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UNDERGROUND STRUCTURES & THE ECOLOGICAL TRANSITION

This document is intended for stakeholders involved in the design, construction, operation and maintenance of underground structures.

It is published in a context where the ecological transition towards sustainable development is a major societal challenge that must now be integrated into all new land use planning and infrastructure projects.

It is also important to take into account the ecological transition in repair or renovation projects.

The aims of this document are to:

- provide some reference data on CO_2 emissions due to underground structures;
- identify the environmental challenges associated with these structures and highlight the main levers for action which can reduce their impact;
- provide some methodological guidelines for the sustainable design of underground structures;
- highlight how the use of underground structures can contribute to the development of more sustainable solutions for mobilities, cities and regions.

Underground structures and the ecological transition: what exactly are we talking about?

The French General Commission for Sustainable Development (CGDD) defines the ecological transition as **a concept aimed at establishing a new economic and social model in order to meet the ecological challenges of our century.** The notion of transition emphasises the acceleration of change towards sustainable **development through concrete actions and local citizen-driven initiatives.**

Underground structures are defined as:

- road, rail and guided transport **tunnels**;
- **technical structures**: sewerage and stormwater drainage networks, research and logistics infrastructures;
- **urban underground spaces** housing various functions, such as stations, shopping centres, theatres, gymnasiums, swimming pools etc.

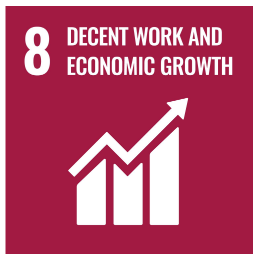
UNDERGROUND STRUCTURES & SUSTAINABLE DEVELOPMENT

Underground structures can contribute to 10 of the 17 sustainable development goals (SDGs) identified by the United Nations to meet global challenges by 2030.

Ensure the comfort and safety of users and local residents. Preserve air quality and the acoustic environment.

Preserve water resources. Distribute and purify water for the population.

Capture and produce energy (geothermal, hydroelectric).



Develop local employment during construction and operation.

Support industry and promote innovation through sustainable construction and operation.

Connect regions and neighbourhoods. Promote more serene uses of the surface

Develop the circular economy. Manage and recycle waste and excavated materials.

Limit Greenhouse gas (GHG) emissions and make cities more resilient to extreme weather events.

Ensure the continuity of green infrastructures. Limit land artificialisation.

Develop a national strategy for underground structures and bring together stakeholders.

The SDGs cover all aspects of sustainable development, such as climate, biodiversity, energy and water, as well as economic prosperity, peace and education...They form the core of the "2030 Agenda" adopted by the UN in 2015.

For more information: sdgs.un.org/fr/goals

ROAD TUNNELS & CO_2 emissions

A FEW FIGURES

FOR THE TUNNEL STRUCTURE

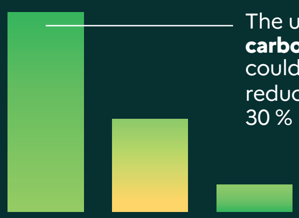
conventional construction method

55 to 80%

of construction emissions in tonnes of CO_2 equivalent (tCO_2e) **are due to construction materials**.

90%

of CO_2e emissions from construction materials **are due to concrete and steel.**



FOR EQUIPMENT

construction and operation*

from 1 to 6 tCO_2e

per linear metre over 100 years are emitted by **lighting systems.** The use of LEDs can reduce these emissions by at least 20%.

from 0,5 to 5 tCO_2e

per linear metre over 100 years are emitted by **ventilation systems.**

In comparison:

1 tCO_2e is the equivalent of a flight from Paris to New York.

10 tCO_2e represent the average annual emissions of a French person.

*estimated figures based on current operating scenarios

Key facts...

- The impacts of a tunnel's construction mainly depend on its dimensions and the geology encountered.
- During operation, the impacts are mainly related to the power consumption of equipment and to a lesser extent to equipment renewal and recycling.
- About 65 % of French road tunnels have lighting. They account for 95% of the cumulative length of all tubes.
- About 15 % of French road tunnels are ventilated. They account for 70 % of the cumulative length of all tubes.
- Throughout the structure's life cycle, the supply of materials and products, as well as waste disposal, can have a significant impact, depending on distances and modes of transport.

Illustration...

Below is an example for a 2,000 [illegible]. The CO_2 equivalent [illegible] for construction, equipment and traffic are given for [illegible] 100 [illegible] and correspond to [illegible] 40,000 vehicle[illegible] 126 g CO_2/km/vehicle.

CONSTRUCTION

55,000

tonnes of CO_2e

come from construction materials.

In comparison, this is equivalent to the annual emissions of 5,500 French people.

EQUIPMENT

15,000

tonnes of CO_2e

come from lighting and ventilation systems. (manufacturing, maintenance and recycling of equipment).

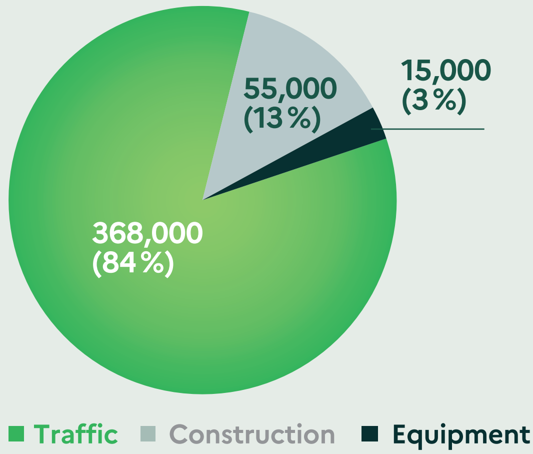
TRAFFIC

368,000

tonnes of CO_2e

come from vehicles (traffic and emission rates assumed to be constant).

Breakdown of emissions in tonnes of CO_2e over 100 years



n.b. In this example, only lighting and ventilation systems have been taken into consideration.

Note

If this tunnel avoids the use of a route that is 6 times longer, the emissions due to the tunnel will be offset in just 3 years!

TOWARDS MORE SUSTAINABLE UNDERGROUND STRUCTURES

Main ecological challenges & levers of action

The majority of the levers of action below help to combat climate change. By reducing CO_2 emissions, they not only enable more sustainable structures to be designed, built and operated, but also contribute to the resilience of cities and regions.

Promote energy efficiency

- Promote construction sites that are less energy-consuming, by renewing and maintaining the fleet of construction machinery and vehicles.
- Limit transportation for the supply of materials and products, as well as for waste disposal.
- Choose more energy-efficient equipment.
- Rethink tunnel operation organisation to limit field interventions.
- Take advantage of the thermal stability of the subsoil, to reduce air conditioning or heating requirements.
- Capture and produce energy from structures in operation (geothermal energy, solar panels near the structure...).

LED lighting in the Marange cut-and-cover tunnel (© CETU)

Preserve the natural and living environment

- Integrate the underground into urban planning to reduce land use and heat islands, promote a more serene use of the surface and reduce real estate pressure.
- Optimise ventilation and improve air quality in tunnels and at tunnel portals.
- Use the underground to protect the population from extreme weather events (e.g. water storage to prevent flooding).
- Ensure rational water management that respects the environment during construction and operation.

Old port district in Marseille (© V. Michiel)

Facilitate the mobility transition

- Identify the risks and challenges associated with the development of active transport modes, new propulsion modes and automated vehicles.
- Develop regulations and technical guidelines to ensure the safety of users.
- Integrate new modes of transport into existing tunnels and adapt these structures and their operation accordingly.

Croix-Rousse tunnel (Lyon): tube for active transport modes and public transport (© CETU)

Develop the circular economy

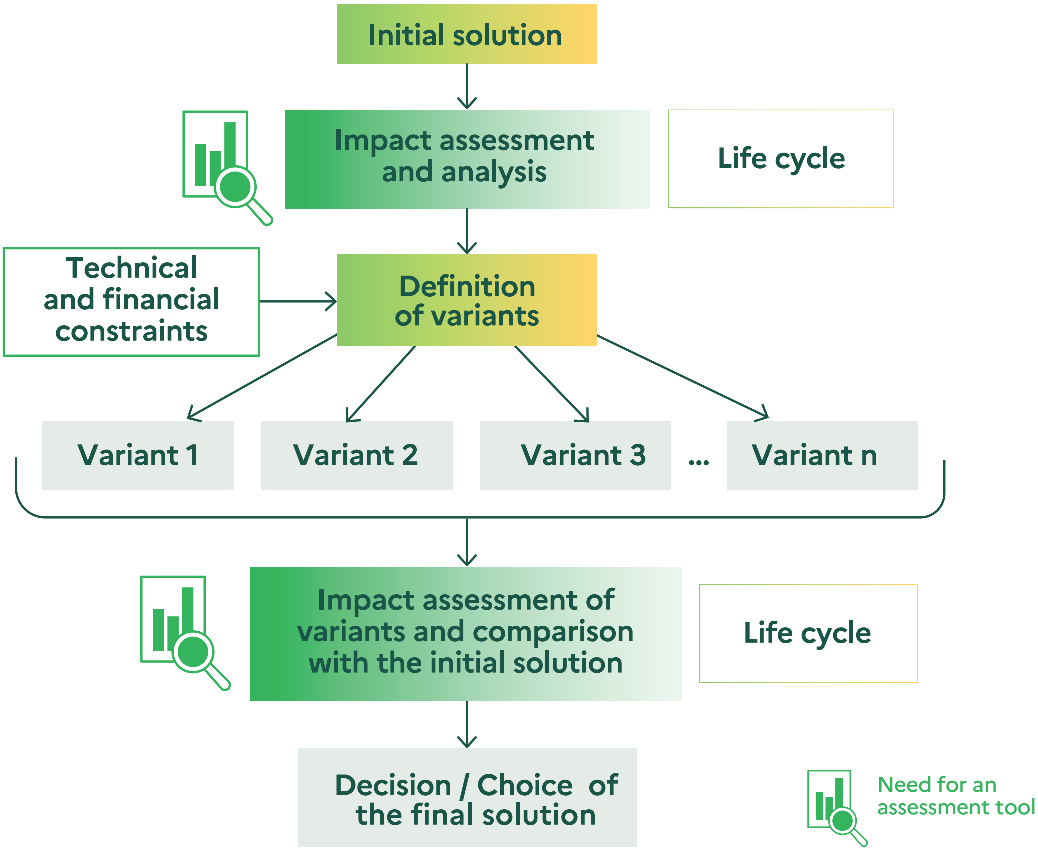
Preserve resources and limit waste:

- optimise the design of structures by adopting a rational use of materials and equipment, based on informed choices;
- select products that incorporate materials from recycling channels by developing the reuse and recovery of equipment and materials (excavated materials in particular);
- choose equipment that is maintainable and recyclable ;
- ensure the maintenance of equipment and structures to extend service life.

Trommel used to sort excavated materials (© CETU)

ECO-DESIGN:
a systemic approach to reduce environmental impacts throughout the entire life cycle

The ECO-DESIGN APPROACH



A two-step implementation to aid decision-making

1 In the first step, the eco-design approach allows a comparison of the underground solution with above-ground solutions, in addition to reflections on the possible pooling of requirements (multifunctionality study).

2 Once the underground solution has been approved, the approach can be used to optimise the design and operation of the structure, by comparing different possible routes, construction methods and the choice of materials and products.

Life cycle analysis (LCA): an efficient assessment tool

WHAT IS IT?

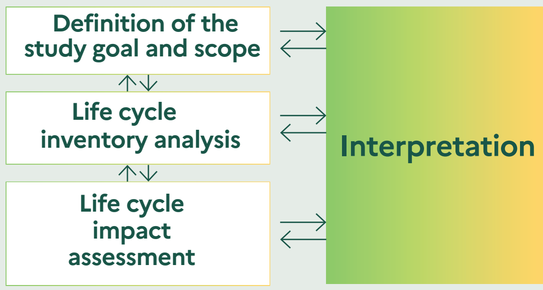
Based on a proven regulatory framework, LCA is a multi-criteria method applicable to civil engineering structures. It enables the assessment of their potential environmental impacts throughout their entire life cycle.

LCA in 4 steps

Identification of assumptions and system boundaries; choice of functional unit

Quantification of material and energy flows entering and leaving the system under study

Conversion of flows and aggregation within different impact categories.



Regulatory framework
NF EN ISO 14040
NF EN ISO 14044
...

Several impact indicators
Global warming, resource depletion, energy use, eco-toxicity...

INSIGHT FOR DECISION-MAKING

Based on several environmental impact indicators, LCA enables an objective comparison of different solutions. It enriches technical and financial analyses by providing decision-makers with environmental insights.

Example: comparison of construction material impacts for three design solutions

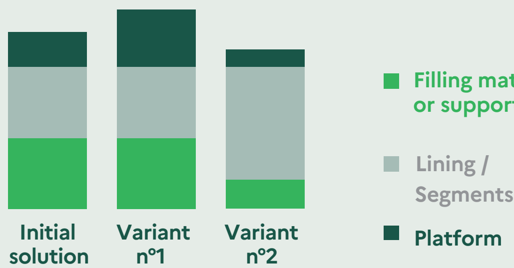
Initial solution:
Conventional method with straight invert

Variant n°1:
With a reverse-arch invert

Variant n°2:
Mechanised tunnelling with a TBM

Result for one linear metre of tunnel

Example: "climate change" indicator

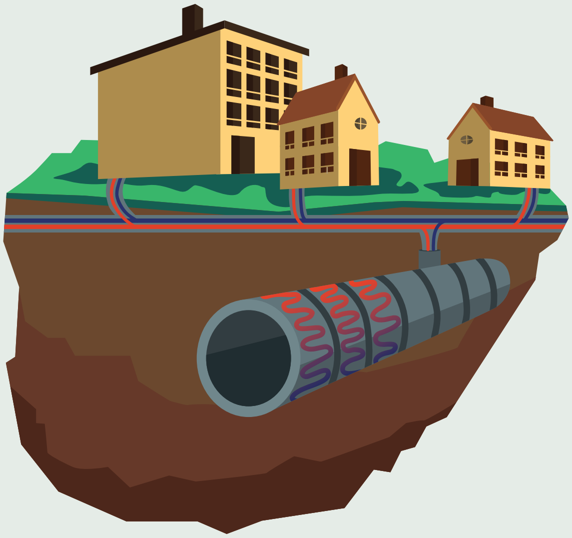


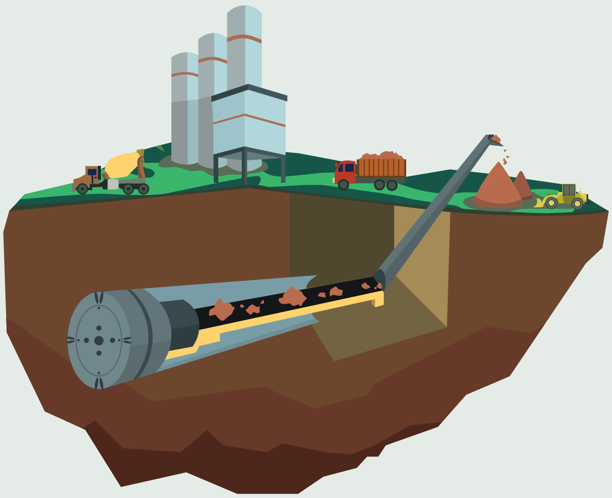
Key facts...

- Single-criterion tools, such as GHG emission assessment or carbon footprint are sometimes used.
- Work is underway to adapt tools that also incorporate social and economic dimensions to underground structures.

HOW UNDERGROUND STRUCTURES CAN SUPPORT THE ECOLOGICAL TRANSITION

Opportunities for more sustainable cities and regions





Include the underground into urban and regional planning to improve traffic flow, preserve land, promote more serene uses of the surface and increase resilience.

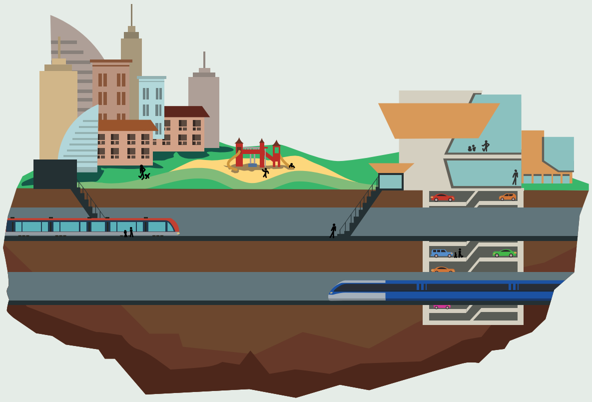
Develop a multifunctional approach and anticipate changes in the use of the underground, in order to optimise the design of structures and control their impacts.

Develop synergies between underground spaces and the surface, in order to improve the use of underground resources: excavated materials, geothermal energy...

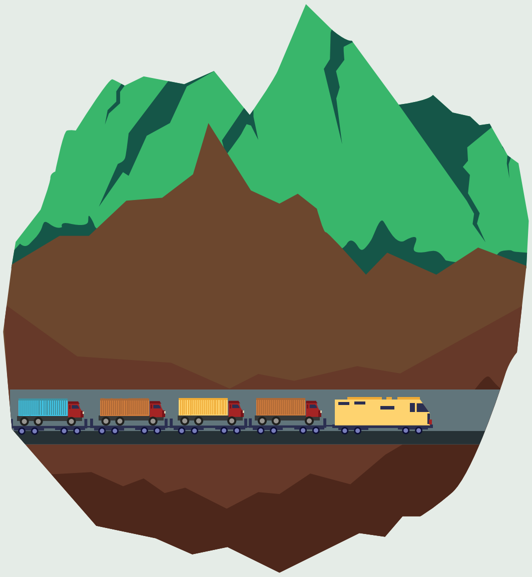
Underground spaces can accommodate a variety of functions.

Many examples already exist: data centres, logistics warehouses, technical facilities, shopping centres, museums, concert halls, mushroom farms etc.

Valuable assets for tomorrow's mobility



Promote a modal shift towards more carbon-free transport, by facilitating the interconnection of transport networks (mobility hubs).



Contribute to reducing the impact of travel by crossing natural obstacles and reducing the length and gradient of routes.

Support the mobility transition by adapting underground infrastructures and their operation.

Illustrations: Julie Schwartzentruber

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For more information on how underground structures can support the ecological transition:

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