ENVIRONMENTAL IMPACTS OF SATCOM

ESA Ecodesign Days

September 18th, 2025

Agenda

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Tier 1 assessment

Tier 2 assessment

Tier 3 assessment

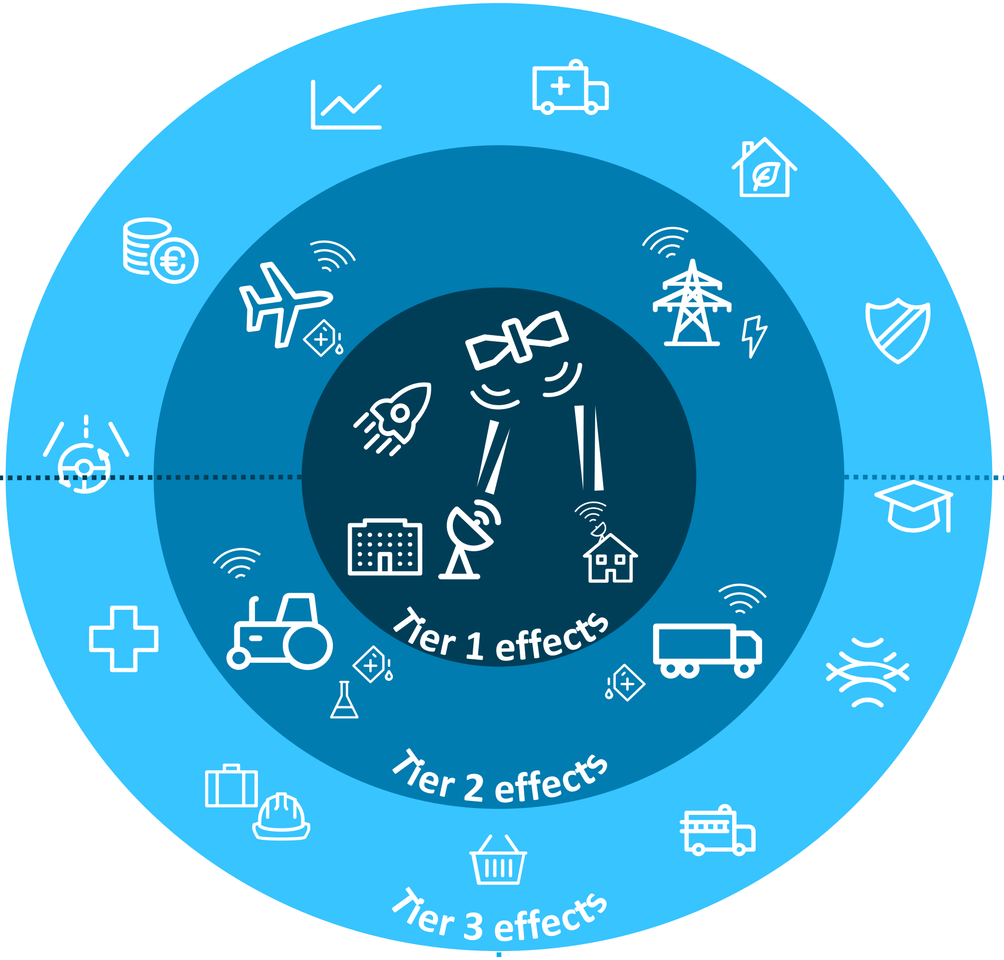
Conclusion

Context and objectives

ESA seeks to assess the environmental impacts of both satcom constellations, and the services enabled by satcom.

Direct environmental impacts (Tier 1 effects)

First order impacts (Tier 1 effects) which are the direct environmental impacts over the whole life cycle of two representatives broadband satcom systems, one operating in GEO and one in NGSO. Identify an initial group of measures applicable to reduce the environmental impact of the satcom production and operations.



Indirect environmental impacts (Tier 2 effects)

Second order impacts (Tier 2 effects) which are the indirect environmental impacts related to the effect of the use of satcom services.

Economic and society impact (Tier 3 effects)

Third order impact (Tier 3 effects) which are the effects of satcom service on the economy and the society with potential “rebound effects”.

The Consortium brings together all the expertise in satellite and ground-based communication

Deloitte Sustainability
Expertise in **methodological studies**, simplified and complete **LCA** and environmental **project management**.

Gangoona and Giovanni Romano
Technology consultants
Expertise in **ground Telecommunications** Systems and services.

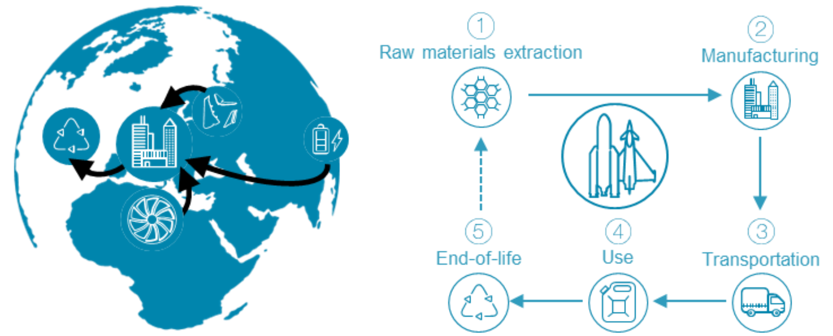
Thales Alenia Space
Global **space manufacturer**
Telecommunications Geostationary and satellite Constellations

Airbus Defense and Space
Global **space manufacturer**
Telecommunications Geostationary and satellite Constellations

How to assess environmental performance?

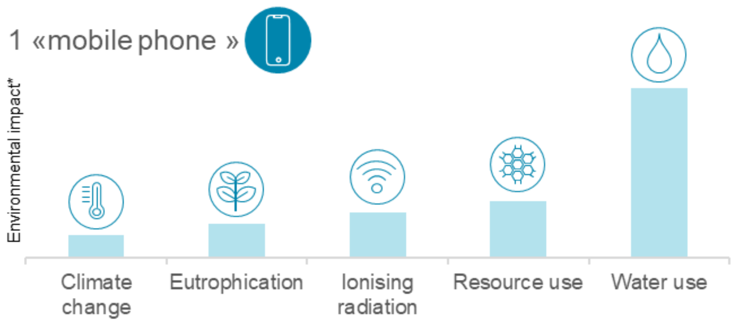
Life Cycle Analysis (LCA) is a widely recognised science-based methodology to assess the environmental performance of products and services during their entire life cycle.

LCA is based on 4 principles:



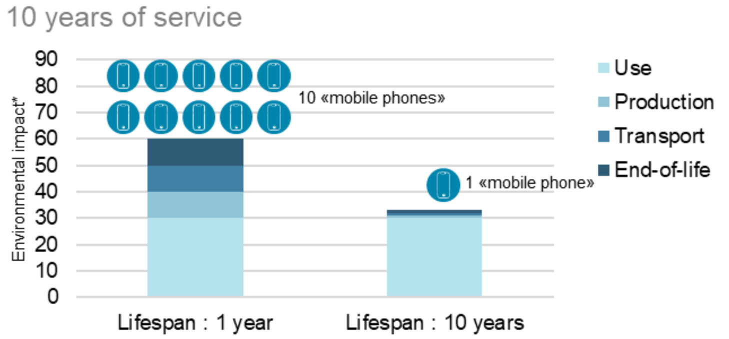
1.MULTI-STEP

It is a **systemic assessment for each life cycle phase** (from the extraction of the material to the end-of-life) of the system under study.



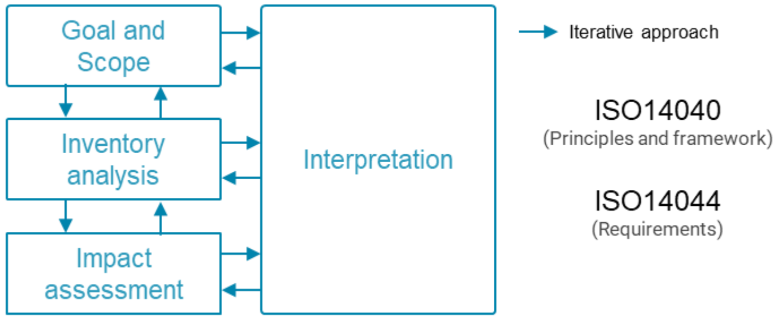
2.MULTICRITERIA

Following the requirements of PEF methodology developed by the European Commission, LCA approach assesses **16 environmental indicators**. 4 other indicators are added in ESA methodology.



3.SERVICE PROVIDED

To assess or to compare a product or a service in terms of environmental impact**, a functional unit** based on the service provided is define as a reference unit.



4.STANDARDIZED

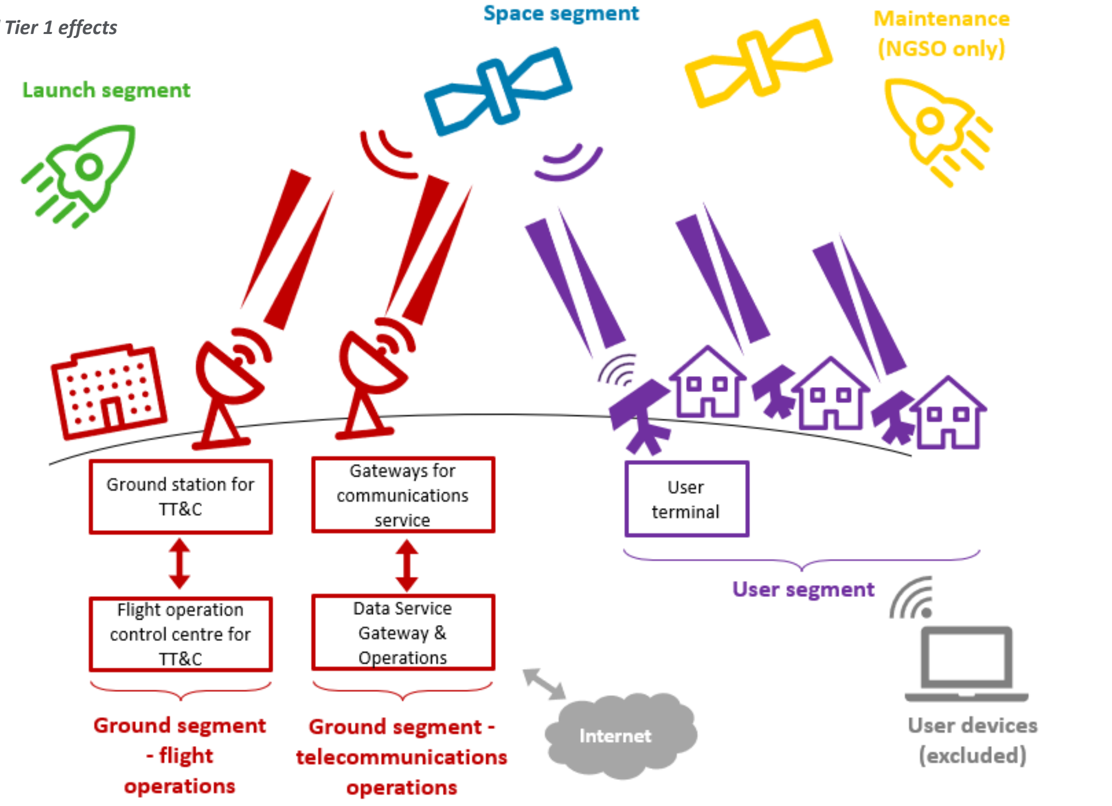
LCA is conducted in 4 steps standardized by ISO 14040 & ISO 14044.

* Values for illustration purposes

The study covered the entire lifecycle of satellite and ground-based communication services, from design to end-of-life disposal

Functional Unit (i.e service provided under study) : *"Provide broadband internet access for 10 years to Europe"*

Assessed Tier 1 effects



Assessed Tier 3 effects

Assessed Tier 2 effects

Two types of users are considered:

GEO system	NGSO system
B2C with 1 million users	B2B with 100,000 companies

Tier 1 assessment

At least 50% of the impacts are from the user segment for all systems

Compared to ground-based systems, NGSO constellation has significantly more impacts on all indicators while GEO system have slightly greater impacts on most indicators

GEO – 1M terminals

92% of the impacts, on average for all indicators, are caused by the **User segment**.

Ground-based telecom systems – 1M terminals

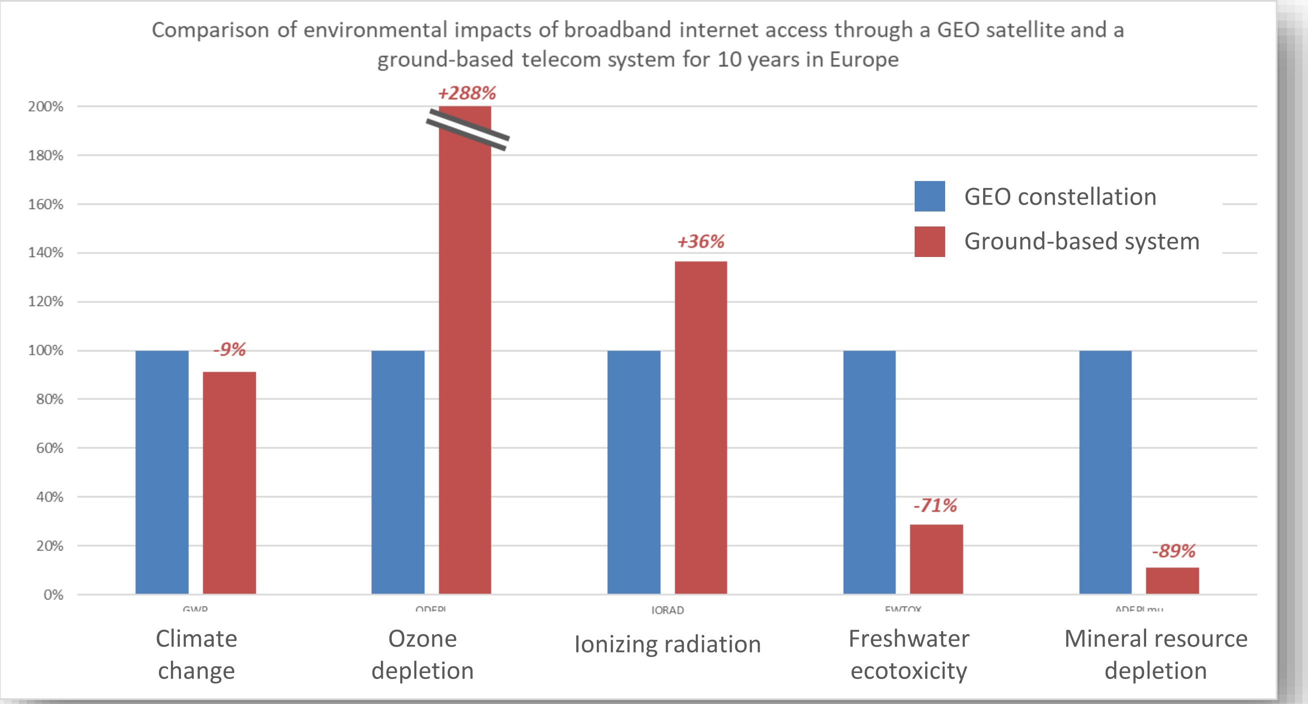
86% of the impacts, on average for all indicators, are caused by the **User segment**.

NGSO – 100k terminals

50% of the impacts, on average for all indicators, are caused by the **User segment** **and 25% by the Ground segment.**

Ground-based telecom systems – 100k terminals

53% of the impacts, on average for all indicators, are caused by the **User segment**.



***Functional Unit (i.e service provided under study)** : "Provide broadband internet access for 10 years to Europe"*

Ecodesign solutions for future works by segment

A focus on the ecodesign of connectivity devices or the use of direct-to-device services could be done.

User segment

Ecodesign of connectivity devices:

- Deploy standardised devices that are compatible with both LEO and GEO satellites
- Refurbishing or reconditioning of existing chipsets to extend their lifecycle and reduce the need for new component manufacturing

Direct-to-device services:

- Use on standard consumer devices to eliminate the need for dedicated connectivity terminals (SpaceX & T-Mobile, Huawei & China Telecom)
- Emerging startups, such as Lynk Global, are also investing in the construction of satellite constellations dedicated to providing direct-to-device connectivity
- Integrate 5G technology into terminals could offers additional benefits

Ground segment

Optimising the ground segment primarily involves reducing the number of sites and associated energy consumption.

- Mutualise ground stations
- Reuse of existing infrastructure, particularly buildings, is also a significant consideration.
- Adopt new types of gateways, such as Gateway Arrays developed by ThinKom

Space segment

Several ecodesign actions can also be implemented, primarily in manufacturing and propulsion.

- Use of recycled materials, such as aluminium.
- Integrate of bio-based materials in manufacturing.
- Adopt sodium-ion batteries as alternatives to traditional technologies.
- Replace xenon or krypton with iodine for propulsion or introduce new manufacturing processes for xenon.

Tier 2 assessment

Precision farming (fuel optimisation) and road freight optimisation for the GEO system, as well as in-flight connectivity for the NGSO system, have the greatest potential to generate savings

GEO system

Difference in impacts > 5%

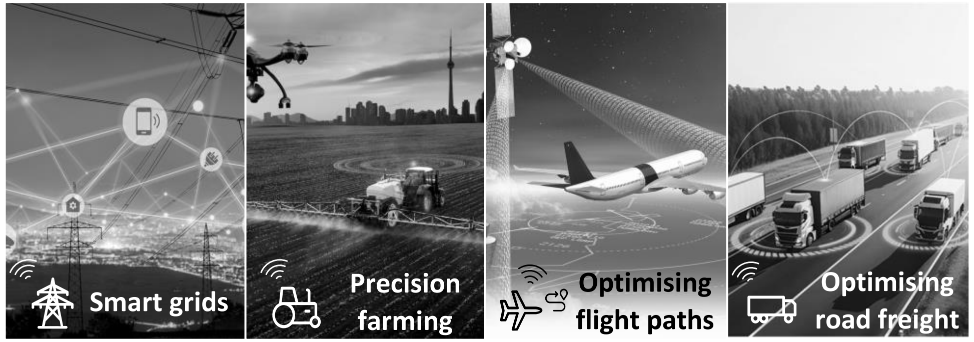
-10% to -15% on climate change and acidification

- 5% to -10% on ozone depletion and climate change

Negligible difference in impacts

NGSO system

-10% to -15% on primary energy consumption, on acidification and on climate change

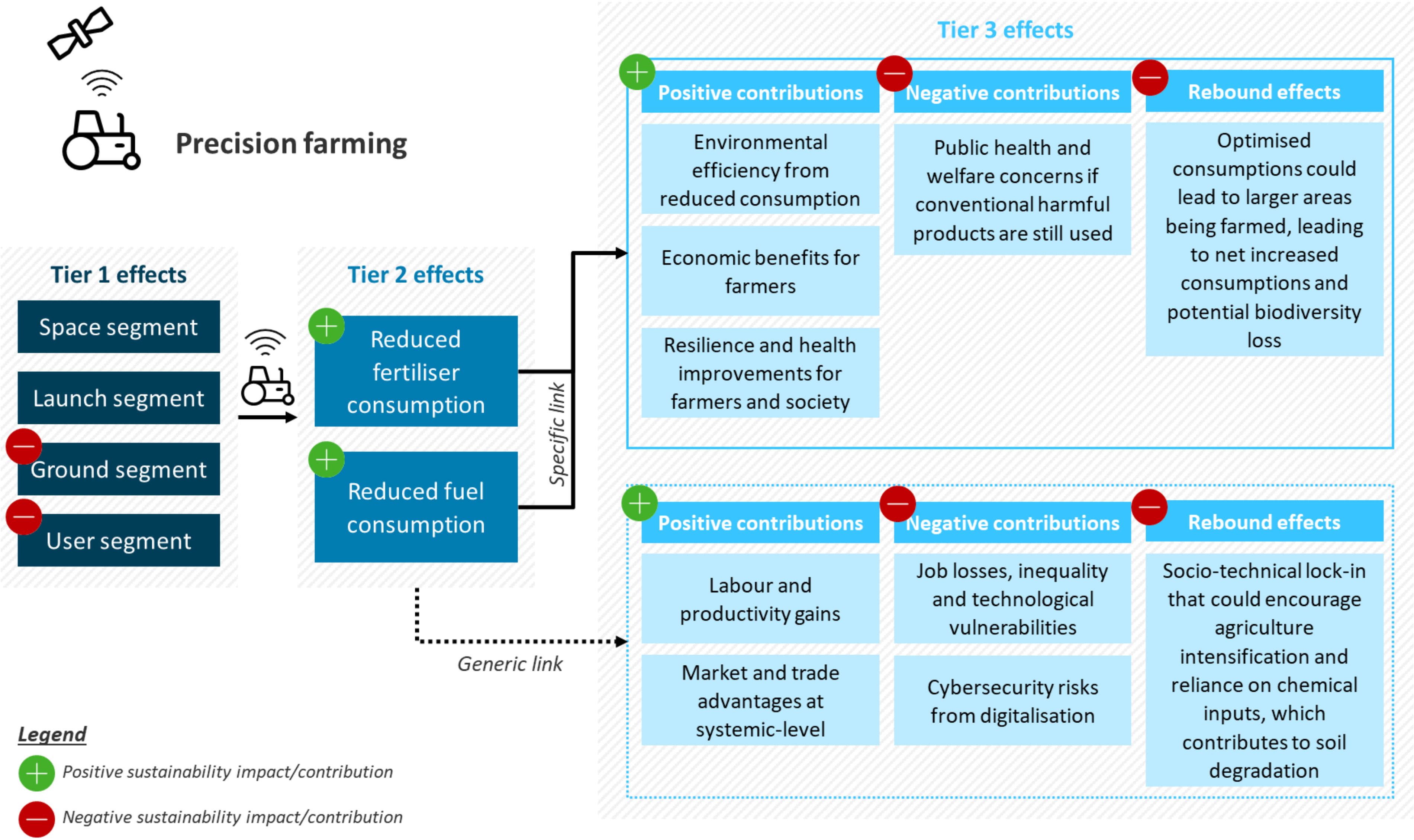


The difference in impacts between the Tier 1 effects and the potential Tier 2 effects, or environmental savings, varied **from <1% to 15% in environmental savings**, across all assessed indicators (climate change, ozone depletion, acidification, resource use and primary energy consumption).

These potential savings need to be interpreted with caution, as **major limits were involved** in the calculations and estimations.

Tier 3 assessment

Precision farming provides potential positive contributions to the environment, water resources and conduct of business and negative contributions to the intensification of agriculture, biodiversity and farmers dependency.



Each application has positive and negative contributions while any optimisation could lead to rebound effects with an increased demand or a social-technical lock-in effect.

Positive contributions

- **Optimise fuel/electricity/ fertiliser consumption** from Tier 2 assessment
- Improve **safety measures** during flight or road freight and for coordination during a natural disaster
- **Enhance market and consumer-related aspects** with monitored energy consumption, enhanced productivity in farms, optimised costs for airlines or identified new opportunities with e-commerce
- Create **skilled jobs** and **business opportunities** for the satcom sector

Negative contributions

- Amplify **cybersecurity risks** for all applications, specifically the transportation sector being the second most targeted
- Degrade **working condition** on farms and logistics hub and **employment challenges** with job replacement for all applications
- Increase **business competition** and **monopolies of large private entities**, due to technological advancement and cost reasons
- **Undermine sovereignty of states** with private companies dominating the space sector

Rebound effects

- **Increase overall consumption and demand**, due to optimisation which can offset the benefits

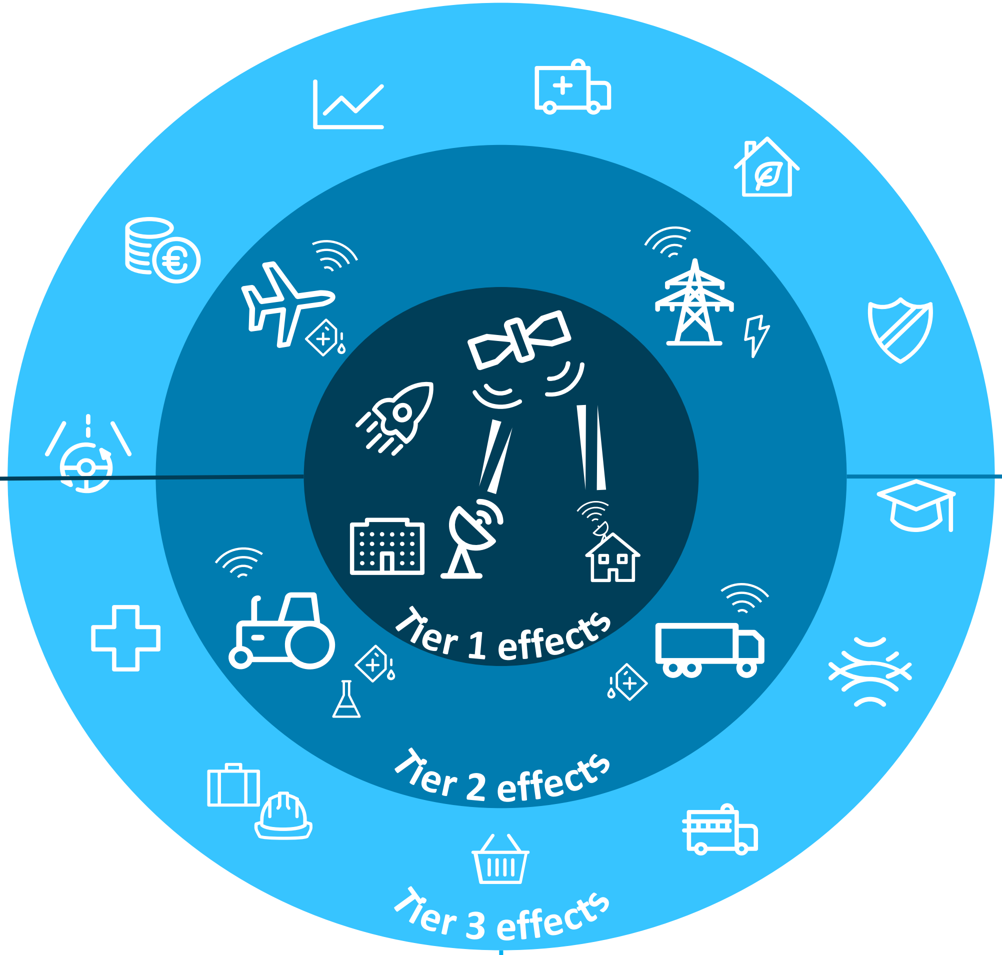
  It is the case for all applications except connectivity in disaster area or remote location.
- Induce **socio-technical lock-in effect** by not shifting to alternative cleaner technologies and only optimising a high-impact conventional one like current means of transportation or intensive agriculture

Conclusion

The main limitations in all assessments stem from a lack of data and methodological choices that could influence the conclusions

Tier 1 effects – Limits

- Inherent limits of LCA methodology
- Methodological choices and exclusion
- Data availability and data estimations



Tier 2 effects – Limits

- Allocating environmental savings to satcom
- Quantifying environmental savings
- Scaling the environmental savings to the required Tier 1 functional unit
- Literature and publicly available data only
- Extrapolation of data

Tier 3 effects – Limits

- Literature and publicly available data only

3 key messages to remember from the study

1

Direct environmental impacts of satcom are driven by the user segment

The **user segment and ground segment are** the largest contributors for all systems.

Compared to ground-based communication, NGSO constellation has **significantly more impacts** while GEO system has slightly greater impacts on most indicators.

A focus on the **ecodesign of user segment terminals** could be a more promising avenue for more significant environmental impact reductions.

2

Potential benefits enabled by satcom

Quantification of **potential benefits enabled by satcom** needs to be improved.

The greatest potential environmental savings were observed for **precision farming, optimising of road freight and in-flight connectivity**.

Positive contributions could be **counterbalanced with negative contributions** like cybersecurity and **rebound effects** with an increased demand and lock-in effects.

3

Sat-based and ground-based communication are complementary

Satellite telecommunication and ground-based telecommunication are **not always used in the same cases** (eg remote vs high density areas).

They are **complementary** and are necessary for **European governance and sovereignty**.

Further study should continue to explore different scenarios relating to satcom, including **hybrid networks, synergies with other space-based technologies,** other satcom applications and different geographic and temporal scopes.

Questions