carbone4

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Avoided emissions report

Emissions avoided by the LCA60T compared to other solution in different projects

FLYING WHALES

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Context and objectives

Context

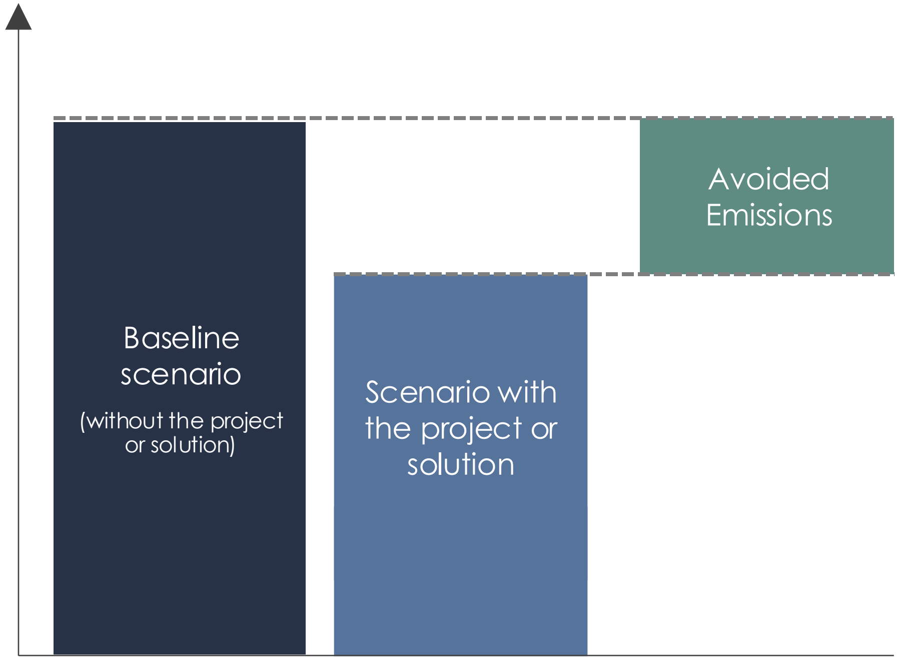
- FLYING WHALES is a French-Canadian company that is developing a unique airship solution, with a loading/unloading capacity up to 60 tons in hovering flight.
- Within FLYING WHALES, the CSR department oversees environmental issues, in particular to assess and confirm the benefits brought by the airship solution (on CO_2 emissions, noise, biodiversity, etc.), in order to validate the companies purpose statement.
- To do this, FLYING WHALES is reluctant to engage in any greenwashing, and wishes to talk about its product while being very sure of what the company is communicating. This can also be a way to attract young talent.
- The company therefore needs to refine its **knowledge of the environmental impact of its solution**, and above all to compare it to competing modes, through the evaluation of potential **avoided greenhouse gas emissions** (GHG).
- This report is an independent review to assess GHG emissions potential benefits for 4 different projects based on a tool co-developed by Carbone 4 and FLYING WHALES.

Objectives

- In this context, Carbone 4 proposes to focus primarily on GHG emissions, as climate change is the number one environmental issue for freight transport today. The approach should enable a **robust assessment of avoided emissions by the airship developed by FLYING WHALES in four specific use cases**:
  - Material construction transportation in French Guiana
  - Pylon transportation in French Alps
  - Wind facility transportation in Fioulebise region
  - Wood transportation in Gliere region

Understanding the concept of avoided emissions

- **Definition :** An avoided emission is **a non-emission of CO_2e* compared to a baseline scenario.**
- **Purpose :** incentivize organizations to assess and increase their contributions to reducing emissions of third parties over time:
  - either through the **sales of low-carbon products and solutions**
  - or through the **financing of emissions reduction projects outside value chain**



Calculation principle of avoided emissions

CO_2e : The 'CO_2 equivalent' (CO_2e) is a unit created by the IPCC to compare the impact of the different GHGs on global warming and to be able to cumulate their emissions.

The avoided emissions have been assessed for four different scenarios

Isolated area – French Guiana

Transport of 60 tons of construction materials from Cayenne to Maripasoula in French Guiana in 2028

Wind Park - Fioulebise

Transport of 9 wind turbine blades from manufacturing site to Fioulebise Wind park

Pylons - Alps

Transport operation for the dismantling of 36 pylons at Fioulebise Valley

Forestry - Glieres

Transport operation for 2,640 tons of wood from plateau des Glières to a storage site 15km away

The avoided emissions have been assessed based on a tool developed by Carbone 4, with various key parameters

The tool is configurable so that FLYING WHALES can test the carbon impact of key parameters and calculate avoided emissions on other case studies close to the ones studied. The following parameters are configurable:

Geographic perimeter

- Country of LCA60T production
- Country of project

*This choice only impacts the emission factor for electricity

Temporal perimeter

- Year of operation
- Year of construction of the airship

*This choice only impacts the emission factor of electricity

Vehicles available

- Pirogue,
- Blade lifter,
- Wing carrier,
- Helicopter (light or heavy load),
- Other vehicles commonly used for air, sea, and road transportation

LCA60T – type of fuel

- Kerosene
- SAF (Sustainable Aviation Fuel) :
  - Made from cooking oils
  - Made from forestry residues
- eSAF
- Hydrogen :
  - Steamforming with natural gas
  - Steamforming with biomethane
  - Electrolysis based on any country electricity mix / renewable electricity

Land use change

- Crop
- Coastal
- Forest
- Grassland
- Heathland
- Shrub
- Sparsely Vegetated
- Tundra
- Wetland

LCA60T system architecture*

1st generation: hybrid electric propulsion chain

Fuel: Kerosene **(Model 1.A)** or SAF **(Model 1.B)**

Kerosene or SAF Production & Supply → Fuel System → Mechanical Power generator → Electrical Power generator → Electrical Power distribution → Electric thrusters

2nd generation: all electric propulsion chain

Fuel: Green Hydrogen **(Model 2)**

Green H_2 Production & Supply → H_2 Tank → Fuel Cell → Electrical Power distribution → Electric thrusters

No substitution necessary

* This slide has been prepared by Flying Whales

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Isolated area | Perimeter of the case study (1/2)

Transport of 60 tons of construction materials from Cayenne to Maripasoula in French Guiana in 2028

Baseline scenario n°1 : Pirogue + Truck

- Transport of materials from Cayenne to Saint-Laurent-du-Maroni **by truck** and from Saint-Laurent-du-Maroni to Maripasoula **by pirogue**
- Emissions category included in perimeter :
  - Transport – **pirogue** : **fuel consumption,**
  - Transport – **truck** : **fuel consumption, truck fabrication and maintenance, road maintenances**
- Excluded from perimeter :
  - **Construction, maintenance and end of life of the pirogue**
  - **Infrastructures for pirogue & road transportation** : GHG emissions for existing infrastructures are not considered because they have already been emitted, and the use of those infrastructures will not induce the construction of new ones
  - **No extra transport by air** has been considered (considered that the totality of the transport happens when rivers are practicable)

Baseline scenario n°2 : Helicopter

- Transport of materials from Cayenne to Maripasoula airport by **helicopter in 67 trips.**
- Emissions category included in perimeter :
  - Transport – **helicopter : fuel consumption**
- Excluded from perimeter :
  - **Construction, maintenance and end of life of the helicopter**
  - **Infrastructures - land use change due to artificialization** for pick-up and delivery areas: no land use change, use of existing infrastructure

Isolated area | Perimeter of the case study (2/2)

Transport of 60 tons of construction materials from Cayenne to Maripasoula in French Guiana in 2028

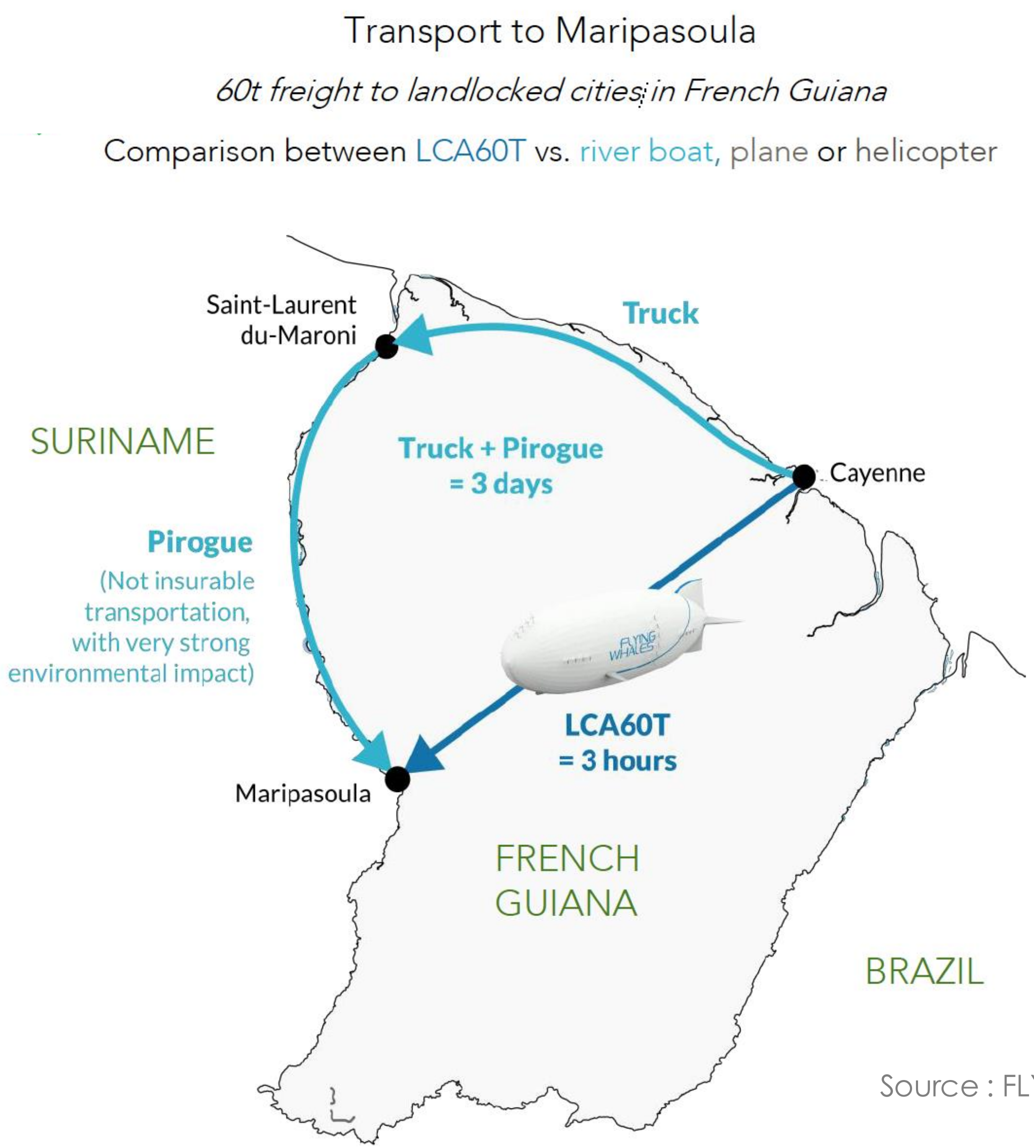
Baseline scenario n°3 : Plane

- Transport of materials from Cayenne to Maripasoula airport by a small capacity **plane (10-25t).**
- Same emissions category included than fot the helicopter scenario

Scenarios with LCA60T

- Transport of materials from Cayenne to Maripasoula airport by **LCA60T in 1 trip.**
- Emissions category included in perimeter :
  - Infrastructures – LCA60T **Base & FAL : Energy consumption and building construction**
  - Transport – **Airship : fuel consumption, airship production, helium first filling, maintenance and road transport for ballast water**
- Excluded from perimeter :
  - **Infrastructures - land use change due to artificialization** for pick-up and delivery areas : no land use change, use of existing infrastructure
  - **Rebound effect** : cheaper transport leads to increased construction over the years which results in an overall increase in emissions
- Three different LCA60T scenarios are possible :
  - The **kerosene LCA60T scenario**: the classic scenario of the first LCA60T hybrid electric version that is going to be launched with kerosene as the main fuel
  - The **renewable hydrogen LCA60T scenario**: an alternative scenario of with hydrogen made from electrolysis from renewable elecrtricity as the main fuel
  - The **SAF LCA60T scenario**: an alternative scenario of SAF (Sustainable Aviation Fuel) made from used cooking oil as the main fuel

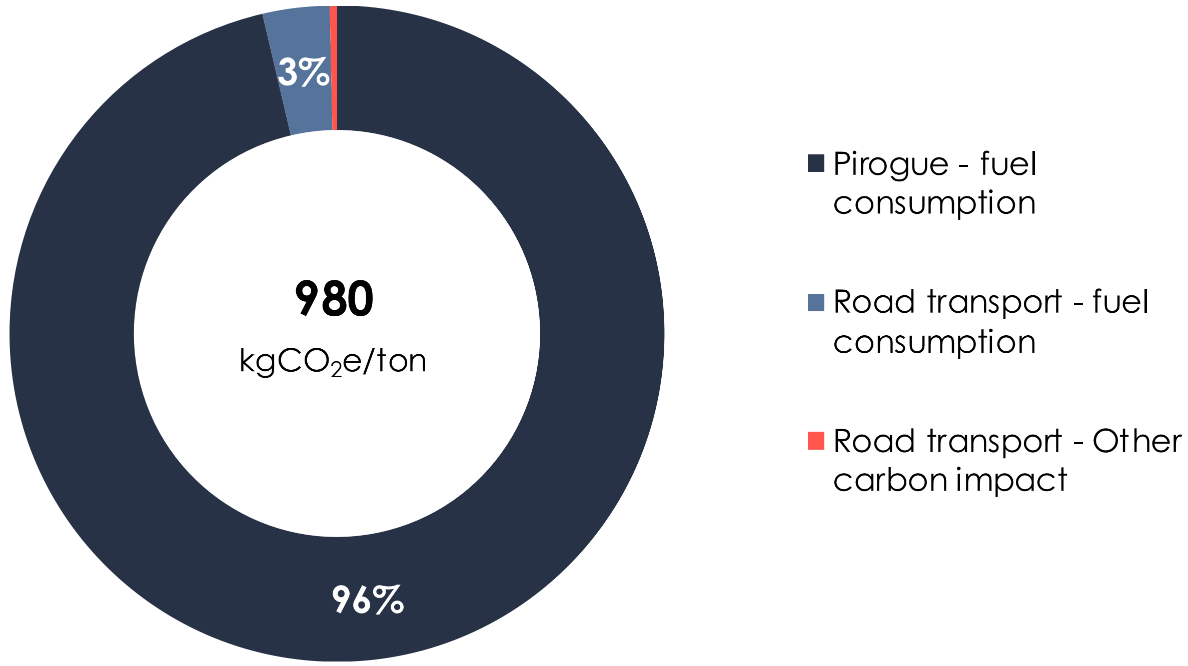
Isolated area | Scenario illustration



Source : FLYING WHALES report

Isolated area | The baseline scenario n°1 with pirogue & truck emits 980 $kgCO_2e$ / ton carried, mainly because of the impact of pirogue trips

Breakdown of CO_2e emissions by emissions category for the baseline scenario n°1 | tCO_2e, % of total emissions



- To transport the equivalent of the construction goods of one LCA60T, the baseline scenario n°1 emits 59 tCO_2e, which means 1 tCO_2e per ton carried.
- **Almost all of the carbon impacts (94%) come from the pirogue's fuel consumption.** This is mainly explained by the high emission factor for freight transport by pirogue, which requires 6 trips to carry 60 tons.

⚠ Fuel consumption for pirogue are based on field data. **There is high uncertainty to use this data for generalizing to other areas in the world**

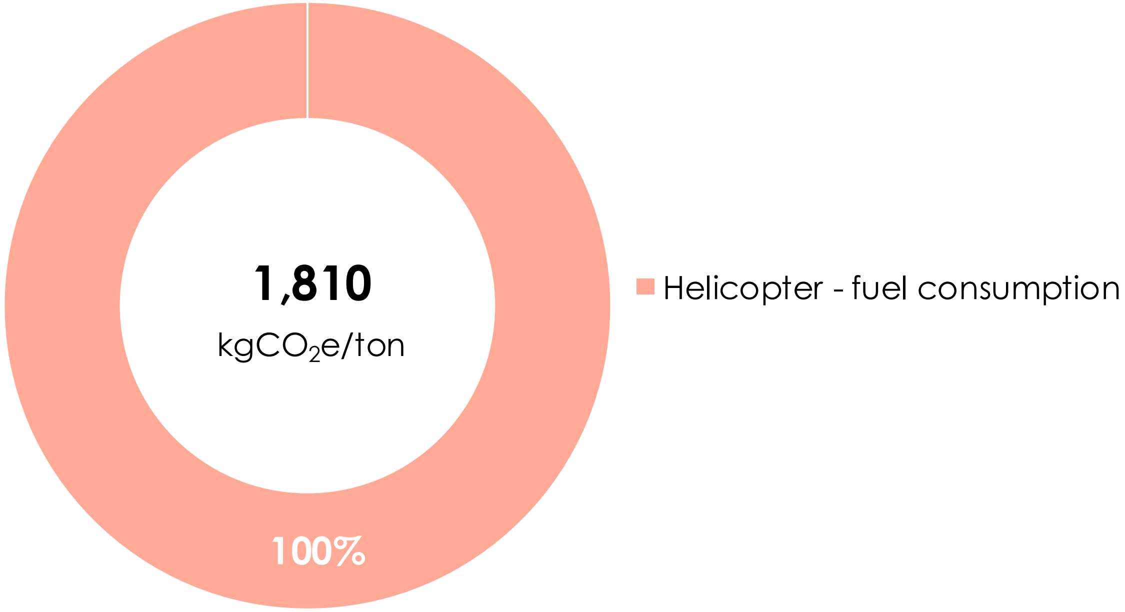
Notes :

(1) **Pirogue :**
- The pirogue carrying 10 tons, 6 trips are required to carry the 60 tons that can be carried by a LCA60T
- **Fuel consumption:** 2 000 L for the trip Apatou – Maripasoula with a 10 tons load and 600 L for an empty load (source : Eiffage Infrastructures).
- **Hypothesis:** 3% of shipments are lost in the river (source : Eiffage Infrastructures) ; transportation happens during rain season ; no air transport is considered; other carbon impacts for the pirogue are not considered.

(2) **Road transportation :**
- **Distance considered:** 263 km from Carapa quarry to Aquatou by road
- **Type of truck considered:** Rigid, On-road diesel, including 7 % bio-based : 20 to 26 tons
- **Other carbon impact considered:** Truck manufacturing and maintenance, and road maintenance. Emissions for road construction are not considered because they have already been emitted.

Isolated area | The baseline scenario n°2 with helicopter emits 1,810 kgCO_2e / ton carried, because of the fuel consumed by the helicopter

Breakdown of CO_2e emissions by emissions category for the baseline scenario n°2 | tCO_2e, % of total emissions



- To transport the equivalent of the construction goods of one LCA60T, the baseline scenario n°2 emits 109 tCO_2e, which means 1,8 tCO_2e per ton carried.
- **All of the carbon impacts come from the helicopter fuel consumption.** This is mainly explained by the high jet fuel consumption during cruise and operation, and the number of trips required

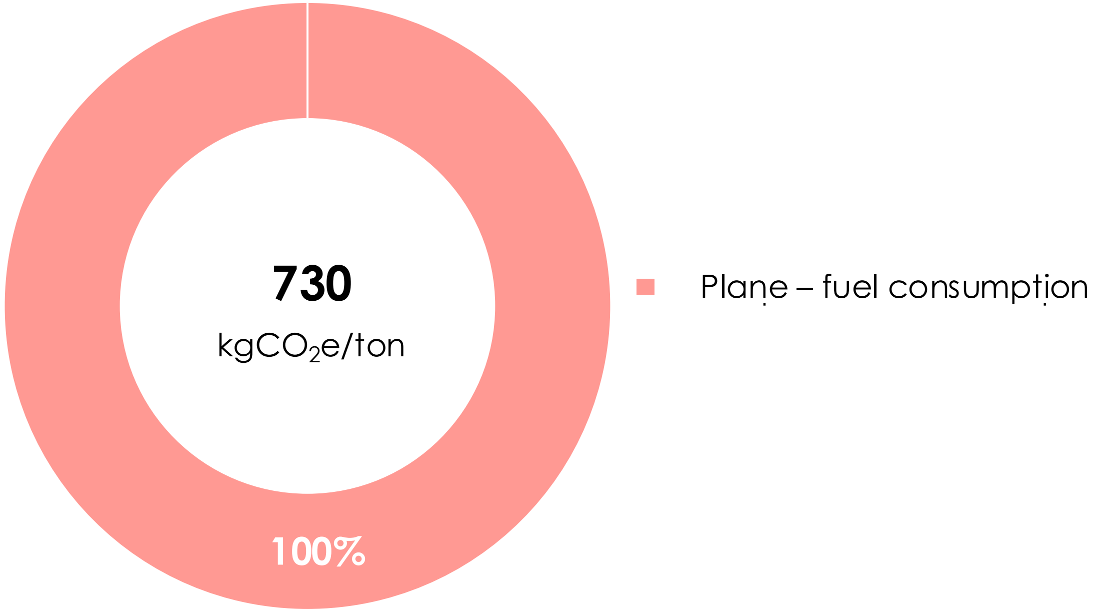
Notes :

(1) **Helicopter :**

- The helicopter carrying 900kg of goods, 67 trips are required to carry the 60 tons that can be carried by a LCA60T. It is based on a Gazelle model.
- The cruise impact is assessed considering the distance covered (263km), the speed of the helicopter (220 km/h) and the cruise consumption (600 kg/h)
- The operation impact is assessed considering the hovering time per operation (8 minutes), the number of operations (67) and the operation consumption (775 kg/h)
- The consumption are based on the data of the Super Puma model

Isolated area | The baseline scenario n°3 with plane emits 730 kgCO_2e / ton carried, because of the fuel consumed by the helicopter

Breakdown of CO_2e emissions by emissions category for the baseline scenario n°2 | tCO_2e, % of total emissions

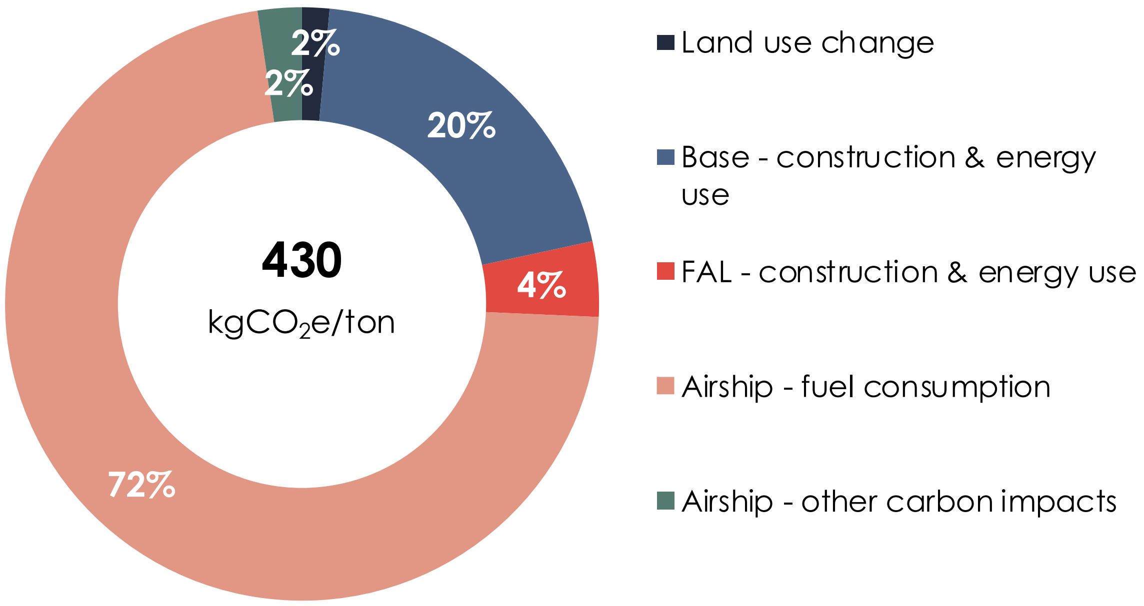


- To transport the equivalent of the construction goods of one LCA60T, the baseline scenario n°2 emits 44 tCO_2e, which means 0,7 tCO_2e per ton carried.
- **All of the carbon impacts come from the helicopter fuel consumption.**

Notes :
(1) **Plane :**
- The emissions are assessed based on the ADEME 10-25t cargo plane emission factor : 3,1 kgCO_2e/tkm
- A tkm is a ton of good carried over one kilometer. The distance covered being 236km, and the weight of goods 60t, the tkm considered are 14160 tkm.

Isolated area | The scenario with the kerosene LCA60T emits 430 tCO_2e / ton carried, mainly because of the fuel consumption

Breakdown of CO_2e emissions by emissions category for the scenario with the Kerosene LCA60T | tCO_2e, % of total emissions



- One trip with the diesel LCA60T loaded at 60 tons emits about 26tCO_2e, which means **430 $kgCO_2e$ / ton carried.**
- **The majority of carbon impacts (72%) comes from the airship's fuel consumption.**
- **The energy consumption of the base represents 20%** of the carbon footprint of the solution due to the high emission factor for electricity in French Guiana.

Notes :

(1) Airship:
- **Fuel consumption:** During cruise : 900 kg/h (900 km/h) ; during hovering : 840 kg/h (0,67 h/trip) ; Distance covered : 475km round trip
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

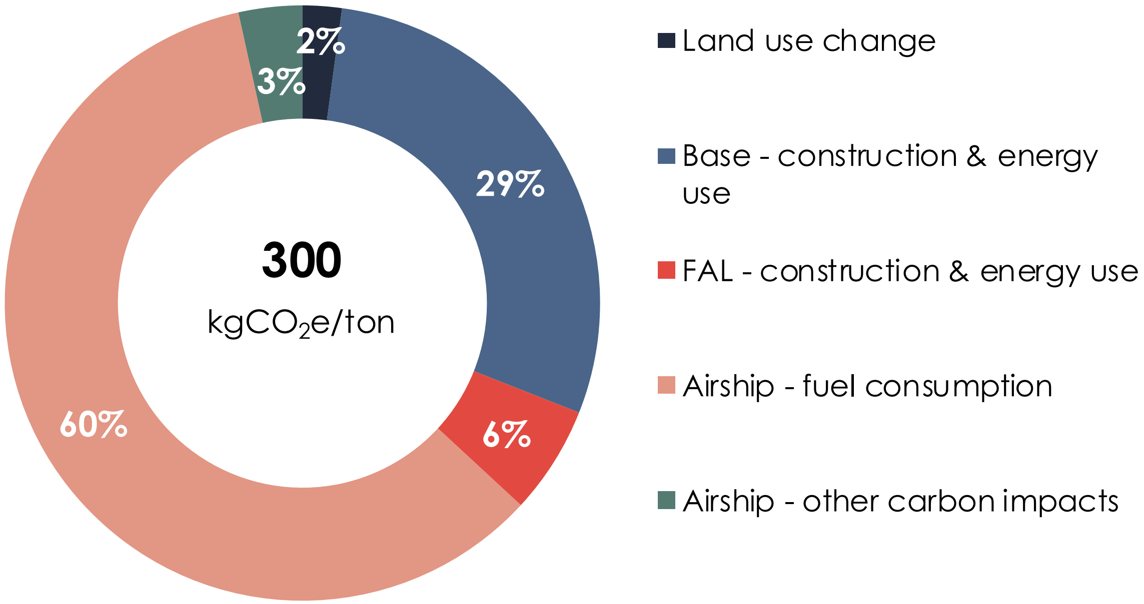
(2) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(3) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Isolated area | The scenario with the SAF LCA60T emits 300 tCO_2e / ton carried, mainly because of the base

Breakdown of CO_2e emissions by emissions category for the scenario with the SAF LCA60T | tCO_2e, % of total emissions



- The SAF LCA60T fuel is composed with 50% of Kerosene and 50% of SAF made from used cooking oil.
- One trip with the SAF LCA60T loaded at 60 tons emits about 18tCO_2e, which means **300 $kgCO_2e$ / ton carried.**
- **Most of the carbon impacts comes from the fuel consumption**, especially because it is sill made of 50% Kerosene.
- The SAF made from cooking oil is 6 times less emissive than the jet fuel

⚠ The SAF considered is made from used cooking oil : its impact is low but the resources are very limited. SAF impact from non sustainable resources can be much higher.

Notes :

(1) **GHG emissions are allocated to the project proportionally of days of use**

(2) **Airship:**
- **Fuel consumption:** The SAF consumption of the LCA60T is considered as the same as the kerosene, since their physical characteristics are closed
- **Fuel impact :** The SAF emission factor has been assessed based on the ICCT report "Assessing the sustainability implications of alternative aviation fuels"
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

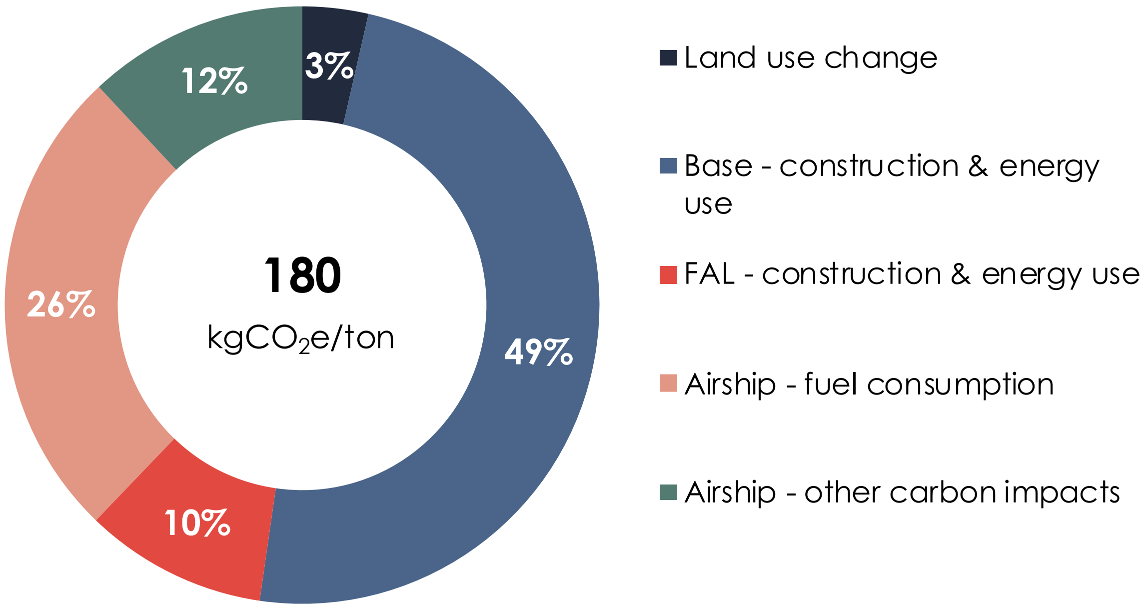
(3) **Base :**
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) **FAL:**
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(5) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Isolated area | The scenario with the renewable hydrogen LCA60T emits 180 tCO_2e / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with the renewable hydrogen LCA60T | tCO_2e, % of total emissions



Notes :
(1) GHG emissions are allocated to the project proportionally of days of use
(2) Airship:
- **Fuel consumption**: The hydrogen consumption is based on a ratio assessed by flying whales of 0,3 kgH2/kgfuel consumed
- **Fuel impact** : The hydrogen emission factor has been assessed by Carbone 4 based on data from IEA and ADEME.
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

(3) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

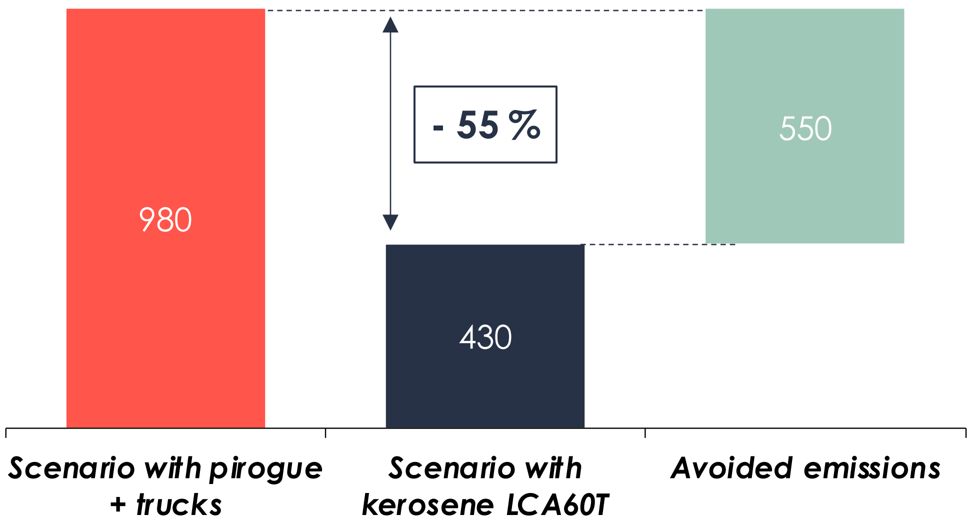
(5) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

- One trip with the hydrogen LCA60T loaded at 60 tons emits about 11 tCO_2e, which means **180 $kgCO_2e$ / ton carried.**
- **Half of carbon impacts comes from the energy consumption of the base,** due to the high emission factor for electricity in Guiana.
- The renewable hydrogen emission factor being much lower than the jet fuel, the fuel consumption impact is much lower

⚠ Hydrogen considered is made from renewable electricity. If it was made from Guiana's electricity mix, emissions would rise up to 78,3 tCO_2e, which means 1 305 $kgCO_2e$ / ton carried. It could be even higher with hydrogen made from fossil source

Isolated area | Using LCA60T instead of the pirogue & truck transportation avoids 550 $kgCO_2e$ / t carried

Avoided emissions for the French Guiana case study with baseline scenario 1 | *$kgCO_2e$ / t carried*



- In this case study, the scenario with LCA60T emits **55% less emissions** than the baseline scenario.
- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation of freight by pirogue & truck.**

⚠ **The rebound effect of the solution** (ex: cheaper transport leads to increased construction in isolated zone over the years , which results in an overall increase in emissions) **has not been studied.**

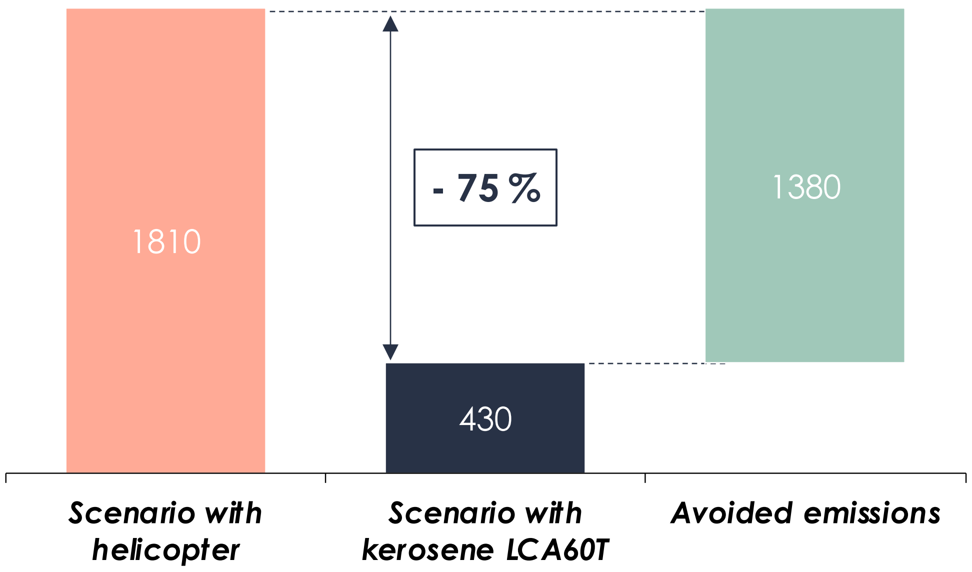
Example of communication

In this case study :

- Using LCA60T instead of pirogue & trucks avoids **550 $kgCO_2e$ per ton carried**
- Using LCA60T instead of pirogue & trucks avoids **33 tCO2e over the project** of carrying 60 tons of goods

Isolated area | Using LCA60T instead of the helicopter avoids 1.4 tCO_2e / t carried

Avoided emissions for the French Guiana case study with baseline scenario 2 | *$kgCO_2e$ / t carried*



- In this case study, the scenario with LCA60T emits **75% less emissions** than the baseline scenario.
- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation of freight by helicopter.**

⚠ **The rebound effect of the solution** (ex: cheaper transport leads to increased construction in isolated zone over the years , which results in an overall increase in emissions) **has not been studied.**

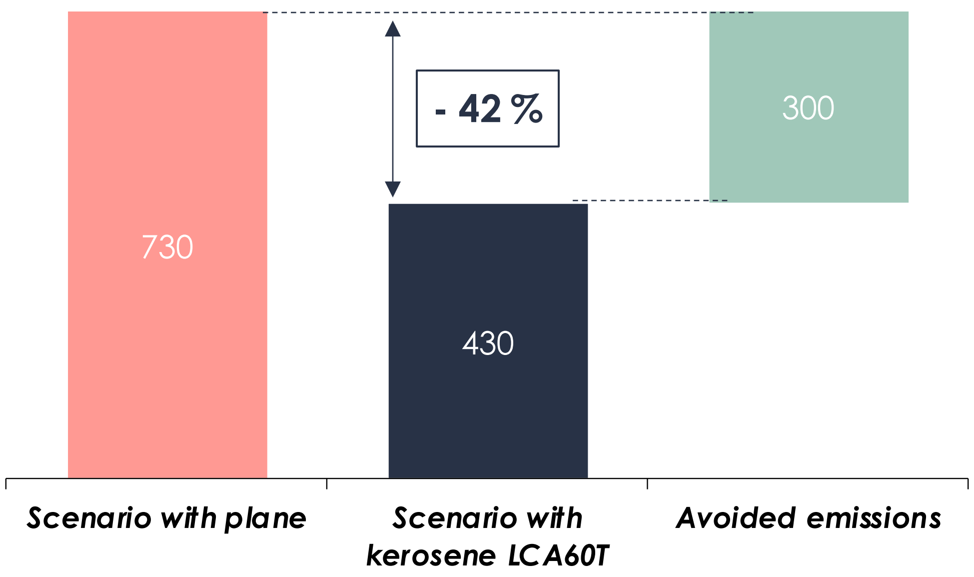
Example of communication

In this case study :

- Using LCA60T instead of helicopter avoids **1,380 $kgCO_2e$ per ton carried**
- Using LCA60T instead of helicopter avoids **83 tCO2e over the project** of carrying 60 tons of goods

Isolated area | Using LCA60T instead of the plane avoids 0.7 tCO_2e / t carried

Avoided emissions for the French Guiana case study with baseline scenario 3 | *$kgCO_2e$ / t carried*



- In this case study, the scenario with LCA60T emits **42% less emissions** than the baseline scenario.
- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation of freight by plane.**

⚠ **The rebound effect of the solution** (ex: cheaper transport leads to increased construction in isolated zone over the years , which results in an overall increase in emissions) **has not been studied.**

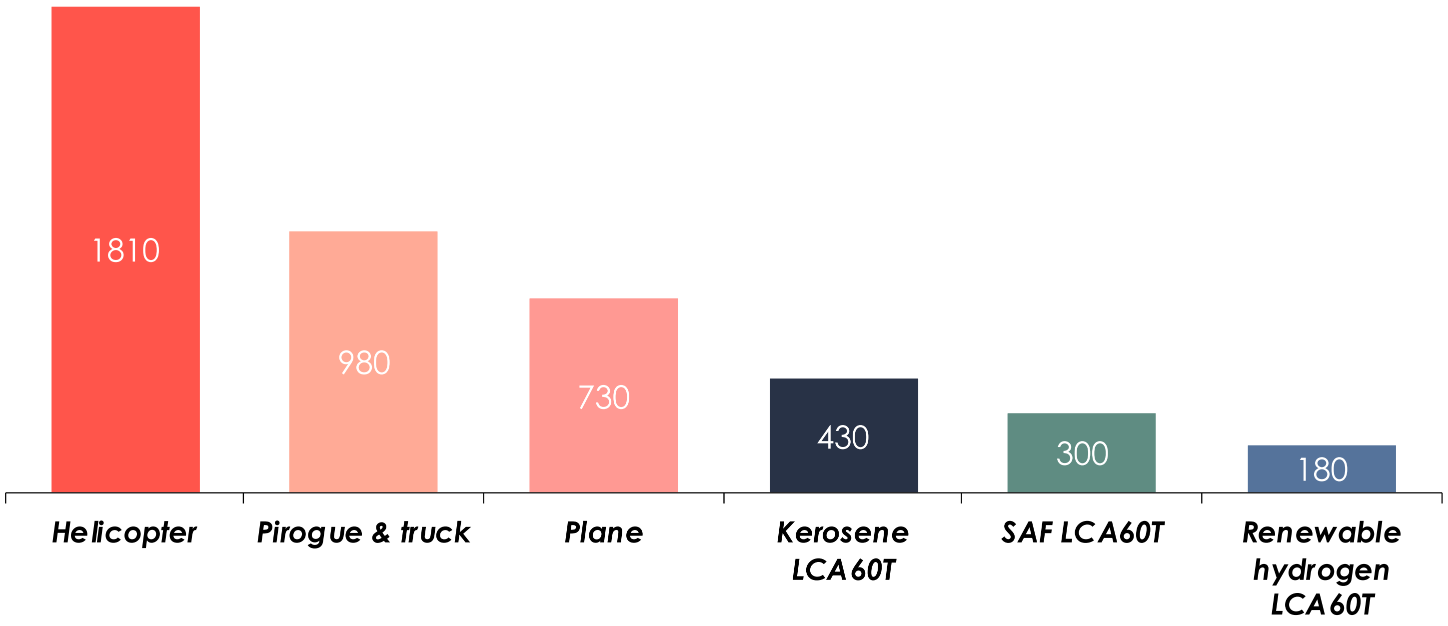
Example of communication

In this case study :

- Using LCA60T instead of plane avoids **1,380 $kgCO_2e$ per ton carried**
- Using LCA60T instead of plane avoids **18 tCO2e over the project** of carrying 60 tons of goods

Isolated area | Comparison of all scenarios of the Guiana use case

Comparison of the emissions of each scenario | *$kgCO_2e$ / t carried*



- **The use of LCA60T is relevant from a GHG emissions perspective in this case scenario**, since it replaces a more emissive mode of transport
- Low carbon fuels allow to avoid even more emission
- Avoided emissions range from 40% to 90% depending on the scenario replaced and the LCA60T fuel considered

⚠ **SAF are rare and there is a strong competition for their use**

⚠ **Low carbon H2 is rare and there is a strong competition for their use**

Isolated area | Uncertainty analysis – Baseline scenario

	Source of emissions	Significance	Degree of certainty of results	Commentary
Baseline scenario	Pirogue – fuel consumption	■■■	■■□	Fuel consumption for pirogue transportation is based on field operation specific to this case study. This data should not be used to generalize to other areas in the world
	Helicopter – fuel consumption	■■■	■■□	Fuel consumption for helicopter transportation is based on a mode type (super puma). This data is a generic data for a helicopter that carries light loads (<5t); it does not consider the load rate that would impact energy consumption
	Plane – emission factor	■■■	■■□	The emission of the cargo is dependent on the plane model, the volume carried, and the distance travelled. The emissions are based on the ADEME emission factor that is generic and does not consider these variations.
	Road transport – fuel consumption	■□□	■■■	Physical data is used based on the distance traveled by type of transport
	Road transport – Other carbon impact	■□□	■■■	Physical data is used based on the distance traveled by type of transport

Isolated area | Uncertainty analysis – Scenario with LCA60T

	Source of emissions	Significance	Degree of certainty of results	Commentary
Scenario with LCA60T	Airship – fuel consumption	■■■	■■■	Fuel consumption specific to the LCA60T is used
	Airship – other carbon impact	■□□	■■■	Physical data specific to the LCA60T is used
	FAL - construction	■□□	■■■	Building materials for the FAL are based on on real data (Flying Whales 2024 LCA)
	FAL – energy use	■□□	■■□	Energy consumption is specific to the base and for a use in France Metropolitan not Guiana
	Base - construction	■□□	■■□	Building materials for the base are an estimate based on the FAL and not based on real data
	Base – energy use	■■□	■■□	Energy consumption for the Base is an estimate based on the FAL and not on real data

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Wind park | Perimeter of the case study

Transport of 9 wind turbine blades from manufacturing site to Fioulebise Wind park

Baseline scenario

- Transport from manufacturing site in the Netherlands to **La Rochelle by sea cargo** and La Rochelle to Fioulebise mountain pass **by wing carrier and Blade lifter** (machine dedicated exclusively to transporting wind turbine blades).
- Emissions category included in perimeter :
  - Transport - **sea cargo : fuel consumption**,
  - Transport - **wing carrier : fuel consumption, truck manufacturing and maintenance, road maintenance, escort vehicules**
  - Landscape modifications - **Roadwork, Land use Change and tree-cutting for the blade lifter to pass are included**
- Excluded from perimeter :
  - Manufacturing, maintenance and end of life of the sea cargo : not significant

Scenarios with LCA60T

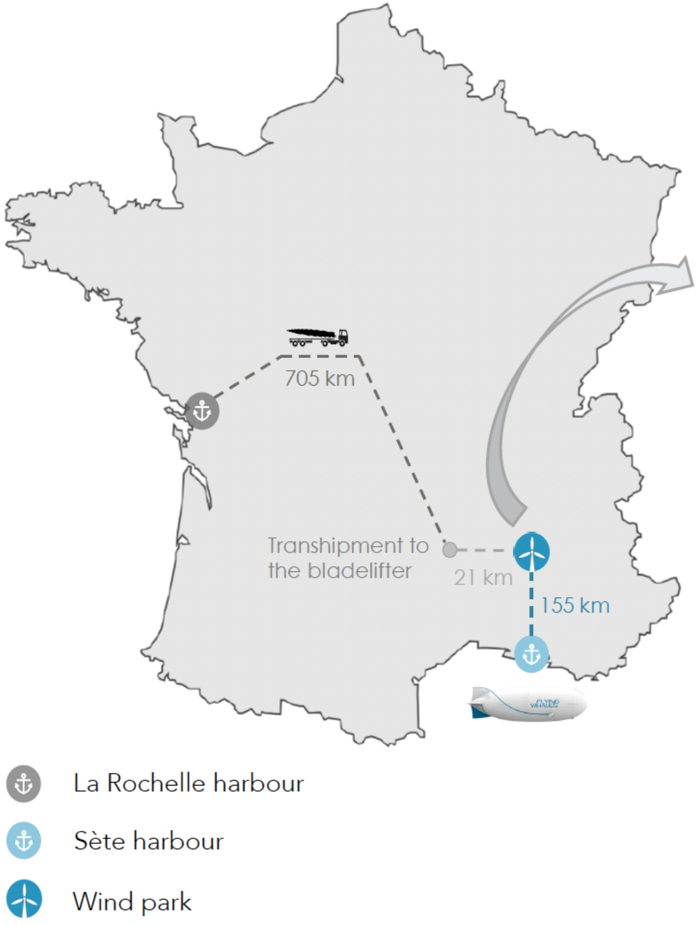
- Transport from manufacturing site in the Netherlands to **Sète by sea cargo** and **Sète to LCA60T pick up area by truck** and then from **the pick-up area to the wind park by airship**.
  - Infrastructures - **Base & FAL : Energy consumption and building construction**
  - Transport - **Airship : fuel consumption, airship production, helium first filling, maintenance and road transport for ballast water**
- Excluded from perimeter :
  - Infrastructures - transport LCA60T – from FAL to base : not significant
  - **Infrastructures - land use change due to artificialization** for pick-up and delivery areas : no land use change, use of existing infrastructure

The following GHG emissions are excluded from the analysis because they are considered identical in both scenario :
- **Energy consumption for the machines and equipment** (cranes, fork lifter, etc..) to carry the blades on the truck at the pick-up site or the delivery site,
- **Road construction and modifications due to the transport of other wind turbines elements.**

Wind park | Scenario illustration

Blades transport operation at *Col de Fioulebise*

Transporting 9 wind blades from harbour to wind park
Comparison LCA60T vs wing carriers & bladelifters



- Wing carrier (705 km) : loading from La Rochelle harbour
  → Sète harbour cannot accomodate trucks for blades above 55 meters
- Bladelifter (last 21 km) including:
  2.5 km road modification to access windpark site: roadworks, landuse change, and tree cutting
- LCA (155 km) : able to load blades from Sète harbour

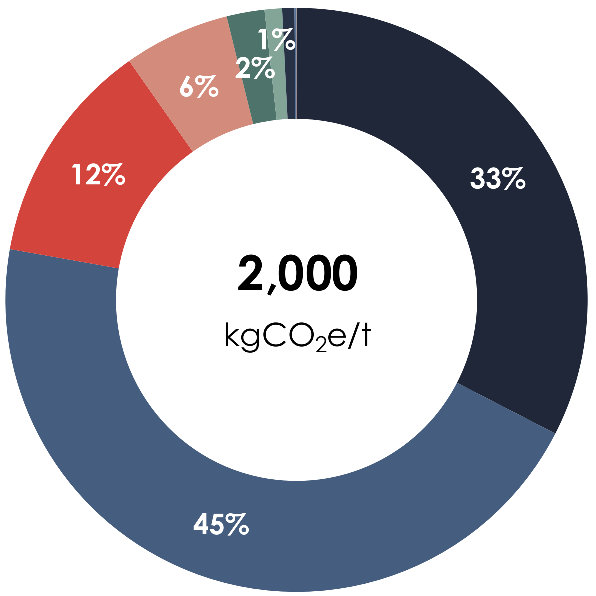
Features

- Blade size: 62 metres
- Number of blades: 9
- Average mass: 15 tonnes
- Location: Col de Fioulebise

Source : FLYING WHALES report

Wind park | The baseline scenario emits 270 tCO_2e or 2,000 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the baseline scenario | tCO_2e, % of total emissions



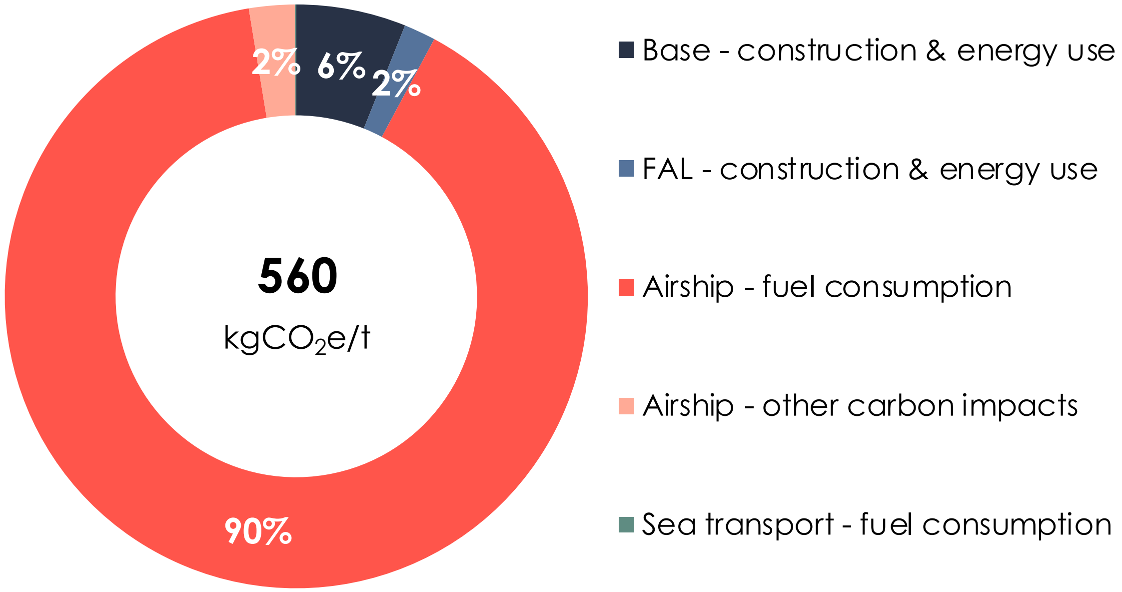
- The baseline scenario emits **about 114 tCO_2e or 2,000 $kgCO_2e$ / ton carried or 30 tCO_2e / blade.**
- **Most of the impact is due to the road works (energy and materials used to make the road) and land transformation** for the blade lifter which needs a widened road to reach Fioulebise.
- Even if Land transformation is temporary in the baseline scenario, carbon stored in soil and biomass released has been considered, since it takes a very long time to come back to normal level (up to 100 years)

⚠ There is high uncertainty on the emission of the Road works (energy and materials used) since the impact od is based on monetary data. Furthermore, trucks and road construction emissions of the reference situation could be lower by 2028/2030 thanks to industry and transportation decarbonation

Notes :
(1) **Road modifications :** Road enlargement of 1m over 2,5km for the blade lifter, based on road survey. The change is temporary
(2) **Sea transport :** distance traveled : 1 665 km from Amsterdam to La Rochelle port by sea cargo
(3) **Wing carrier :**
- **3 wing carriers** were considered for 9 roundtrips in total (one trip = one blade)
- **Distance considered:** From la Rochelle harbor to transhipment location to blade lifter : 705km ; Blade lifter up to the end location : 21km.
- **Other carbon impact considered:** Truck manufacturing and maintenance, and road maintenance, fuel consumption and manufacturing for escort vehicules (2 average cars per truck per trip). Emissions for road construction are not considered because they have already been emitted.

Wind park | The scenario with the kerosene LCA60T emits 74 tCO_2e or 560 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with the kerosene LCA60T | tCO_2e, % of total emissions



- The kerosene LCA60T scenario emits **about 74 tCO_2e or 560 $kgCO_2e$ / ton carried or 8,5 tCO_2e / blade.**
- The vast majority of GHG emissions (90%) are due to the **airship's fuel consumption.**

Notes :
(1) **Sea transport :** distance traveled : 1 665 km from Amsterdam to Sète harbor by sea cargo
(2) **Airship:**
- **Fuel consumption:** 900 kg/h during cruise and 840 kg/h while overing
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

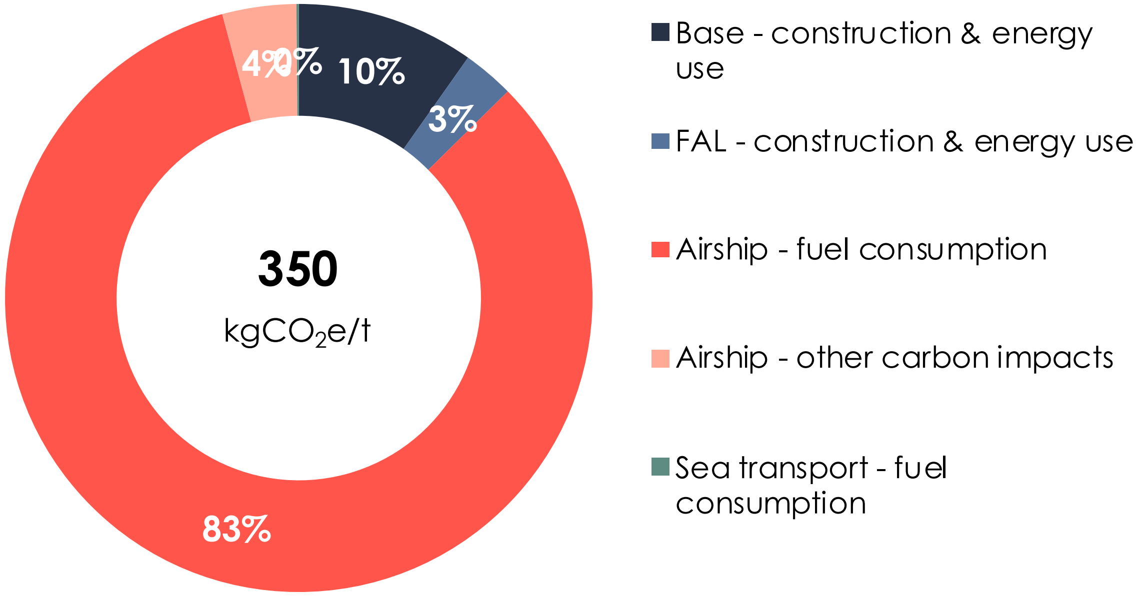
(3) **Base :**
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) **FAL:**
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(5) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Wind park | The scenario with the SAF LCA60T emits 45 tCO_2e or 350 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with the SAF LCA60T | tCO_2e, % of total emissions



Notes :
(1) **Sea transport :** distance traveled : 1 665 km from Amsterdam to Sète harbor by sea cargo
(2) **Airship:**
- **Fuel consumption:** The SAF consumption of the LCA60T is considered as the same as the kerosene, since their physical characteristics are closed
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

(3) **Base :**
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) **FAL:**
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

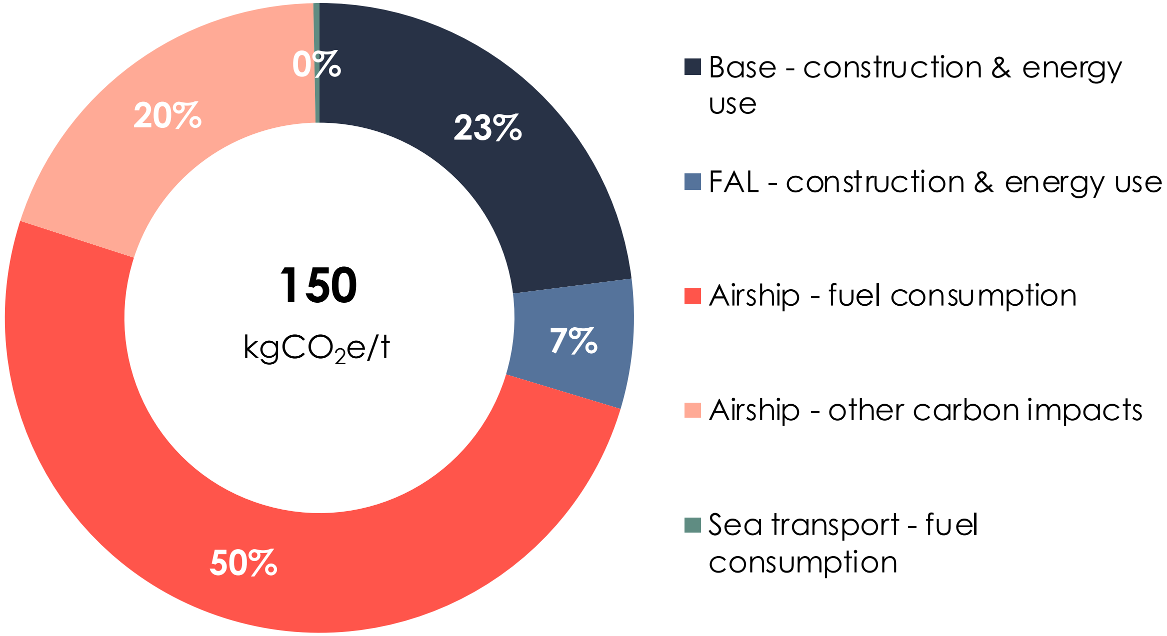
(5) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

- The SAF scenario emits **about 45 tCO_2e or 350 $kgCO_2e$ / ton carried or 5 tCO_2e / blade.**
- Renewable SAF LCA60T enables to reduce emissions by 75% compared to Kerosene LCA60T
- Most of GHG emissions (83%) are due to the **fuel consumption**, especially because it is sill made of 50% Kerosene.
- The SAF made from cooking oil is 6 times less emissive than the jet fuel

⚠ The SAF considered is made from used cooking oil : its impact is low but the resources are very limited. SAF impact from non sustainable resources can be much higher.

Wind park | The scenario with the renewable hydrogen LCA60T emits 20 tCO_2e or 150 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with the renewable hydrogen LCA60T | tCO_2e, % of total emissions



- The renewable hydrogen LCA60T scenario emits **about 20 tCO_2e or 150 $kgCO_2e$ / ton carried or 2,2 tCO_2e / blade.**
- Renewable hydrogen LCA60T enables to reduce emissions by 75% compared to Kerosene LCA60T
- Half of GHG emissions (50%) are due to the **production of the renewable hydrogen consumed**

⚠ Hydrogen considered is made from renewable electricity. It could be much higher if the hydrogen was made from another source

Notes :
(1) **Sea transport :** distance traveled : 1 665 km from Amsterdam to Sète harbor by sea cargo
(2) **Airship:**
- **Fuel consumption:** The hydrogen consumption is based on a ratio assessed by flying whales of 0,3 kgH2/kgfuel consumed
- **Fuel impact :** The hydrogen emission factor has been assessed by Carbone 4 based on data from IEA and ADEME.
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

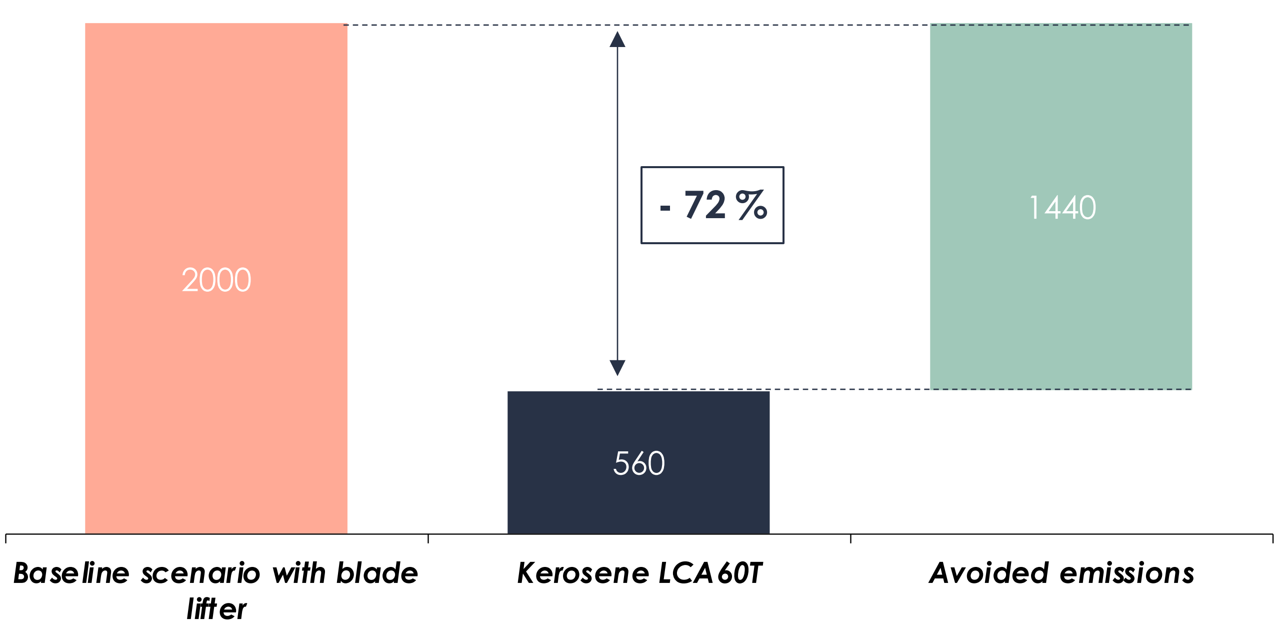
(3) **Base :**
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) **FAL:**
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(5) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Wind park | Using LCA60T avoids 280 kgCO_2e per ton carried in this case study

Added emissions for the windpark case study | *en tCO_2e*

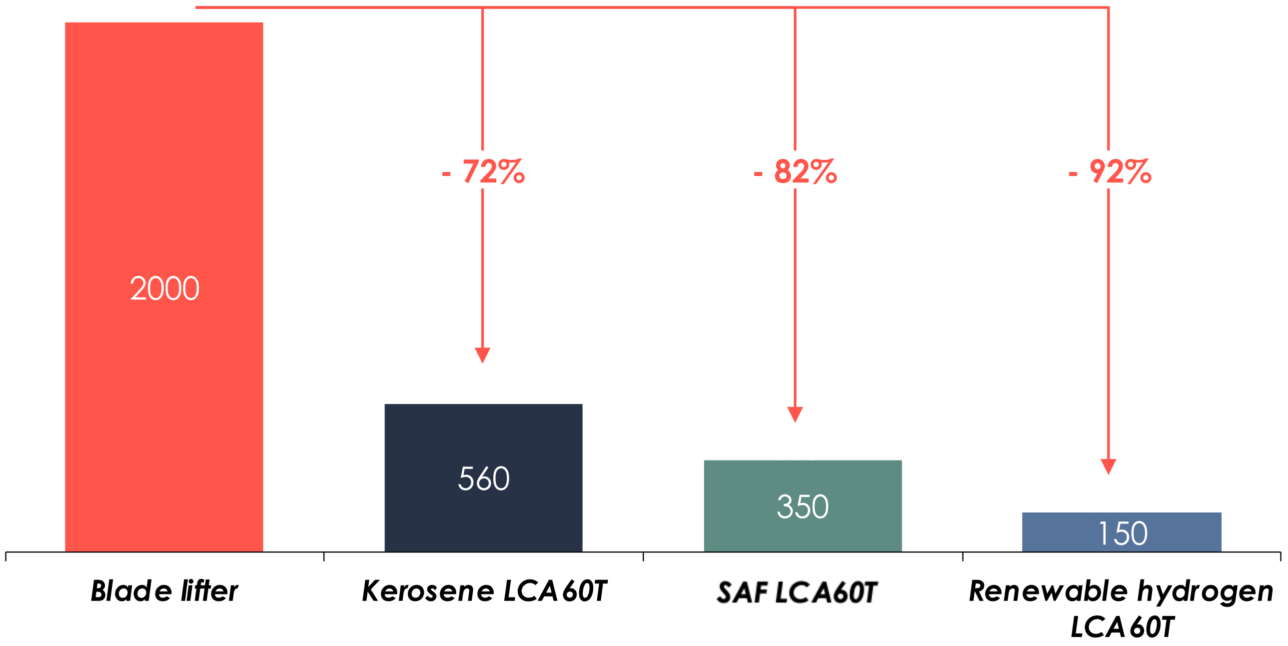


- In this case study, the scenario with LCA60T emits **71% less emissions** than the baseline scenario.
- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation with blade lifter that requires roadworks**

The relevance of LCA60T is due to important roadworks required for the bladelifter to pass in this specific case.

Wind park | Comparison of all scenarios

Comparison of the emissions of each scenario | *kgCO_2e / t carried*



- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation with blade lifter that requires important roadworks and land use change**

SAF made from cooking oil are rare and there is a strong competition for their use

Low carbon H2 is rare and there is a strong competition for their use

Wind park | Uncertainty analysis – Baseline scenario

	Source of emissions	Significance	Degree of certainty of results	Commentary
Baseline scenario	Road works (energy and materials)	■■■	■□□	Use of monetary data and emission factor (less accurate than physical data). The monetary data provided by Flying Whale's client is not precise
	Land transformation	■■■	■■□	Use of physical data, and ADEME land use change emission factor
	Wing carrier – fuel consumption	■■□	■■□	Physical data is used but is an estimate based on the weight of the vehicle and its load
	Wing carrier – escort vehicles	■■□	■■■	Physical data is used
	Wing carrier – other impact	■■□	■■□	Physical data used but other carbon impacts of a wing carrier are an estimate based on the weight of the vehicle and its load
	Sea transport – fuel consumption	■■□	■■■	Physical data is used

Wind park | Uncertainty analysis - Scenario with LCA60T

	Source of emissions	Significance	Degree of certainty of results	Commentary
Scenario with LCA60T	Airship – fuel consumption	■■■	■■■	Fuel consumption for LCA60T and the emission factor used are accurate
	Airship – other carbon impact	■□□	■■■	Specific data for the LCA60T is used
	FAL - construction	■□□	■■■	Building materials for the FAL are based on on real data (Flying Whales 2024 LCA)
	FAL – energy use	■□□	■■■	Energy consumption is specific to the base and for a use in France Metropolitan
	Base - construction	■□□	■■□	Building materials for the base are an estimate based on the FAL and not based on real data
	Base – energy use	■■□	■■□	Energy consumption for the Base is an estimate based on the FAL and not on real data

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Pylon | Perimeter of the case study

Transport operation for the dismantling of 36 pylons at Fioulebise Valley

Baseline scenario

- Transporting dismantled pylons to a deposit zone nearby in the valley **by a helicopter (Super Puma model)**
- Emissions category included in perimeter :
  - Transport - **helicopter : fuel consumption**
- Excluded from perimeter :
  - Manufacturing, maintenance and end of life of helicopter : not significant
- The result of the baseline scenario is highly dependent on the weight of the pylons since it determines the number of roundtrips required by pylon.

Scenarios with LCA60T

- Transporting dismantled pylons to a deposit zone nearby in the valley **by airship.** No matter the pylons weight, the airship transport them in one single piece.
  - Infrastructures - **Base & FAL : Energy consumption and building construction**
  - Transport - **Airship : fuel consumption, airship production, helium first filling, maintenance and road transport for ballast water**
- Excluded from perimeter :
  - Infrastructures - transport LCA60T – from FAL to base : not significant
  - **Infrastructures - land use change due to artificialization** for pick-up and delivery areas : no land use change, use of existing infrastructure

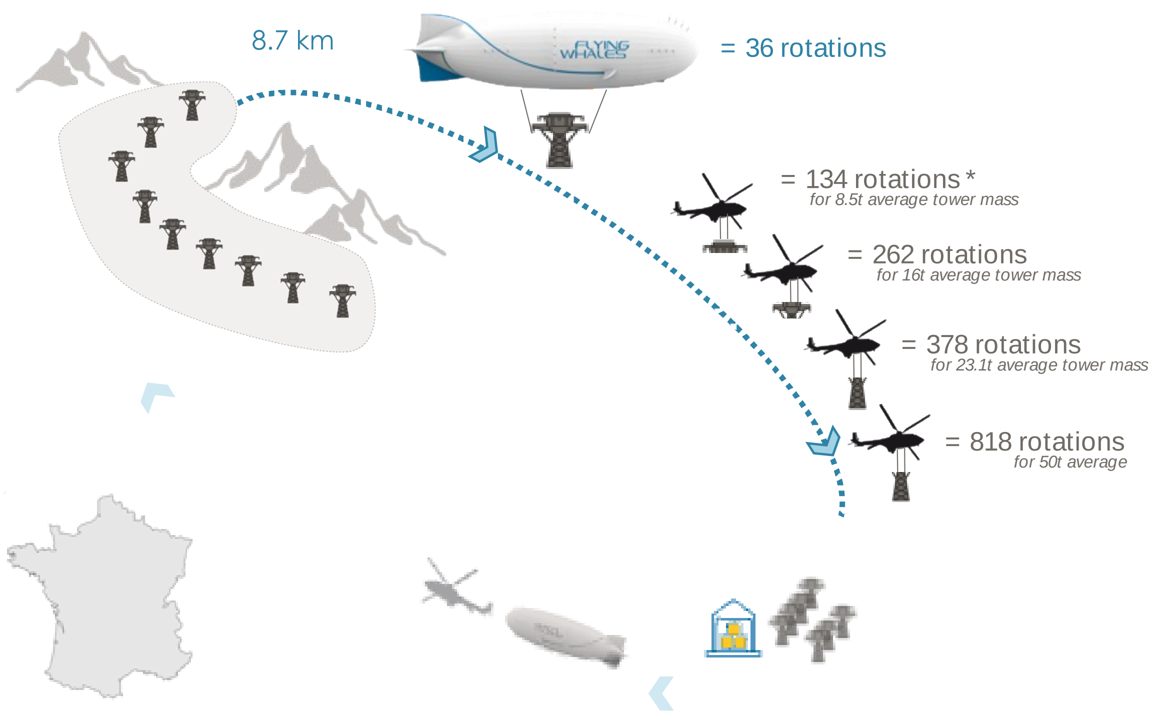
The following GHG emissions are excluded from the analysis :

- Dismantling operation of pylons in the baseline scenario : not significant compared to helicopter energy consumption
- Downstream transport of dismantled pylons from deposit to destination : identical in both scenario

Pylon | Scenario illustration

Transport operation for 36 pylons at Maurienne Valley

Dismantling a 150kV high-voltage line in a mountainous area.
Comparison between LCA60T and helicopter H225



Features

- Number of towers: 36
- Average elevation: 1200 meters
- Average rotation distance: 8.7 km
- Site: Maurienne Valley

** Source : case study Aussois-Echaillon*

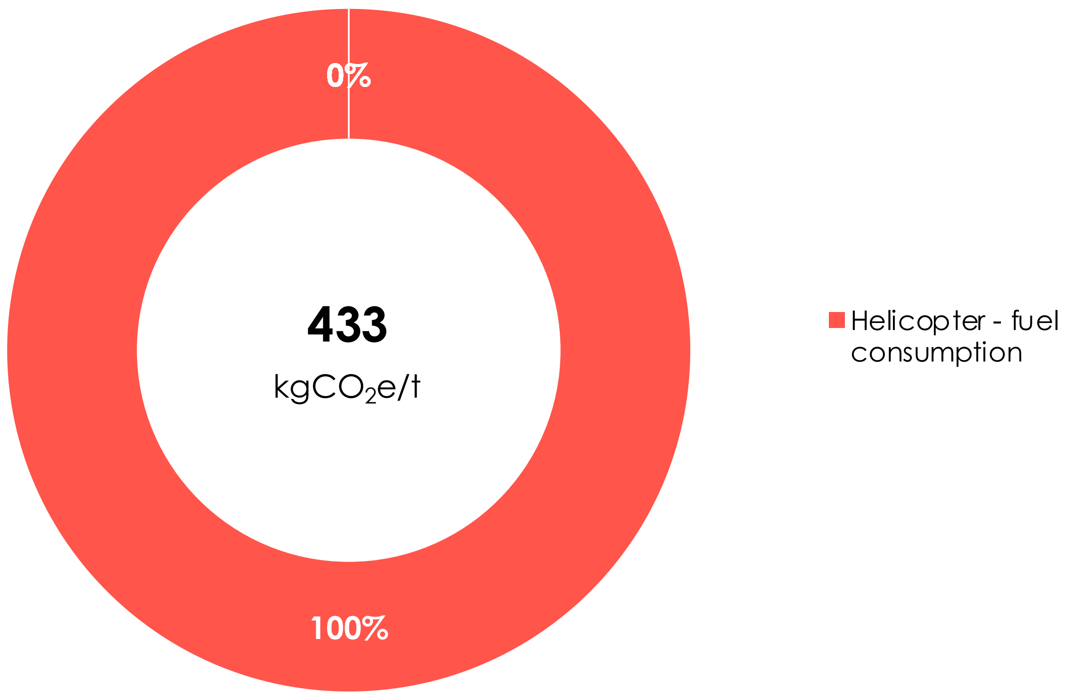
Dismantling a line involves:

- Helicopter operation: cutting pylons into sections (< 2t)
- LCA60T operation: pylon transported in one piece (up to 60t)

Source : FLYING WHALES report

Pylon | The baseline scenario emits 250 tCO_2e or 433 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the baseline scenario | tCO_2e, % of total emissions



- The baseline scenario emits **about 250 tCO_2e or 433 $kgCO_2e$ / ton carried or 7 tCO_2e / 16t pylons.**
- 16 tons pylons have been considered in this use case. Since the helicopter average load is 2,2t at this attitude, it requires 262 rotation to carry out the pylons transportation. The rotation number is highly dependent on the pylon weight.
- The impact is exclusively due to helicopter fuel consumption

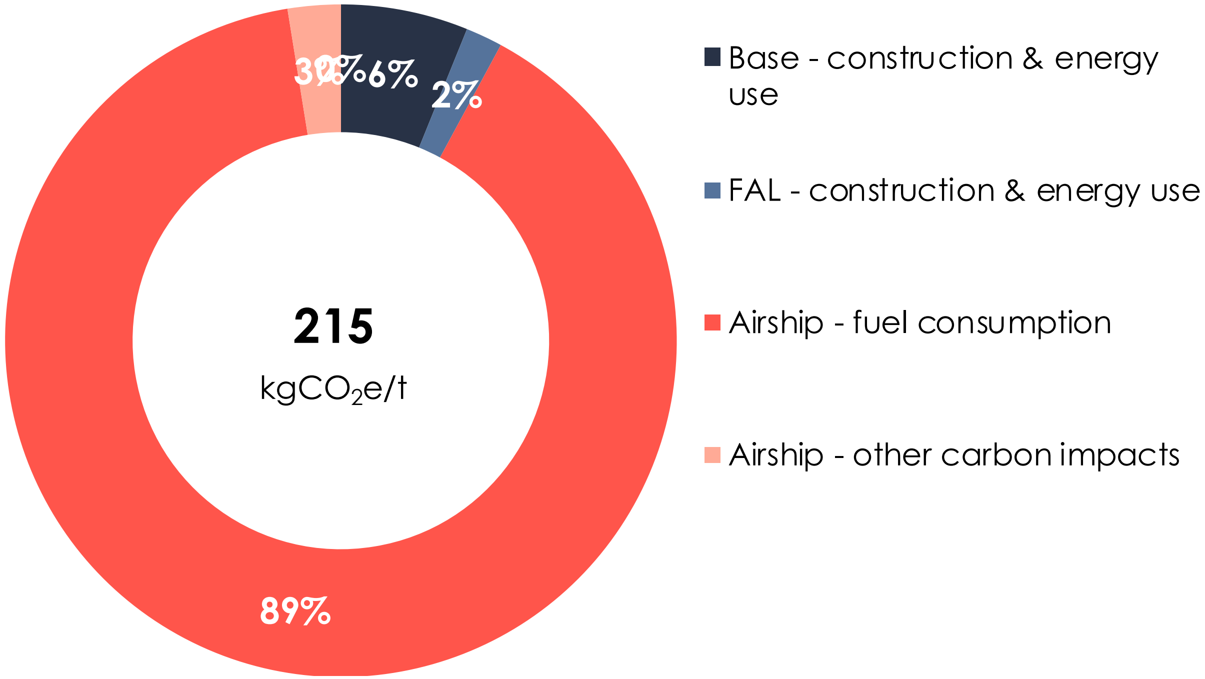
Notes :

(1) **Helicopter :**

- The helicopter requires 262 rotations to carry the 36 pylons dismantled, since it carries 2,2t of goods on average
- The operation time by rotation is assessed considering the daily time of operation (6h) and the average daily number of rotation (16,7)
- The hovering time is assessed based on the assumption that 5min is required to load the helicopter and 5min to unload it. The remaining time of operation is for cruise
- The consumption are based on the data of the Super Puma model

Pylon | The kerosene LCA60T scenario emits 124 tCO_2e or 215 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with kerosene LCA60T | tCO_2e, % of total emissions



- The kerosene LCA60T emits **about 124 tCO_2e or 215 $kgCO_2e$ / ton carried or 3,4 tCO_2e / 16t pylon transported.**
- 16 tons pylons have been considered in this use case. Since the airship carries the pylons one by one, the relative impact ($kgCO_2e$/t or /pylon) is highly dependent on the pylon weight that can range from 8 to 30 tons.
- Most of the impact is due to the **airship fuel consumption**

Notes :

(1) Airship:
- **Fuel consumption**: 900 kg/h during cruise and 840 kg/h while overing
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

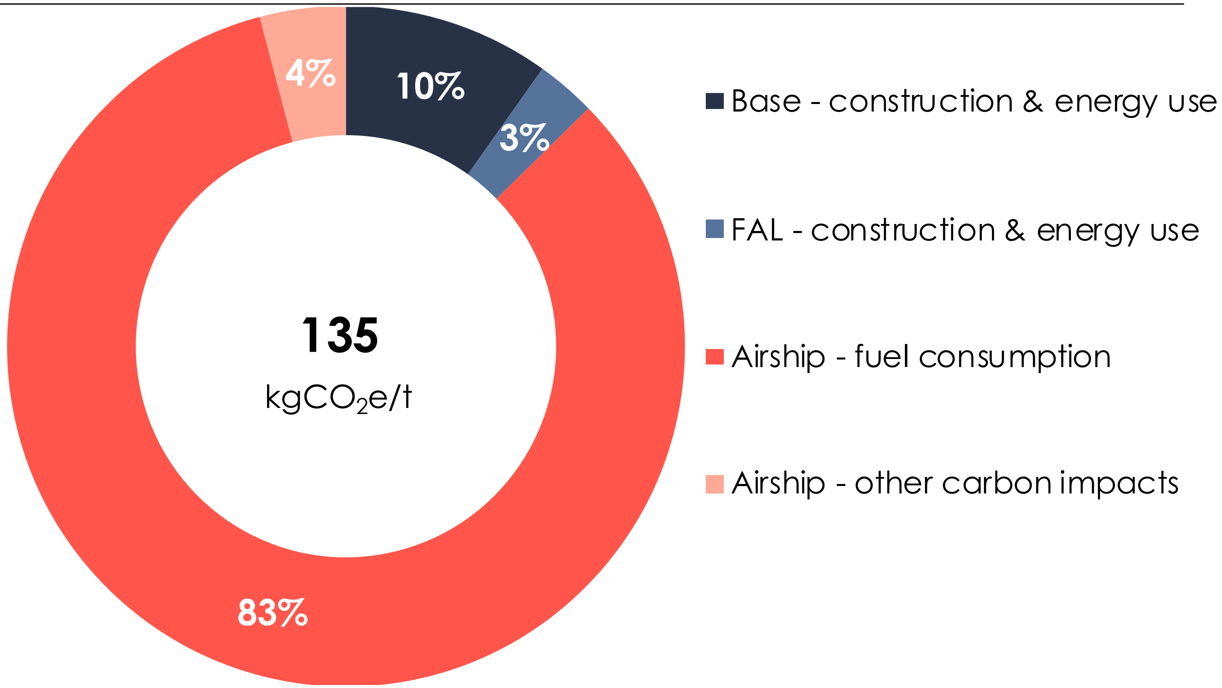
(2) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction**: LCA FLYING WHALES 2024

(3) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction**: LCA FLYING WHALES 2024

(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Pylon | The SAF LCA60T scenario emits 78 tCO_2e or 135 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with SAF LCA60T | tCO_2e, % of total emissions



- The SAF LCA60T scenario emits **about 35 tCO_2e or 135 $kgCO_2e$ / ton carried or 1 tCO_2e / 16t pylon transported.**
- 16 tons pylons have been considered in this use case. Since the airship carries the pylons one by one, the relative impact ($kgCO_2e$/t) is highly dependent on the pylon weight that can range from 8 to 30 tons.
- Most of GHG emissions (83%) are due to the **fuel consumption**, especially because it is sill made of 50% Kerosene.
- The SAF made from cooking oil is 6 times less emissive than the jet fuel

⚠ The SAF considered is made from used cooking oil : its impact is low but the resources are very limited. SAF impact from non sustainable resources can be much higher.

Notes :

(1) **Airship:**
- **Fuel consumption:** The SAF consumption of the LCA60T is considered as the same as the kerosene, since their physical characteristics are closed
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

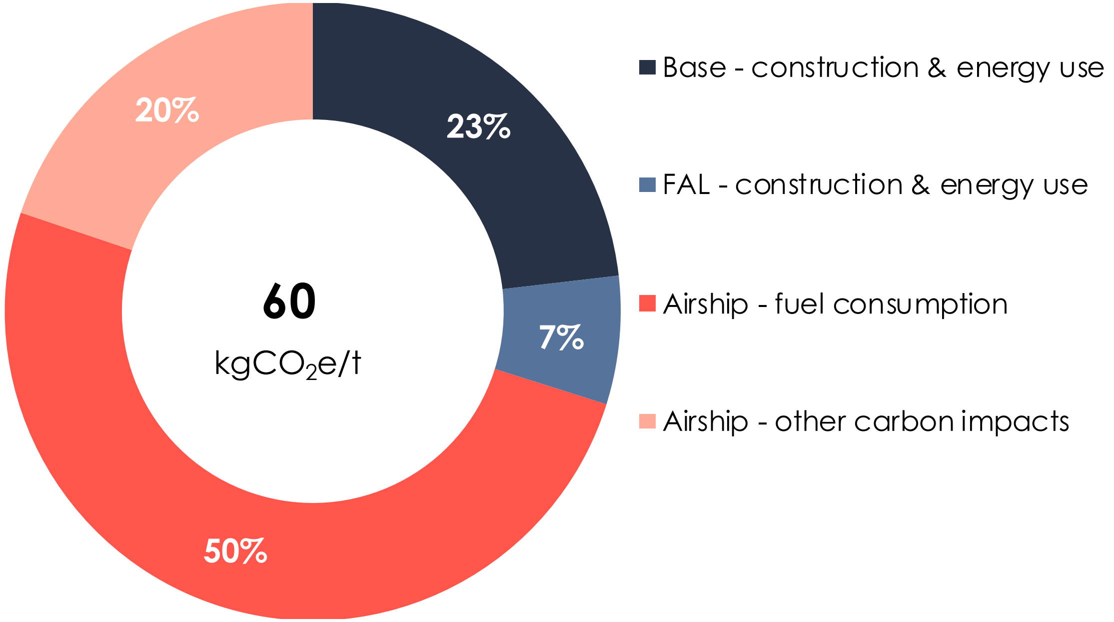
(2) **Base :**
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(3) **FAL:**
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Pylon | The renewable hydrogen LCA60T scenario emits 35 tCO_2e or 60 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with renewable hydrogen LCA60T | tCO_2e, % of total emissions



- The renewable hydrogen LCA60T scenario emits **about 35 tCO_2e or 60 $kgCO_2e$ / ton carried or 1,7 tCO_2e / 16t pylon transported.**
- 16 tons pylons have been considered in this use case. Since the airship carries the pylons one by one, the relative impact ($kgCO_2e/t$) is highly dependent on the pylon weight that can range from 8 to 30 tons.
- Half of GHG emissions (50%) are due to the **production of the renewable hydrogen consumed**

⚠ Hydrogen considered is made from renewable electricity. It could be much higher if the hydrogen was made from another source

Notes :

(1) Airship:
- **Fuel consumption:** The hydrogen consumption is based on a ratio assessed by flying whales of 0,3 kgH2/kgfuel consumed
- **Fuel impact** : The hydrogen emission factor has been assessed by Carbone 4 based on data from IEA and ADEME.
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

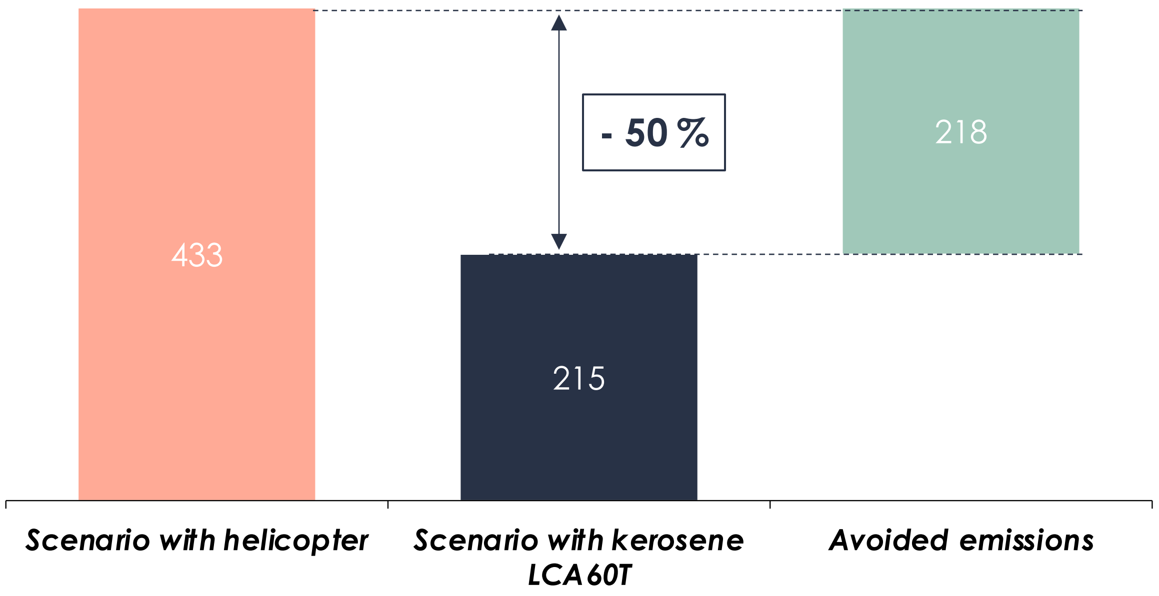
(2) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(3) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Pylon | Using LCA60T avoids 218 kgCO_2e per ton carried in this case study

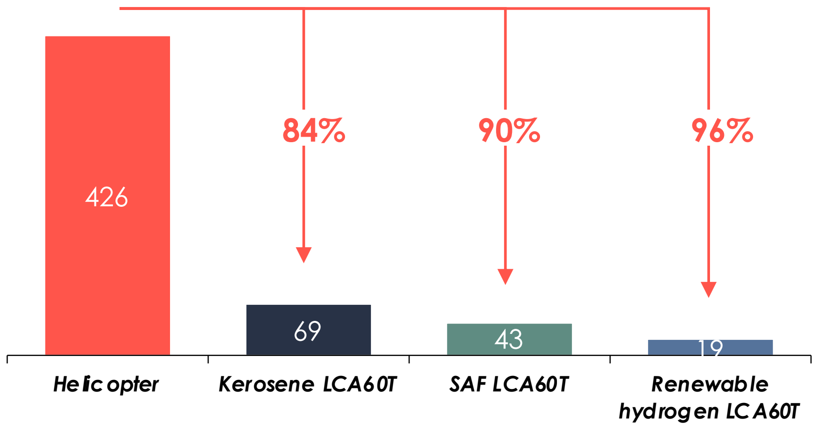
Added emissions for the windpark case study | *en tCO_2e*



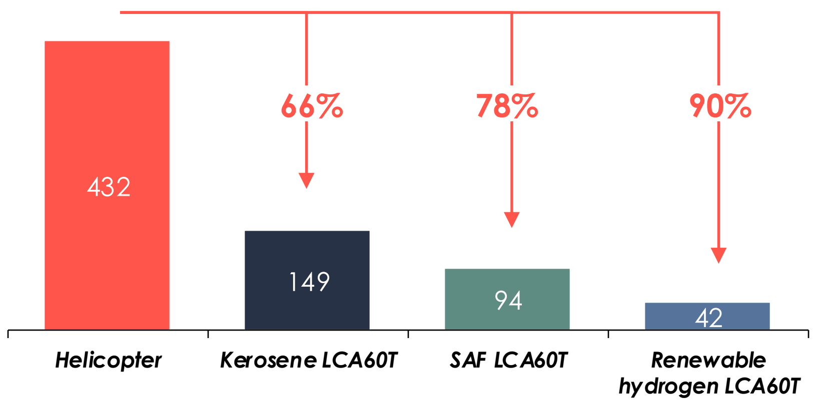
- In this case study, the scenario with LCA60T emits **50% less emissions** than the baseline scenario.
- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation of dismantled pylons with an helicopter**

⚠ The relevance of LCA60T in this case study is dependent on the pylons weight that will determine the number of roundtrips required by helicopter for one pylon (see next slide)

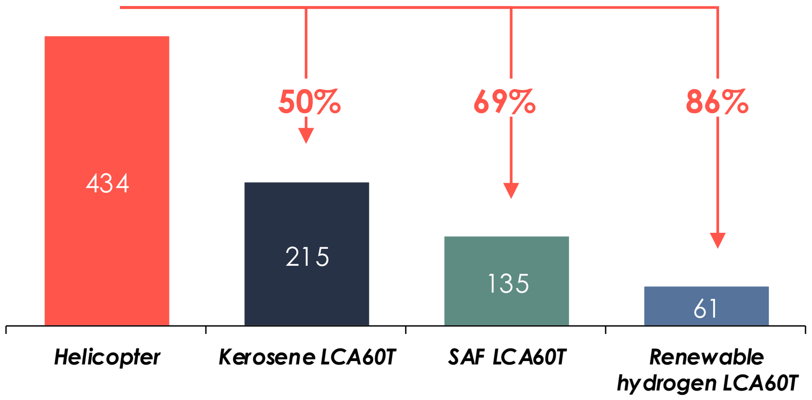
Pylon | Comparison of all scenarios



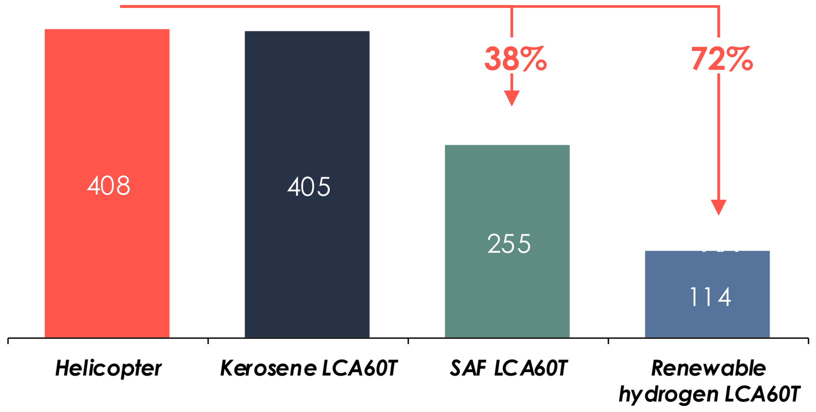
50t pylon



23t pylon



16t pylon



8,5t pylon

The impact reduction of LCA60T pylon transportation compared to helicopter is highly dependent on the pylon weight

Pylon | Uncertainty analysis

Scenario	Source of emissions	Significance	Degree of certainty of results	Commentary
Baseline scenario	Helicopter – fuel consumption	■ ■ ■	■ ■ □	Fuel consumption for helicopter transportation is based on a mode type (Super Puma). This data is a generic data for a helicopter that carries light loads (<5t); it does not consider the load rate that would impact energy consumption
Scenario with LCA60T	Airship – fuel consumption	■ ■ ■	■ ■ ■	Fuel consumption specific to the LCA60T is used
Scenario with LCA60T	Airship – other carbon impact	■ □ □	■ ■ ■	Physical data specific to the LCA60T is used
Scenario with LCA60T	FAL - construction	■ □ □	■ ■ ■	Building materials for the FAL are based on on real data (Flying Whales 2024 LCA)
Scenario with LCA60T	FAL – energy use	■ □ □	■ ■ ■	Energy consumption is specific to the base and for a use in France Metropolitan
Scenario with LCA60T	Base - construction	■ □ □	■ ■ □	Building materials for the base are an estimate based on the FAL and not based on real data
Scenario with LCA60T	Base – energy use	■ ■ □	■ ■ □	Energy consumption for the Base is an estimate based on the FAL and not on real data

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Forestry | Perimeter of the case study

Transport operation for 2,640 tons of wood from plateau des Glières to a storage site at 15km

Baseline scenario

- Transporting wood from plateau des Glieres to a storage site nearby **by truck**
- Emissions category included in perimeter :
  - Transport – **truck** : **fuel consumption, truck fabrication and maintenance, road maintenances**
  - Landscape modifications – **Roadwork, Land use Change and tree-cutting for the blade lifter to pass are included**

Scenarios with LCA60T

- Transporting wood to the storage site nearby **by airship.**
  - Transport - **Airship : fuel consumption, airship construction, helium first filling, maintenance and road transport for ballast water**
  - Infrastructures - **Base & FAL : Energy consumption and building construction**
- Excluded from perimeter :
  - Infrastructures - transport LCA60T – from FAL to base : not significant
  - **Infrastructures - land use change due to artificialization** for pick-up and delivery areas : no land use change, use of existing infrastructure

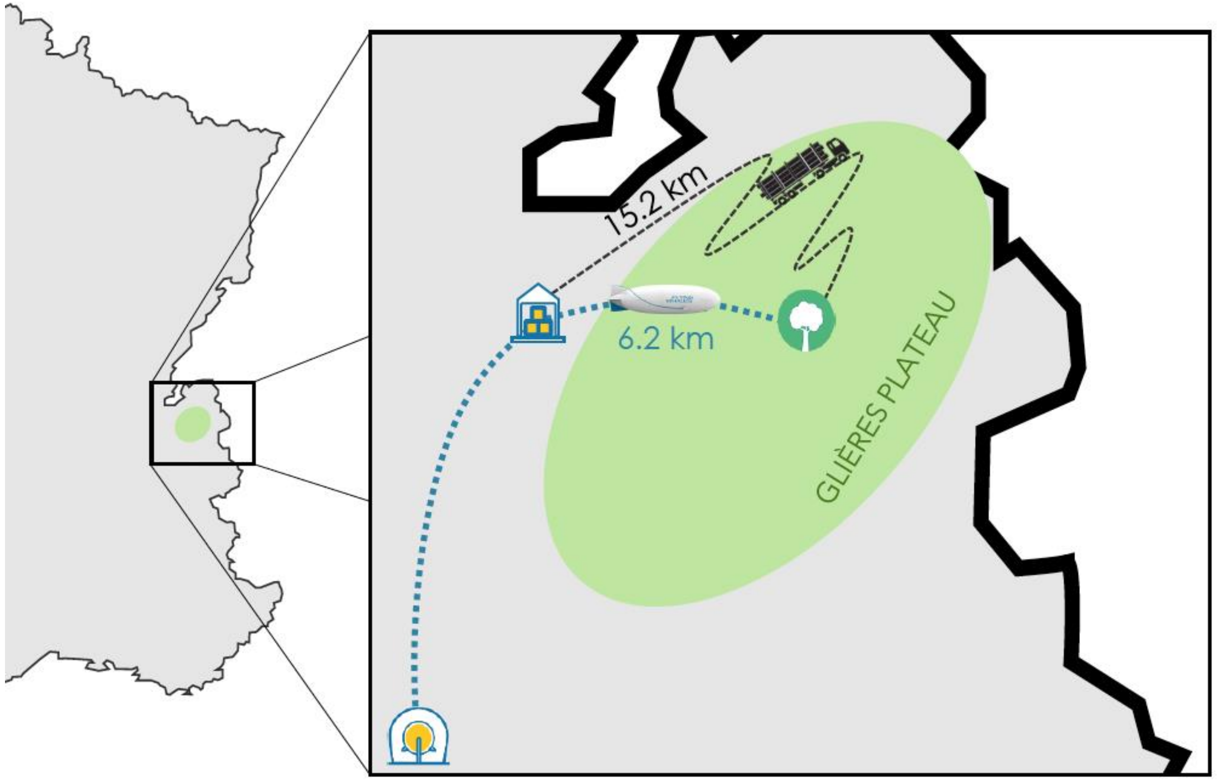
The following GHG emissions are excluded from the analysis because they are considered identical in both scenario :

- Cutting wood operation
- Downstream transport of wood from the storage zone

Forestry | Scenario illustration

Logging operation at « Glières Plateau »

Transport of 3,100m³ of wood from a difficult-to-access plateau to storage site.
Comparison: LCA60T vs. logging trucks with creation of their access road*



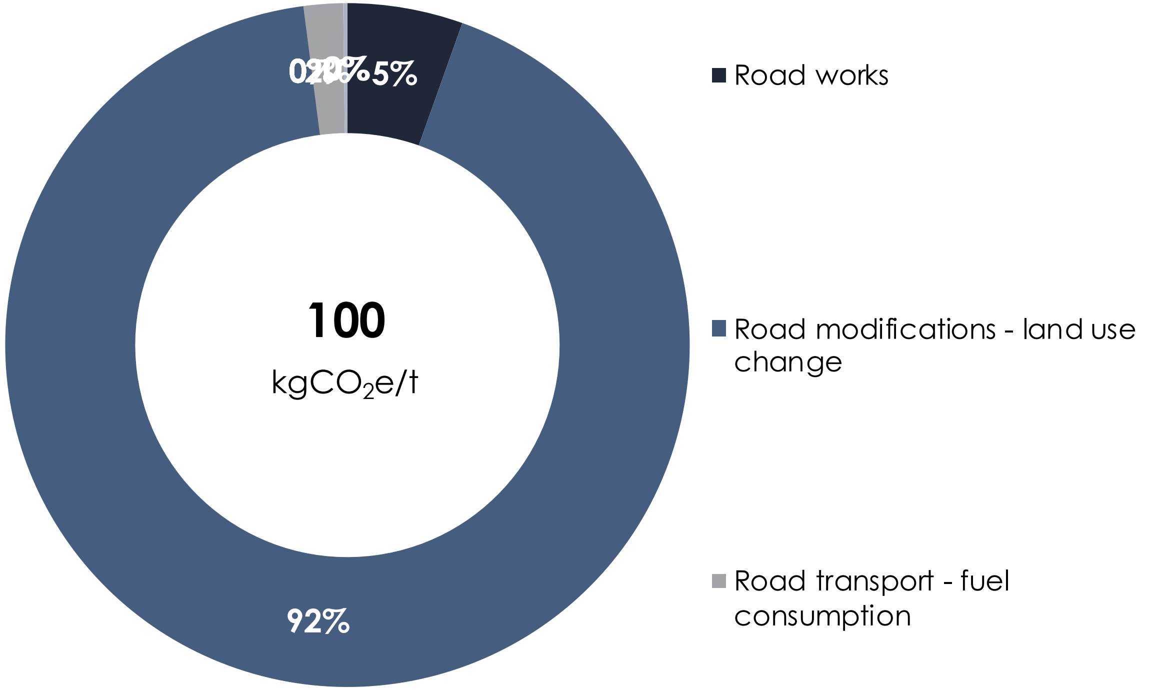
*Carbon-equivalent impacts computed :

- Access road for logging trucks: road construction, removed trees, trucks fuel consumption, emissions amortized over the road's lifespan (15 years)
- LCA60T: FAL, base, fuel consumption

Source : FLYING WHALES report

Forestry | The baseline scenario emits 267 tCO_2e or 100 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the baseline scenario | tCO_2e, % of total emissions



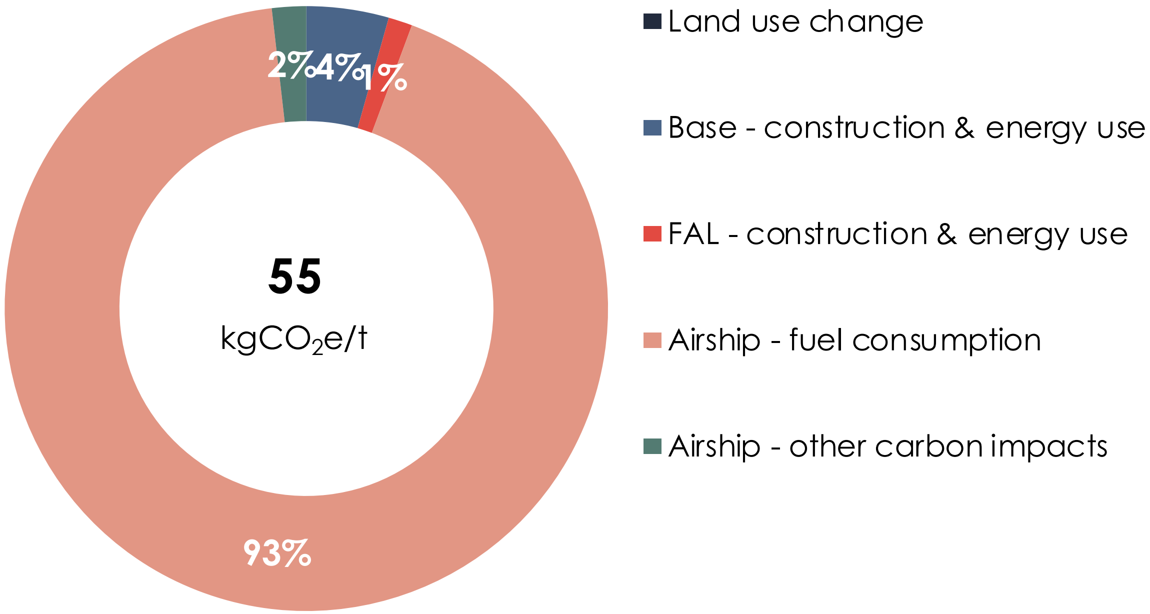
- The baseline scenario emits **about 267 tCO_2e or 100 $kgCO_2e$ / ton carried**
- Most of the impact is due to the road works for the truck to pass. Road works include energy and materials used to make the road and land use change.
- Since the land use change is permanent, both in-ground and biogenic CO_2 removed are taken into account
- The road works impact have been amortized over a period of 15 years, considered as been the road lifespan in these conditions

⚠ There is high uncertainty on the emission of the baseline scenario since the impact od road works is based on monetary data. Furthermore, trucks and road construction emissions of the reference situation could be lower by 2028/2030 thanks to industry and transportation decarbonation

Notes :
(1) **Road modifications :** Road construction of 5m wide built over 15,2km with permanent land use change over a forest

Forestry | The kerosene LCA60T scenario emits 146 tCO_2e or 55 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with kerosene LCA60T | tCO_2e, % of total emissions



- The kerosene LCA60T emits **about 146 tCO_2e or 55 $kgCO_2e$ / ton carried**
- Most of the impact is due to the **airship fuel consumption**

Notes :

(1) Airship:
- **Fuel consumption:** 900 kg/h during cruise and 840 kg/h while overing
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

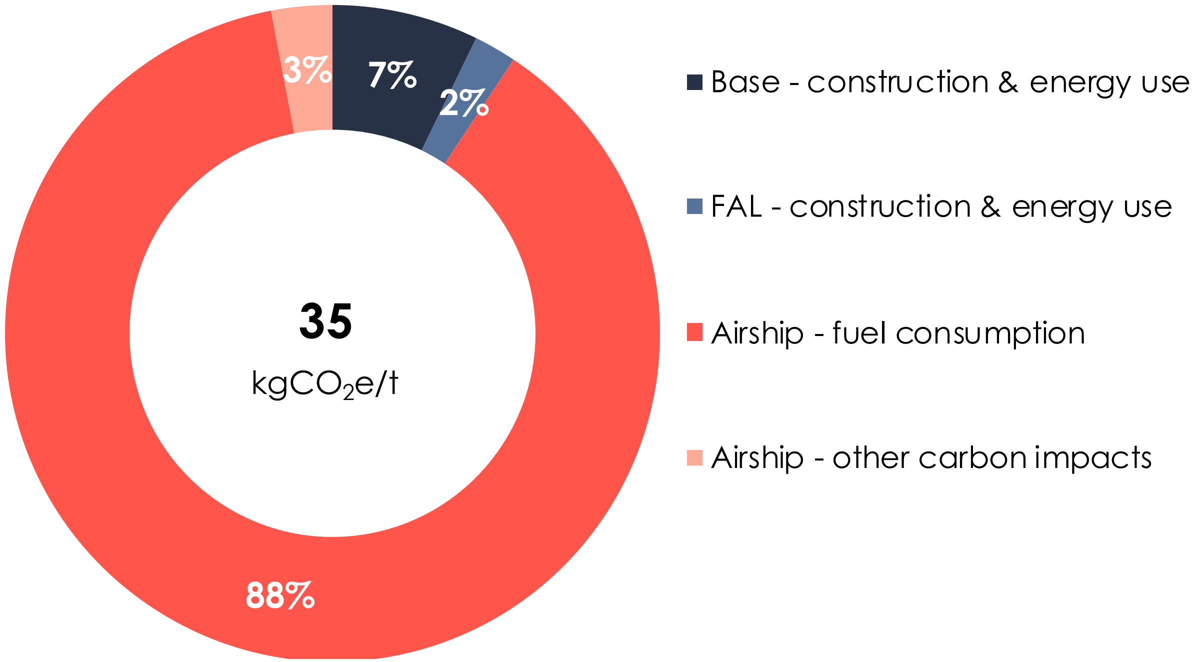
(2) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(3) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Forestry | The SAF LCA60T scenario emits 94 tCO_2e or 35 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with SAF LCA60T | tCO_2e, % of total emissions



- The SAF LCA60T scenario emits **about 94 tCO_2e or 35 $kgCO_2e$ / ton carried**
- Most of GHG emissions (88%) are due to the **fuel consumption**, especially because it is sill made of 50% Kerosene.
- The SAF made from cooking oil is 6 times less emissive than the jet fuel

⚠ The SAF considered is made from used cooking oil : its impact is low but the resources are very limited. SAF impact from non sustainable resources can be much higher.

Notes :
(1) Airship:
- **Fuel consumption:** The SAF consumption of the LCA60T is considered as the same as the kerosene, since their physical characteristics are closed
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

(2) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(3) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
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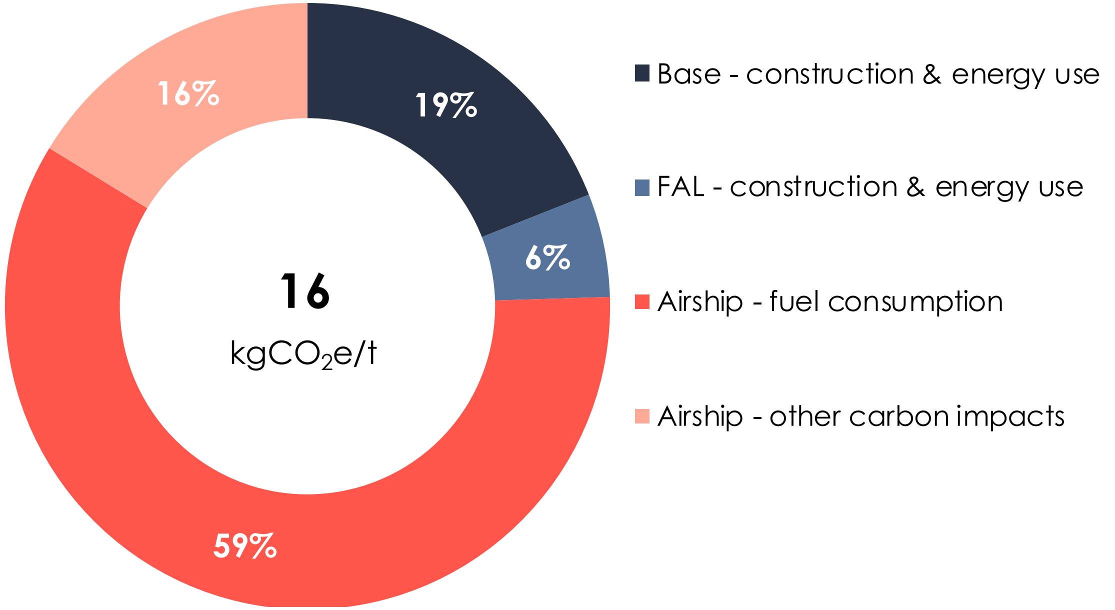
(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Forestry | The renewable hydrogen LCA60T scenario emits 43 tCO_2e or 16 $kgCO_2e$ / ton carried

Breakdown of CO_2e emissions by emissions category for the scenario with renewable hydrogen LCA60T | tCO_2e, % of total emissions



- The renewable hydrogen LCA60T scenario emits **about 43 tCO_2e or 16 $kgCO_2e$ / ton carried.**
- More than half of GHG emissions (59%) are due to the **production of the renewable hydrogen consumed**

⚠ Hydrogen considered is made from renewable electricity. It could be much higher if the hydrogen was made from another source

Notes :

(1) Airship:
- **Fuel consumption:** The hydrogen consumption is based on a ratio assessed by flying whales of 0,3 kgH2/kgfuel consumed
- **Fuel impact** : The hydrogen emission factor has been assessed by Carbone 4 based on data from IEA and ADEME.
- **Other carbon impact studied:** Airship construction, helium first filling, maintenance, and road transportation for ballast water

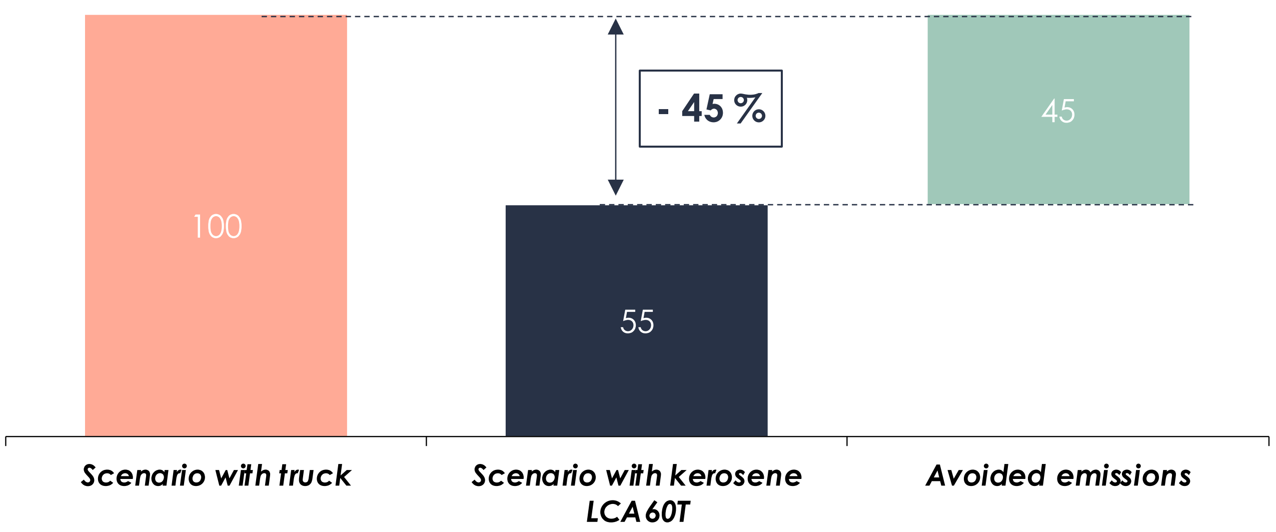
(2) Base :
- **Building lifespan :** 50 years; 230 workdays per year
- **Energy consumption:** 11 MWh for the project (2,5 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(3) FAL:
- **Building lifespan :** 550 years; 230 workdays per year, 10 airships produced/year
- **Energy consumption:** 8 MWh for the project, (9,4 GWh/year, source Données internes FLYING WHALES 2023)
- **Construction:** LCA FLYING WHALES 2024

(4) Use of existing infrastructure for pick-up and delivery platforms (source : FLYING WHALES), therefore no GHG emissions have been considered

Forestry | Using LCA60T avoids 212 kgCO_2e per ton carried in this case study

Added emissions for the forestry case study | *en kgCO_2e/t*

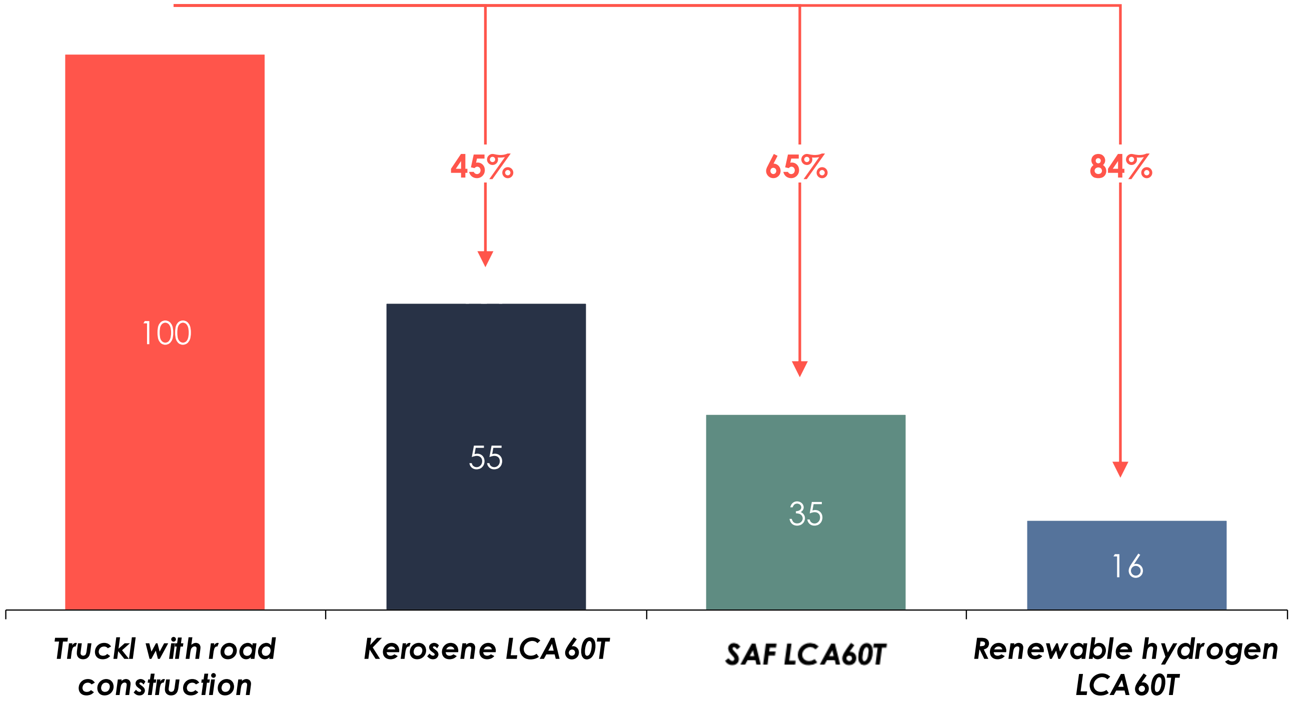


- In this case study, the scenario with LCA60T emits **45% less emissions** than the baseline scenario.
- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with the construction of a road for a truck**

⚠ The relevance of LCA60T in this case study is dependent on the necessity to build a road or not for the truck to pass. Without road works, the conclusion would be different

Forestry | Comparison of all scenarios

Comparison of the emissions of each scenario | *$kgCO_2e$ / t carried*



- This case study shows that **using LCA60T is relevant from a GHG emissions perspective compared to a situation with transportation with truck that requires important road works and permanent land use change.**

SAF are rare and there is a strong competition for their use

Low carbon H2 is rare and there is a strong competition for their use

Forestry | Uncertainty analysis – Baseline scenario

	Source of emissions	Significance	Degree of certainty of results	Commentary
Baseline scenario	Road works	■■□	■□□	Use of monetary data and emission factor (less accurate than physical data). The monetary data provided by Flying Whale’s client is not precise
Baseline scenario	Land transformation	■■■	■■□	Use of physical data, and ADEME land use change emission factor
Baseline scenario	Wing carrier – fuel consumption	■■■	■■□	Physical data is used but is an estimate based on the weight of the vehicle and its load
Baseline scenario	Wing carrier – escort vehicles	■■□	■■■	Physical data is used
Baseline scenario	Wing carrier – other impact	■■□	■■□	Physical data used but other carbon impacts of a wing carrier are an estimate based on the weight of the vehicle and its load
Baseline scenario	Sea transport – fuel consumption	■■□	■■■	Physical data is used

Forestry | Uncertainty analysis - Scenario with LCA60T

Scenario with LCA60T

Source of emissions	Significance	Degree of certainty of results	Commentary
Airship – fuel consumption	■■■	■■■	Fuel consumption for LCA60T and the emission factor used are accurate
Airship – other carbon impact	■□□	■■■	Specific data for the LCA60T is used
FAL - construction	■□□	■■□	Building materials for the FAL are based on on real data (Flying Whales 2024 LCA)
FAL – energy use	■□□	■■■	Energy consumption is specific to the base and for a use in France Metropolitan
Base - construction	■□□	■■■	Building materials for the base are an estimate based on the FAL and not based on real data
Base – energy use	■■□	■■□	Energy consumption for the Base is an estimate based on the FAL and not on real data

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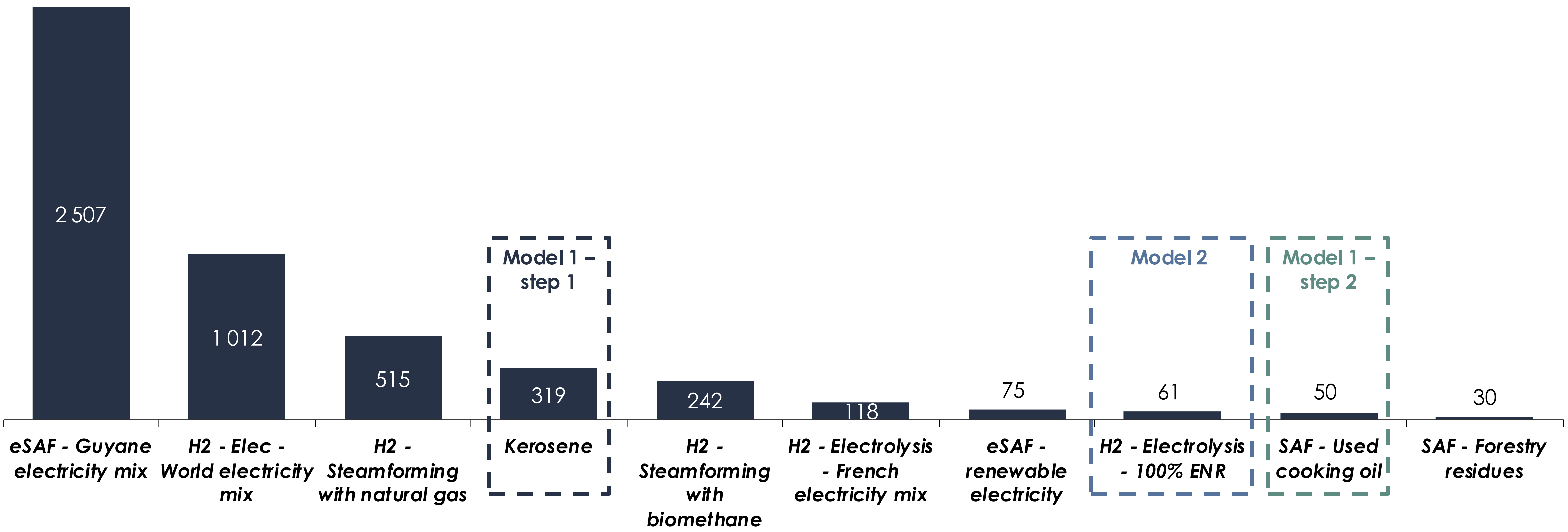
FLYING WHALES avoided emissions can be higher with low carbon fuel alternatives

Comparison of the carbon impact of fuel alternatives for the airship | *gCO_2e/kWh*



NB1 : Pure SAF has been considered here, but the airship can not support more than 50% SAF
NB 2 : The fuel emission factor does not consider the LCA60T model efficiency. The model 2 being more efficient, its emissions are finally lower than the model 1

Key messages from the study

Benefits of FLYING WHALES technology

- Globally, FLYING WHALES is an **interesting alternative from a climate perspective for specific isolated projects that require** :
  - An **emissive mode of transport** such as pirogue, plane or helicopter. The LCA60T is interesting especially for its 60-ton payload capacity that can considerably reduces the number of trips required. Furthermore, the technology relying on helium buoyancy and not aerodynamic lift at high speed, it reduces fuel consumption compared to traditional aircraft.
  - **Significant civil works and land use change** (construction of new roads or roads enlargement) specifically developed for the project. As the LCA60T moves by air and is able to load and unload in stationary flight, the need for new infrastructures is very limited.

Cases where FLYING WHALES enables the development of a new project

- When the **LCA60T enables the development of a new project that would usually not be possible** (ex: because the civil works required would make it unprofitable), FLYING WHALES does not deliver direct avoided emissions. The climate benefits of the LCA60T thus depends on the benefits of the project enabled :
  - If the project made possible avoids emissions (ex : renewable electricity production project), FLYING WHALES solution is an interesting solution from a climate perspective.
  - If the project does not avoid emissions, FLYING WHALES contributes to increased emissions

Potential limits

- A risk for isolated area is to create a **rebound effect**: i.e. projects that would not exist otherwise are developed, leading to emissions. → There could be a **tradeoff between social impact** of de-isolating those areas and the **environmental impact attached**.
- In the cases of an equivalent trip length by road, when there is no need for additional civil works or landscape modification (tree cutting, etc), the LCA60T is generally more emissive than the road-based transport solution.