthy that the emissions were lower than those reported for typical research activities according to DEFRA. This is expected, as the hit to lead phase occurs early in the research chain and is likely to be one of the least resource-intensive segments. However, caution is warranted, as these factors are based on a context specific to the United Kingdom and may not accurately reflect the situation in Brazil. Differences in local practices, energy sources, and infrastructure can significantly affect the actual carbon footprint of research activities.

Results of the LCA	Budgets 2023	250000	USD
	Carbon intensity (USD)	0.10	kgCO2e/USD
	Carbon intensity (FTE)	3.57	tCO2e/FTE
DEFRA Intensity per activity (2020)	*Scientific research and development services*	*0.16*	*kgCO2e/USD*
	Other professional, scientific and technical services	*0.17*	*kgCO2e/USD*
	Human health services	*0.25*	*kgCO2e/USD*
	Other personal services	*0.07*	*kgCO2e/USD*

5. Discussion

This study represents a first attempt to map the carbon footprint of a research project in its early discovery stages, specifically one with a predominantly intellectual output and low material intensity. Traditional carbon accounting tools often overlook or misrepresent such projects, as their environmental impacts do not stem from large-scale production or logistics, but from diffuse and indirect sources such as electricity use, commuting, or IT infrastructure. This lack of visibility has long limited the ability of organisations like DNDi, universities, or any research institutes lacking human and operational resources, to identify and act on emissions hotspots within their research activities.

Despite relying on several major assumptions due to the limited availability of direct data, this analysis demonstrates that even early-stage, low-tech research projects like LOLA can carry a non-negligible carbon footprint, estimated here at around 25 tCO_2e per year. This is equivalent to around five times the global per capita annual carbon emissions or 1.4 times more than the published Phase 1 clinical study by Janssen (17.6 tCO_2e) (LaRoche et al., 2024). More importantly, it identifies two major operational levers for reducing that footprint:

energy consumption and travel (commuting patterns and travel to long-distance conferences and meetings). These sources alone account for nearly 70% of total emissions. These results provide DNDi with important reference points from which project decisions can be made. For example, DNDi project teams can decide to maintain or improve existing early research "standards" (<12 shipments, one international meeting, for example) used in LOLA, and consider reducing long-distance air travel with strategic DNDi staff participation at conferences.

This study also provides DNDi with a concrete basis for action on its interactions with partners, such as encouraging or requiring the use of renewable energy, promoting greener commuting options, and integrating environmental parameters into procurement decisions, when other parameters are comparable. An increased awareness of the impact of project decisions could encourage researchers to rethink traditional approaches and foster innovation, without compromising the quality of the science or diminishing DNDi’s impact at key conferences.

The approach used here, while not a formal ISO-compliant LCA, is robust enough to yield strategic insights. It enables a functional decomposition of emissions by research phase and by emission source, offering a level of granularity often absent in conventional financial-based carbon estimations. For DNDi, this work can thus serve as a decision-support tool, helping to inform internal sustainability roadmaps, guide procurement or partnership choices, and establish baseline expectations across its research portfolio.

Beyond DNDi, the methodology developed here could also be valuable to other public interest research actors, who seek to align their operations with climate goals without the resources required for full LCAs. It points to the possibility of building a simplified, replicable LCA-lite model adapted to non-commercial R&D contexts.

Of course, the findings should be interpreted with caution. The analysis relies on proxy data (e.g., energy usage in Cyprus to estimate Brazilian office consumption), intuitive estimates (e.g., commuting distances and transport modes, conferences distances and frequences), and partial system boundaries (e.g., exclusion of building capital goods or animal housing energy). However, sensitivity analyses suggest that variations in certain parameters (such as commuting distances) would not fundamentally alter the identification of key impact drivers.

In summary, the main added value of this study lies not in the precision of its figures, but in its ability to make visible previously overlooked emissions and to offer a roadmap for integrating climate considerations into research design and operations. It opens the door to more sustainable R&D practices, both for DNDi and for the wider global health and scientific community.

6. Generalisation

We can model the overall environmental impact of research projects like LOLA by focusing on five key variables:

- **S**, Spends on materials and consumables: Costs are correlated with greater material usage.

- EF_{Spends}, Emission factors of spends, estimated in the impact assessment.
- **N**, Number of FTEs: More employees mean increased commuting and energy consumption.
- **C**, Commuting intensity patterns: The transportation modes and distances covered by employees have a significant impact.
- **E**, Electricity consumption per FTE: This depends on the needs for heating, cooling, and equipment.
- **I**, Carbon emissions per kWh: This varies by location, with different energy mixes affecting the overall footprint.

$$Impact\ CO2e \approx \underbrace{S * EF_{Spends}}_{Impact\ of\ Purchases} + \underbrace{N * C}_{Impact\ of\ Commuting} + \underbrace{N * E * I}_{Impact\ of\ Energy}$$

6.1 Case definition

6.1.1 Intensity of spending

For the LOLA projects, spending for purchasing materials, travels, and other costs was about 60 000 USD. Given the result of LOLA analysis, it was considered that spending 1 000 USD had an impact of: 44.9 kgCO2e for 'Inputs', 41.4 kgCO2e for 'Travel' and 48.1 kgCO2e for 'other emissions', giving a total EF_{Spends} of 134.4 kgCO2e/kUSD.

6.1.2 Commuting intensity patterns

Four commuting patterns illustrate the variability in emissions across different urban contexts:

- Dense urban context (LOLA-like): 10 km average commute, predominantly by car with a small share of bus and walking.
- Urban context with strong public transport: A city with a dense center and suburban sprawl, leading to significant car usage but a higher reliance on public transport.
- Highly dense city with excellent infrastructure: Short commutes dominated by light transport modes like walking and cycling.
- Sprawling city with poor infrastructure: Almost exclusive car usage due to long distances and minimal public transport options.

Based on assumptions derived from these commuting patterns, the following carbon intensity estimates were deduced with factors from ecoinvent.

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
days/year	*220*	*220*	*220*	*220*
distance home-office	*10*	*15*	*5*	*20*
% car	*70*	*20*	*10*	*90*
% tram/metro	*0*	*40*	*50*	*5*
% public bus	*15*	*10*	*10*	*5*
% foot, bike	*15*	*30*	*20*	*0*
kgCO2e/FTE	**1216**	**801**	**205**	**3015**

The variability between these scenarios is significant, with a 15-fold difference between the most optimistic (scenario 3) and the least optimistic (scenario 4). This highlights how commuting patterns greatly influence the carbon footprint of research projects.

6.1.3 Energy consumption

To define energy consumption patterns per FTE, several scenarios can be outlined based on climate and heating/cooling needs:

- Temperate: Moderate heating in winter, little air conditioning in summer.
- Mediterranean: Low heating requirements and minimal air conditioning throughout the year.
- Continental: High heating demand in winter and significant air conditioning in summer.
- Tropical: Low heating, but substantial air conditioning throughout the year.

Each scenario affects overall energy use differently, influencing the total carbon emissions associated with office operations.

Considering surveys and reports[13], the basic energy consumption of an office, without considering heating and cooling is estimated to be 50.7 kBTU/ft²/year. In addition, the consumption for heating and cooling are as follows:

- Hot season cooling: 15 kBTU/ ft²/year
- Cool season cooling: 5 kBTU/ ft²/year
- Cold season heating: 35 kBTU/ ft²/year
- Mild season heating: 25 kBTU/ ft²/year

For the four scenarios:

- 5 + 35 = 40 kBTU/ft²/year for Temperate Climate + 50.7 for office = 90,7 kBTU/ ft²/year.
- 5 + 25 = 30 kBTU/ ft²/year for Mediterranean Climate + 50.7 for office so 80,7 kBTU/ ft²/year.
- 35 + 15 = 50 kBTU/ ft²/year for Continental Climate + 50.7 for office so 100,7 kBTU/ ft²/year.
- 15 + 15 = 30 kBTU/ ft²/year for Tropical Climate + 50.7 for office so 80,7 kBTU/ ft²/year.

It is important to note that these hypotheses are simplifications and must be used with caution, no consideration of the technology, means of heating, insulation, etc. was taken.

If we consider that 1 BTU/ft² = 3.26 Wh/m², then the following assumptions are made:

- Temperate: 300 kWh/m²/year
- Mediterranean: 260 kWh/m²/year
- Continental: 330 kWh/m²/year

[13] (U.S. Energy Information Administration, 2019)

- Tropical: 260 kWh/m²/year

Assuming one FTE is equivalent to 25 m² of office space[14] in a research context, this leads to:

- Temperate: 7 500 kWh/FTE
- Mediterranean: 6 500 kWh/FTE
- Continental: 8 250 kWh/FTE
- Tropical: 6 500 kWh/FTE

6.1.4 Carbon intensity of electricity

The carbon intensity of electricity is a known indicator available in tools such as the Humanitarian Carbon Calculator[15]: These figures illustrate the carbon intensity of electricity generation in the listed countries. The more a country relies on carbon-intensive energy generation (such as gas or coal), the higher the value. However, countries that rely on sustainable energy production methods (photovoltaic, hydroelectric, etc.) would have a smaller impact per kilowatt hour generated and distributed.

Country	kgCO2e/kWh
Algeria	0,576
Angola	0,580
Benin	0,992
Botswana	1,626
Cameroon	0,359
Republic of the Congo	0,544
Democratic Republic of the Congo	0,001
Cote d'Ivoire	0,389
Egypt	0,640
Equatorial Guinea	0,393
Eritrea	0,895
Ethiopia	0,001
Gabon	0,672
Ghana	0,275
Kenya	0,197
Libya	0,776
Mauritius	0,842
Morocco	0,735
Mozambique	0,077
Namibia	0,026
Niger	1,083
Nigeria	0,479
Senegal	0,918

Country	kgCO2e/kWh
South Africa	1,097
South Sudan	0,802
Sudan	0,409
United Republic of Tanzania	0,373
Togo	0,616
Tunisia	0,502
Zambia	0,186
Zimbabwe	0,809
Armenia	0,206
Azerbaijan	0,500
Bahrain	0,703
Bangladesh	0,546
Brunei Darussalam	0,802
Cambodia	0,453
People's Republic of China	0,756
Hong Kong (China)	0,879
India	1,001
Indonesia	0,939
Islamic Republic of Iran	0,582
Iraq	1,609
Israel	0,620
Japan	0,598

[14] (Hoxha et al., 2020)
[15] (Climate Charter, n.d.)

Country	kgCO2e/kWh
Jordan	0,487
Kazakhstan	0,680
Kuwait	0,724
Kyrgyzstan	0,057
Lao People's Democratic Republic	0,439
South Korea	0,634
Democratic People's Republic of Korea	0,219
Lebanon	0,803
Malaysia	0,812
Mongolia	1,345
Myanmar	0,403
Oman	0,491
Pakistan	0,512
Philippines	0,845
Qatar	0,496
Saudi Arabia	0,678
Singapore	0,466
Sri Lanka	0,579
Syrian Arab Republic	0,756
Chinese Taipei	0,662
Tajikistan	0,070
Thailand	0,591
Turkey	0,585
Turkmenistan	1,015
United Arab Emirates	0,554
Uzbekistan	0,505
Viet Nam	0,483
Yemen	0,860
Austria	0,187
Belarus	0,407
Belgium	0,234
Bosnia and Herzegovina	0,783
Bulgaria	0,567
Croatia	0,200
Cyprus	0,776
Czech Republic	0,603
Denmark	0,214
Estonia	1,055
Finland	0,147
France	0,069
Georgia	0,089
Germany	0,488
Gibraltar	0,877
Greece	0,701

Country	kgCO2e/kWh
Hungary	0,314
Iceland	0,000
Ireland	0,415
Italy	0,383
Kosovo	1,207
Latvia	0,169
Lithuania	0,113
Luxembourg	0,216
Malta	0,497
Republic of Moldova	0,535
Montenegro	0,439
Netherlands	0,498
Republic of North Macedonia	0,703
Norway	0,011
Poland	0,861
Portugal	0,356
Romania	0,443
Russian Federation	0,457
Serbia	0,816
Slovak Republic	0,194
Slovenia	0,312
Spain	0,323
Sweden	0,016
Switzerland	0,032
United Kingdom	0,283
Ukraine	0,494
Canada	0,161
Costa Rica	0,011
Cuba	0,567
Dominican Republic	0,637
El Salvador	0,190
Guatemala	0,420
Haiti	1,324
Honduras	0,415
Jamaica	0,731
Mexico	0,588
Nicaragua	0,362
Panama	0,197
Trinidad and Tobago	0,562
United States	0,504
Australia	0,868
New Zealand	0,134
Argentina	0,372
Plurinational State of Bolivia	0,436

Country	kgCO2e/kWh
Brazil	0,124
Chile	0,419
Colombia	0,177
Curacao/Netherlands Antilles	0,632
Ecuador	0,224

Country	kgCO2e/kWh
Peru	0,222
Suriname	0,531
Uruguay	0,025
Bolivarian Republic of Venezuela	0,413

6.2 Application example

6.2.1 LOLA-type case

Variable	Name	Scenario	Value	Unit
S	Spending on materials and consumables		60000	USD
N	Number of FTE		7	FTE
C	Commuting Intensity Pattern	Dense - Transport	1216	kgCO2e/FTE
E	Electricity Consumption per FTE	Tropical	6500	kWh/FTE
I	Carbon Emissions per kWh	Brazil	0,124	kgCO2e/kWh
Total kgCO2e	**CO2e emissions**		**22 218**	**kgCO2e**

6.2.2. Case US continental

Variable	Name	Scenario	Value	Unit
S	Spending on materials and consumables		60000	USD
N	Number of FTE		7	FTE
C	Commuting Intensity Pattern	Sprawling City	3015	kgCO2e/FTE
E	Electricity Consumption per FTE	Continental	8250	kWh/FTE
I	Carbon Emissions per kWh	United States	0,504	kgCO2e/kWh
Total kgCO2e	**CO2e emissions**		**58 275**	**kgCO2e**

6.2.3. Case Switzerland city

Variable	Name	Scenario	Value	Unit
S	Spending on materials and consumables		60000	USD
N	Number of FTE		7	FTE
C	Commuting Intensity Pattern	Dense + Transport	205	kgCO2e/FTE
E	Electricity Consumption per FTE	Temperate	7500	kWh/FTE
I	Carbon Emissions per kWh	Switzerland	0,032	kgCO2e/kWh
Total kgCO2e	**CO2e emissions**		**11 083**	**kgCO2e**

6.2.4. Synthesis

Case	LOLA	US	Switzerland
Commuting Pattern	Dense without Transport	Sprawling City	Dense with Transport
Climate	Tropical	Continental	Temperate
Electricity Carbon Intensity	Medium	High	Low
Total tCO2e	**22**	**58**	**11**
Variation/LOLA		+164%	-50%

It is important to highlight that the LOLA project was interpreted with different parameters here according to scenarios defined in this generalisation chapter. Moreover, different emission factors were used for energy and hypotheses for energy per FTE. The LOLA impact calculation made in the first part of the document remains the more complete assessment.

This method provides an understanding of the order of magnitude for the parameters considered critical in this study. While the simplifications offer a clearer perspective on the key impact drivers, it is essential to acknowledge the inherent limitations of this approach.

7. Conclusion

This assessment provides a first operational overview of the carbon footprint associated with an early-stage research project in the pharmaceutical development sector. While based on simplified assumptions, the study offers reasonable insights into where and how emissions are generated across research activities that are primarily intellectual rather than material in nature.

The findings show that two main areas, energy consumption and commuting patterns, account for most of the emissions. These levers are actionable and have the potential for a domino effect. Research organizations can, as a group, consistently communicate to their service providers and partners the importance of non-fossil fuel energy sources, energy efficiency of buildings and equipment, low-carbon commuting, and business travel choices, and award contracts to those who demonstrate decarbonisation efforts, or agree to take reasonable steps in this journey. The greater the research organization's own efforts to reduce its impact in these areas, the more credible and effective the organisation will be as a changemaker ("walk-the-talk").

Beyond the immediate case of LOLA, this work lays the foundation for a replicable, simplified methodology that can inform broader climate strategies in the research sector. It offers a way to move beyond purely financial proxies for emissions and enables a more nuanced integration of sustainability into scientific decision-making.

For DNDi, this approach can support internal target-setting, help identify priority areas for intervention and align the organisation's innovation agenda with its climate commitments. For the wider research community, especially those operating in resource-constrained or low-infrastructure settings, it offers a pragmatic entry point into carbon accountability.

Ultimately, the goal is not to decarbonise research at any cost, but to do so responsibly and equitably, ensuring that environmental impact is considered alongside equity and scientific quality, during project decision-making. This report is an important step towards making those trade-offs visible, measurable, and manageable.

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