ET Assessment of Environmental Impact and Sustainability

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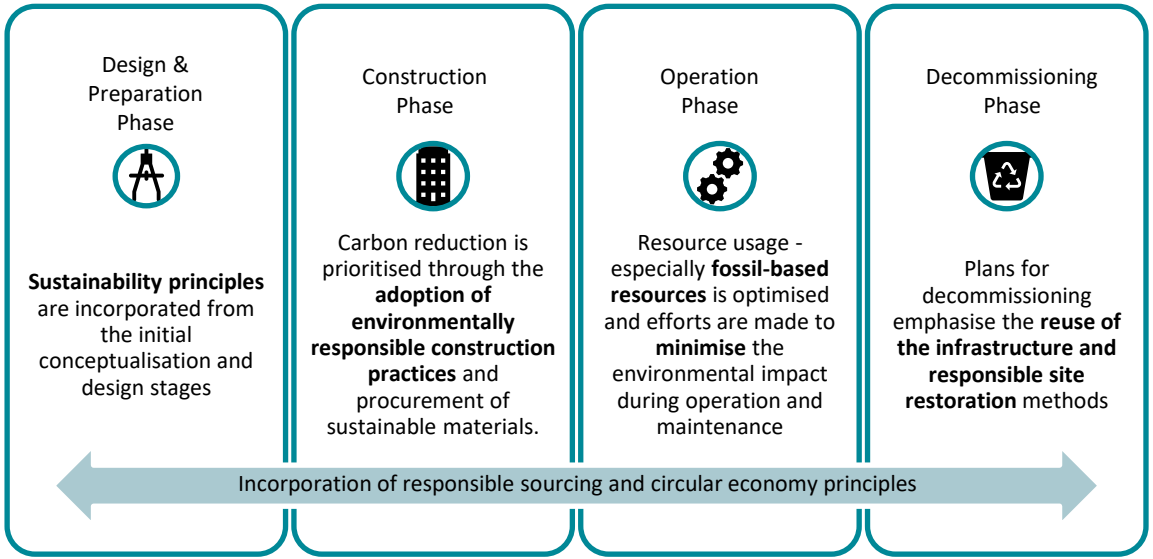
Vision

ET-PP is committed to fulfilling

- Long-term operational requirements while minimising environmental impact
- Adhering to EU and national sustainability directives, as well as international best practices
- Develop a strategy for the realization of a **long-term sustainable research infrastructure on the basis of**

- D9.2: Robust and integrated Environmental Impact Assessment framework aligned with EU EIA Directive (2011/92/EU as amended by 2014/52/EU)
- D9.2 Annex: Strategies for excavation and material reuse
- D9.3: Life-cycle based carbon footprint assessment and mitigation roadmap
- D9.1: Sustainable Development Implementation Strategy based on findings of D9.2 and D9.3



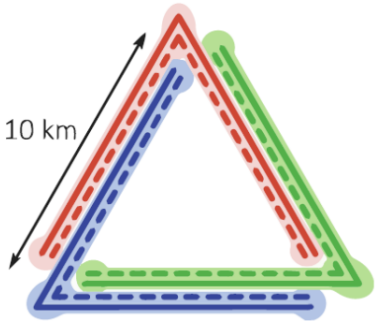
Ref: Horizon Europe Framework Program for Research & Innovation, Strategy Report on Research Infrastructure Roadmap by *European Strategy Forum on Research Infrastructures

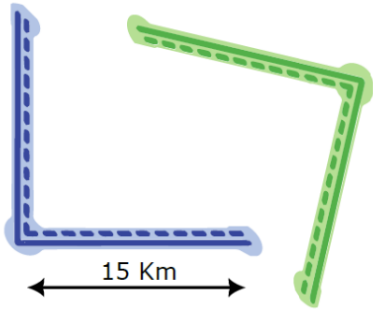
ET Sustainability Development Implementation - Challenges

- It is an underground infrastructure (second only to KAGRA in Japan)
- Geometry and characteristics are still under definition, with many assumptions currently in place
- Ongoing activities include site selection and geometry definition, with a strong focus on sustainability considerations
- Preparatory phase of ESFRI roadmap - pre-feasibility studies managed by candidate sites to prepare technical and economic proposal for candidacy (bid)

KAGRA GW Site - Kamioka mines, Hida city - Japan

EGO-VIRGO GW Site - Cascina (Pisa) - Italy





ET Sustainable Development Strategy - Reports

ET Environmental Impact Assessment & Mitigation Strategy

- Scoping and Baseline Assessment
- Alternatives and Mitigation
- Public Participation and Transparency
- Monitoring and follow-up

ET CO2 Footprint ET Assessment & Mitigation Strategy

- Compute the key Carbon and Environmental Impacts
- Findings and Mitigation Strategies
- Highlight the most critical insights and recommendations for decision-makers


Preparatory Phase for the Einstein Telescope Gravitational Wave Observatory

Milestone 9.1
Preliminary Sustainability Plan

Lead beneficiary: EGO
Delivery Date: 31/10/2023 (vs 1)- 00/00/2025 (revised version)
Dissemination level: Public
NAME : ET-PP-Milestone-9.1
Version: 2.0 (revised)

This project has received funding from the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.


Preparatory Phase for the Einstein Telescope Gravitational Wave Observatory

Deliverable 9.2
Environmental Impact Assessment and Mitigation Strategy

Lead beneficiary: INFN
Delivery Date: 10 Dec. 2025
Dissemination level: internal
NAME : ET-PP-Deliverable-D9.2.
Version: V9.0

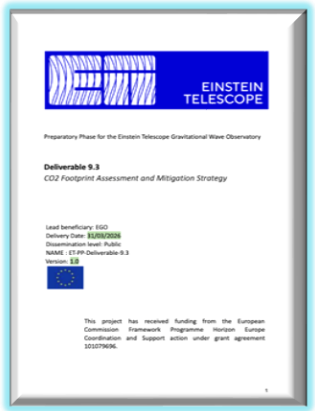
This project has received funding from the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.


Preparatory Phase for the Einstein Telescope Gravitational Wave Observatory

Deliverable 9.2. Annex I
Management of Excavated Materials

Lead beneficiary: Montanuniversität Leoben (MUL)
Delivery Date: Nov. 2025
Dissemination level: internal
NAME : ET-PP-Deliverable-D9.2. Annex 1
Version: 1.2

This project has received funding from the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.


Preparatory Phase for the Einstein Telescope Gravitational Wave Observatory

Deliverable 9.3
CO2 Footprint Assessment and Mitigation Strategy

Lead beneficiary: EGO
Delivery Date: 31/03/2026
Dissemination level: Public
NAME : ET-PP-Deliverable-9.3
Version: 1.0

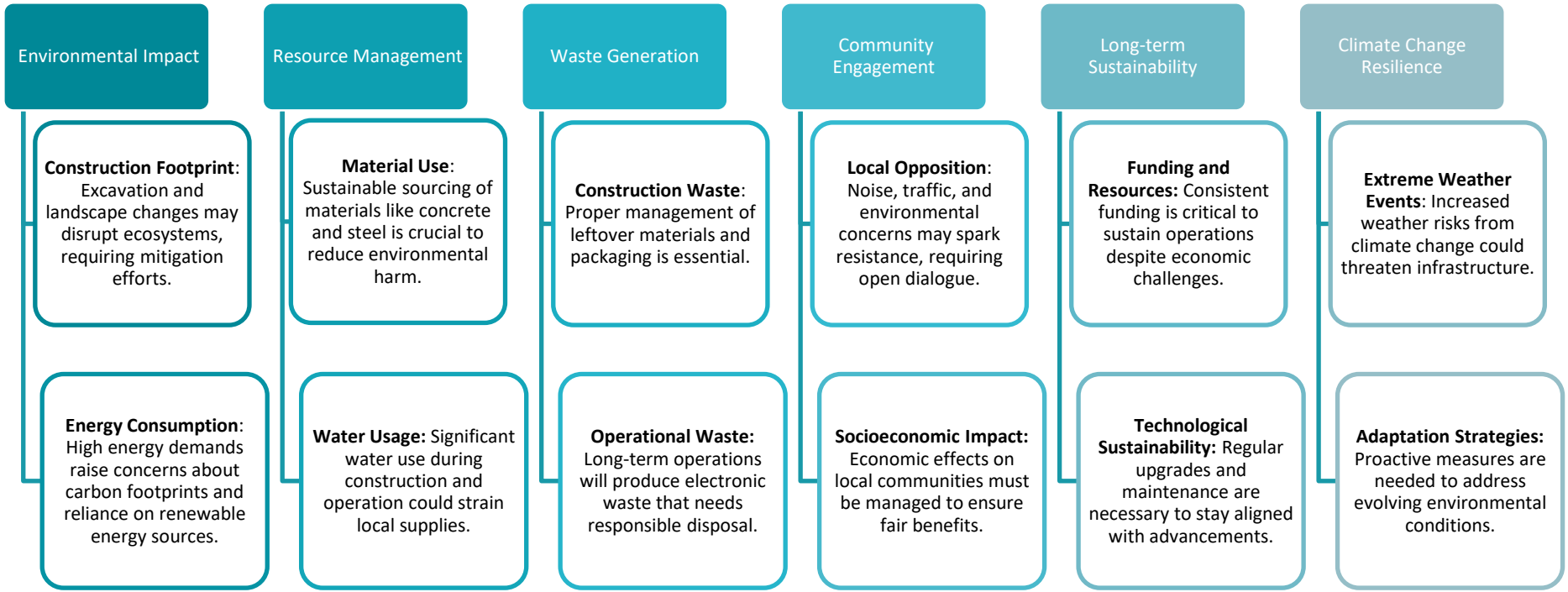
This project has received funding from the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.

Environmental Impact Assessment & Mitigation

- Analytical process for identifying and assessing the potential environmental impacts of a project in its different phases (construction, operation and decommissioning)
- Includes an Environmental Management Plan (EMP) laying out how such measures should be implemented and monitored
- Strategy adheres to the requirements of EU EIA Directive (2011/92/EU as amended by 2014/52/EU) and is articulated in:
  - Scoping and baseline assessment
  - Alternatives and mitigation
  - Public participation and transparency
  - Monitoring and follow-up

WP9 Deliverable D9.2

Environmental Impact Assessment & Mitigation - Key aspects



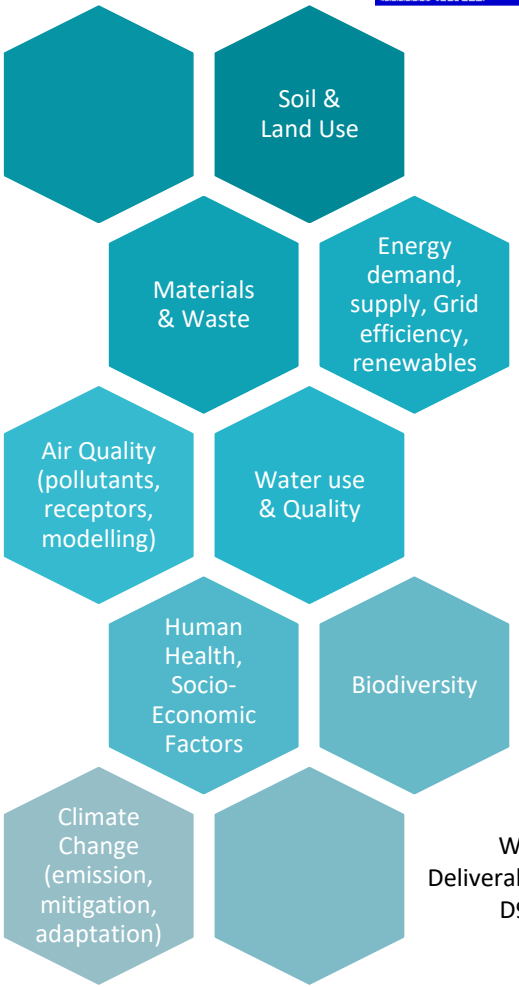
WP9 Deliverable D9.2

Environmental Impact Assessment (EIA) - Workplan

- Define Sustainability Strategy with environmental, social, and economic themes
- Establish **Baseline conditions** using site-specific data (air, water, soil, noise, biodiversity, etc.)
- Conduct detailed **Impact assessments** for both construction and operational phases
- Develop and implement **Strategic KPIs*** (for site comparison) and **Specific KPIs** (for mitigation & performance tracking)
- Identify and evaluate **Alternatives and Mitigation Measures** across EIA themes
- Analyse and define an overall strategy for reclamation, reuse and recycling of excavated materials

Strategic Priorities:
- Early identification of sensitive receptors (ecological, human)
- Alignment with EU/ISO guidelines (e.g., ISO 14001, WFD, Natura 2000)

*KPI: Key parameter Indicators



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Reclamation, Reuse and Recycling of the Excavated Materials

Technical

Tunnel advancing method, dimensions

Site organisation

Material yield parameters

Material analysis

Processing technology

Geological

Geological situation

Chemistry/ Mineralogy/ Strength properties of excavated materials

Project specifications

Processability

Legal

Ownership

Regional Waste law

End of waste character

Economic

Supply and demand

Raw material price vs. Landfilling costs

Transport route/ - range between end points

WP9 Deliverable D9.2 Annex

EIA Data Needs & Availability

Data Requirements

- Baseline data: soil, water, air, biodiversity, climate, energy
- Spatial data: GIS maps, Natura 2000, habitat fragmentation
- Monitoring data: pollutant levels, noise, emissions
- Socio-economic indicators: employment, land use, demographics

Challenges in this phase of the design roadmap

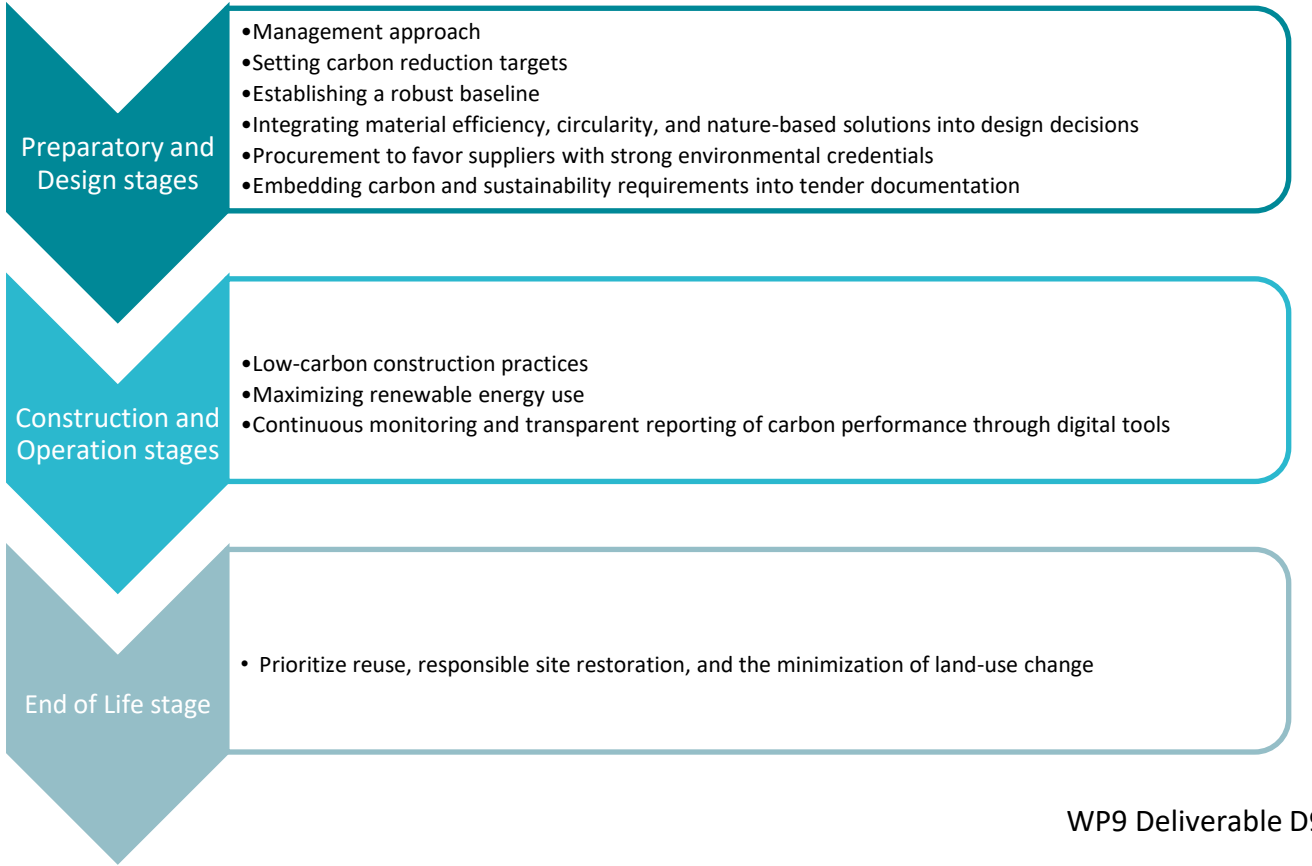
- Data availability varies by theme & location
- Inconsistent formats and quality (e.g., local air quality, biodiversity)
- Time lag between data collection and current conditions

WP9 Deliverable D9.2

CO2 Footprint Assessment & Mitigation

Part 1: Carbon Management approach (designed to span across all project phases)

Establishes clear roles and responsibilities, supported by regular performance reviews.



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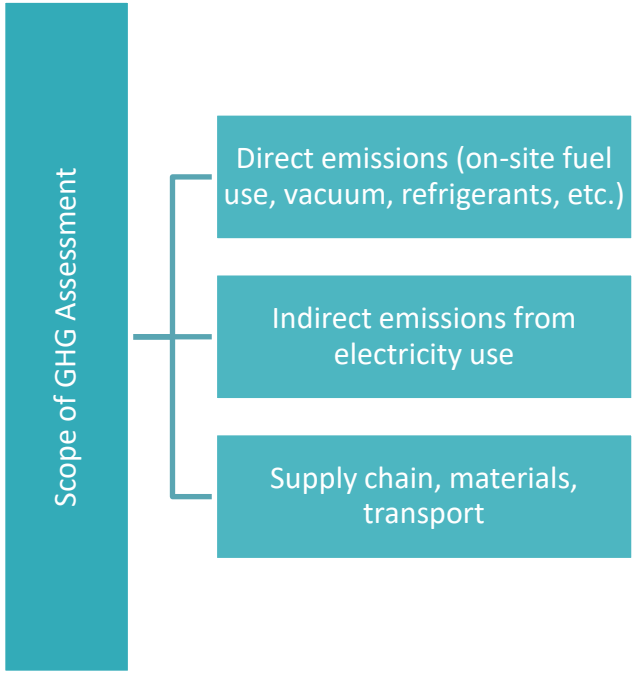
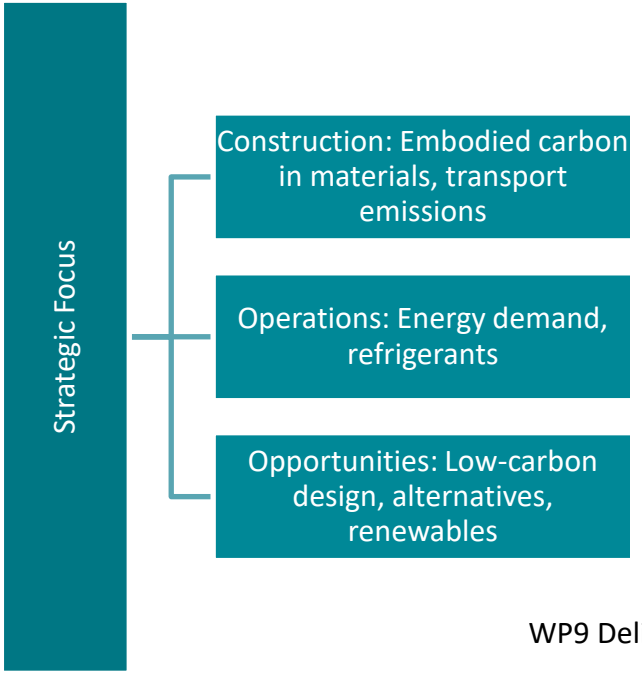
CO2 Footprint Assessment & Mitigation

Part 2: Baseline Whole Life carbon Assessment (undertaken at preparatory phase)

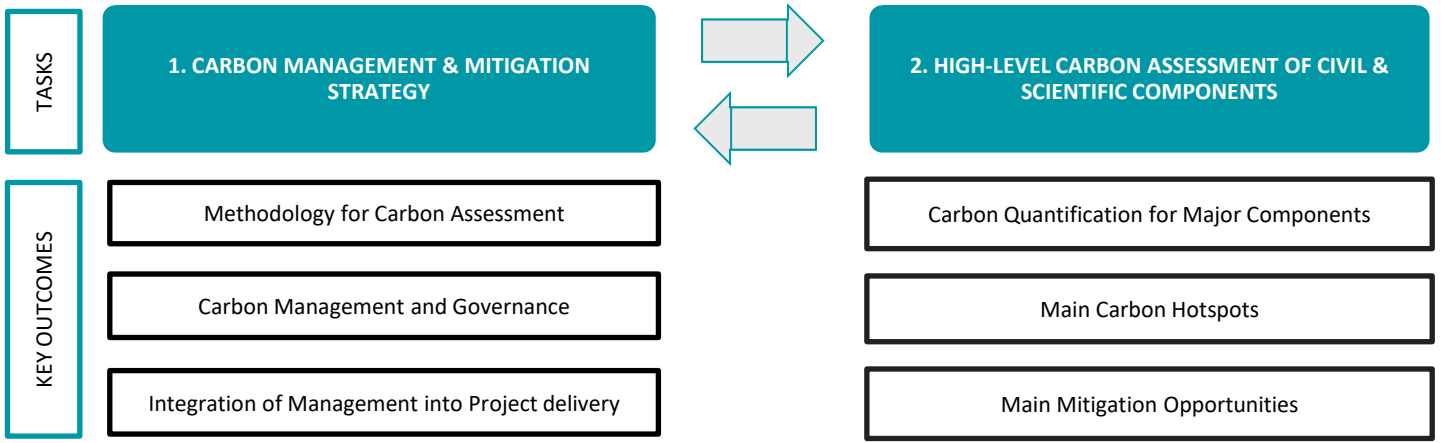
Provides a high-level quantification of the ET's carbon footprint of underground (civil + scientific) infrastructure and surface buildings





WP9 Deliverable D9.3

CO2 Footprint Assessment & Mitigation Strategy - Roadmap



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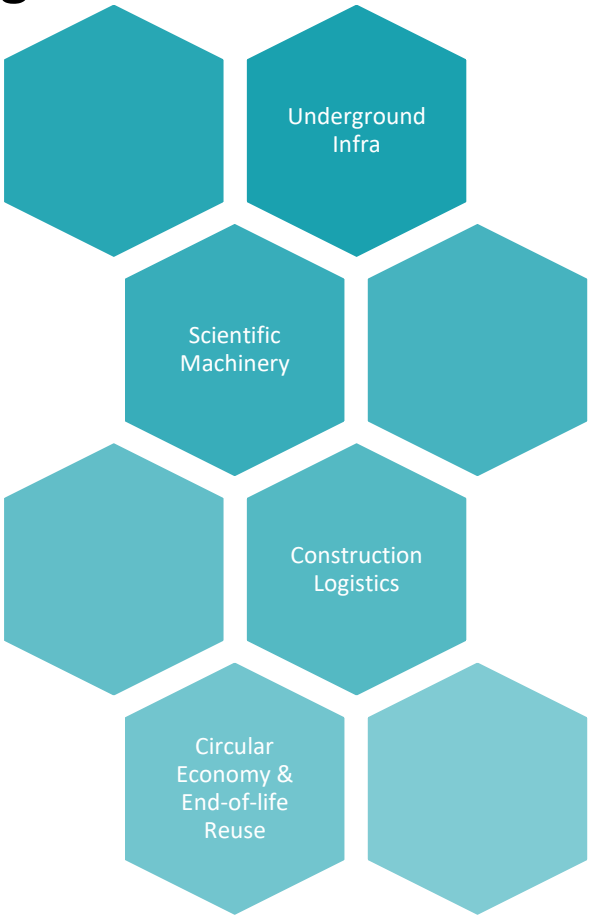
Life Cycle based CO2 Assessment & Mitigation – Workplan

- Define system boundaries for buildings, underground works, scientific equipment, etc.
- Apply LCA* Methodology in alignment with global standards#
- Perform Carbon Budgeting, hotspot analysis & scenario planning (conservative vs circular reuse models)
- Align Scope 1, 2, 3 emissions with GHG Reporting Protocols
- Suggest integrating Low-Carbon Strategies into design, procurement, construction & operations

*Life Cycle Assessment methodology defined by European commission
#PAS 2080:2023, ISO 14040:2006, ISO 14044:2006, EN 15804:2012+A2:2019



WP9
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D9.3

ET High-level CO2 Assessment of Civil Engineering components

WP9 Deliverable D9.3

Goal

- Determine a high-level whole life carbon assessment for the major components of the civil infrastructure of 2 ET configurations (triangle and L-shape).
- The carbon footprints will be used as a baseline before more granular and site-specific carbon assessments are undertaken by the design teams.

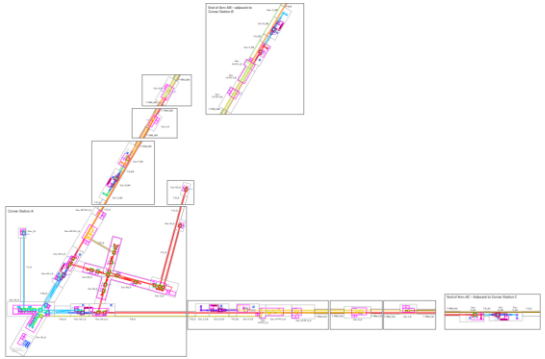


Figure 60: Element Names - Triangle (retrieved from **TD.2**)

Scope and system boundaries

- Top-down carbon assessment of the civil infrastructure of 2 configurations (triangle and L-shape)
- The carbon benchmarks/factors/LCA assumptions are not site specific.
- Whole life carbon assessment including construction, maintenance, operation, and end of life.

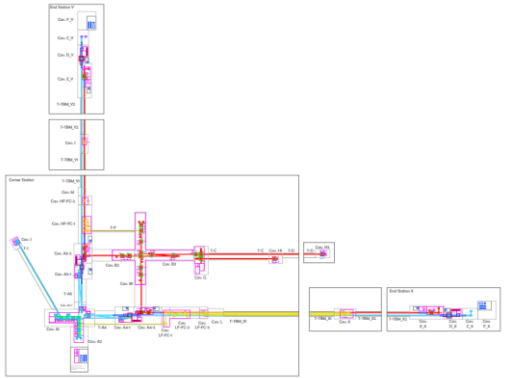
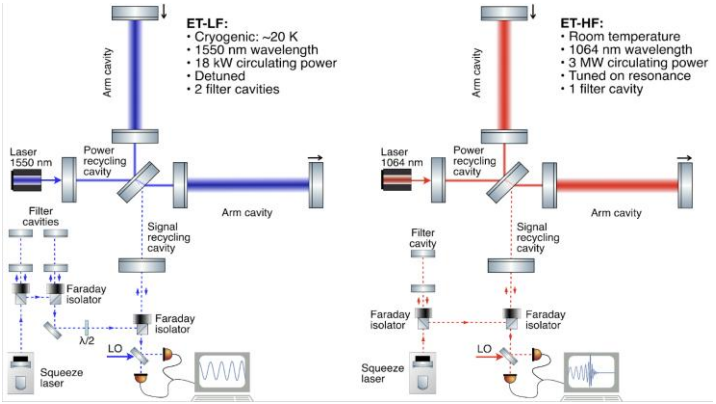


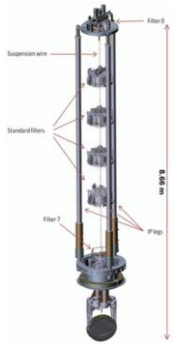
Figure 61: Element Names - L (retrieved from **TD.2**)

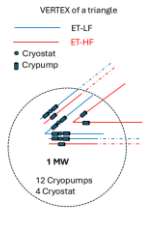
ET High-level CO2 Assessment for Scientific & Civil Engineering components

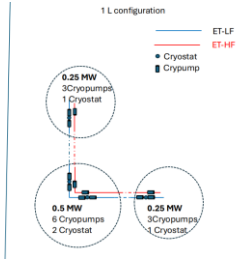
- Civil engineering components of the ET infrastructure (for both the triangular and 2L-shaped layouts):
  - Conventional tunnels
  - TBM (tunnel boring machine) tunnels
  - Shafts (access tunnels)
  - Caverns
  - Excavated material from construction of underground infrastructure
  - Surface buildings, including basic MEP (Mechanical, Electrical, Plumbing) services
  - Operational energy use of the whole ET facility
  - Operational water use of the whole ET facility

- Scientific instrument components of the ET infrastructure (for both the triangular and 2L-shaped layouts):
  - Interferometer (including Optics)
  - Noise Mitigation (including Sensors)
  - Suspension Systems
  - Vacuum Systems
  - Cryogenics Systems
  - Computation Models (Electricity consumption)









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CO2 Footprint Assessment - Data Needs & Importance

Baseline Data Requirements

- Regional emission inventories (transport, industry)
- Materials database (EPDs*, carbon intensity factors)
- On-site Energy usage patterns

Importance of High-Quality Data

- Essential for carbon budgeting and target setting
- Enables credible mitigation and offset planning
- Supports regulatory compliance and stakeholder trust

Data Collection Challenges

- Data availability variations among components
- Lack of uniform documentation
- Inconsistent formats and quality (due to the current stage of designing)
- Time lag between data collection and current conditions
- Indirect emissions (Scope 3) often underreported
- Embodied carbon data can be sparse or generalized

*Environmental Product Declarations

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CO2 Footprint Assessment (Energy)- Key Parameter Indicators

- For baseline pre-assessment related to energy
- With available benchmarks from EU standards and best practices or comparable projects

KPI	Unit	Purpose	Benchmark
Presence of energy infrastructure	Yes/No	Assess site readiness	N.A.
Accessibility of power lines	Distance	Assess site readiness	N.A.
Available connection capacity	MW	Assess site readiness	N.A.
Share of renewable energy in grid mix	%	Evaluate sustainability of supply	CERN uses French grid (low-carbon mix)
Possibility of local production from renewables (PV, wind, on-site cogeneration)	Yes/No	Identify on-site generation potential	N.A.
Energy reuse potential (e.g., heat recovery)	% of waste heat	Identify circular opportunities	CERN reuses LHC cooling water for district heating
Proximity of the site to centres of thermal demand	Yes/No	Identify circular opportunities	N.A.
Capacity of the local network to absorb recovered heat	Yes/No	Assess site readiness	N.A.

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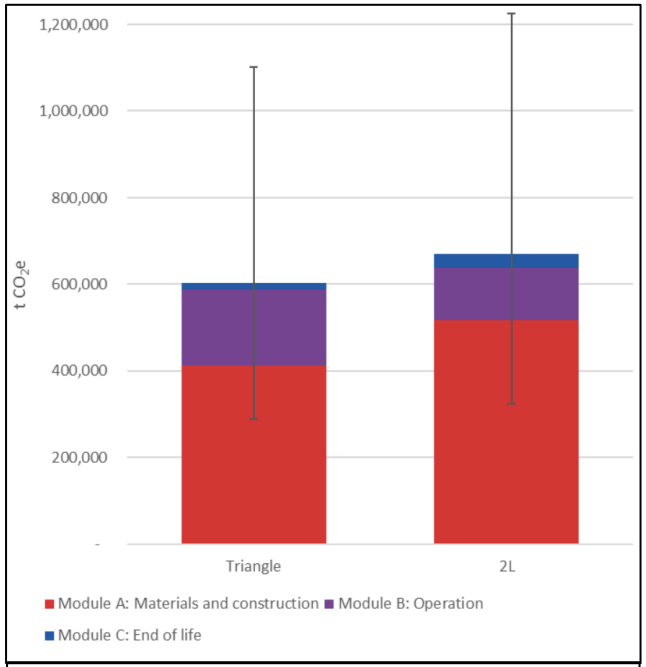
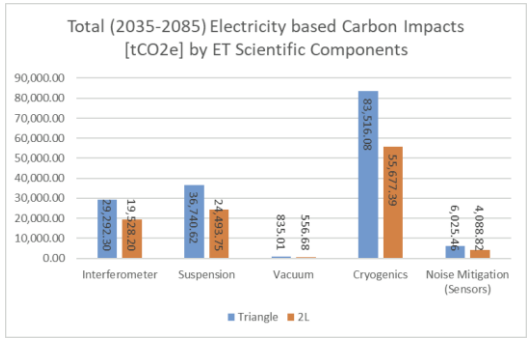
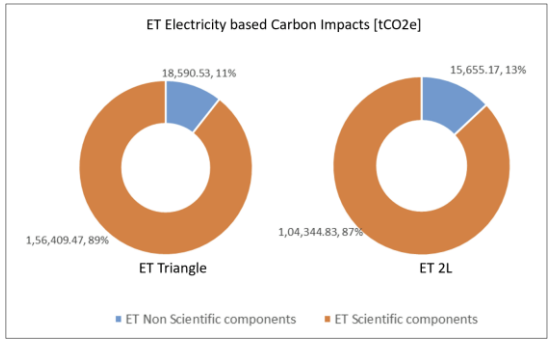
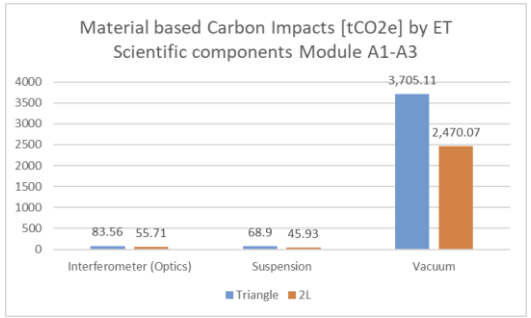
Baseline Whole Life Carbon Assessment - Preliminary takeaways (**under review**)

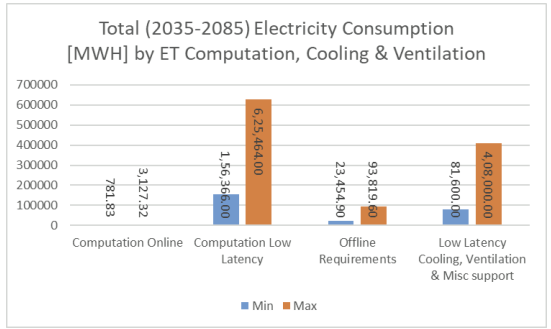


Carbon impacts of ET underground and surface infrastructure including uncertainty









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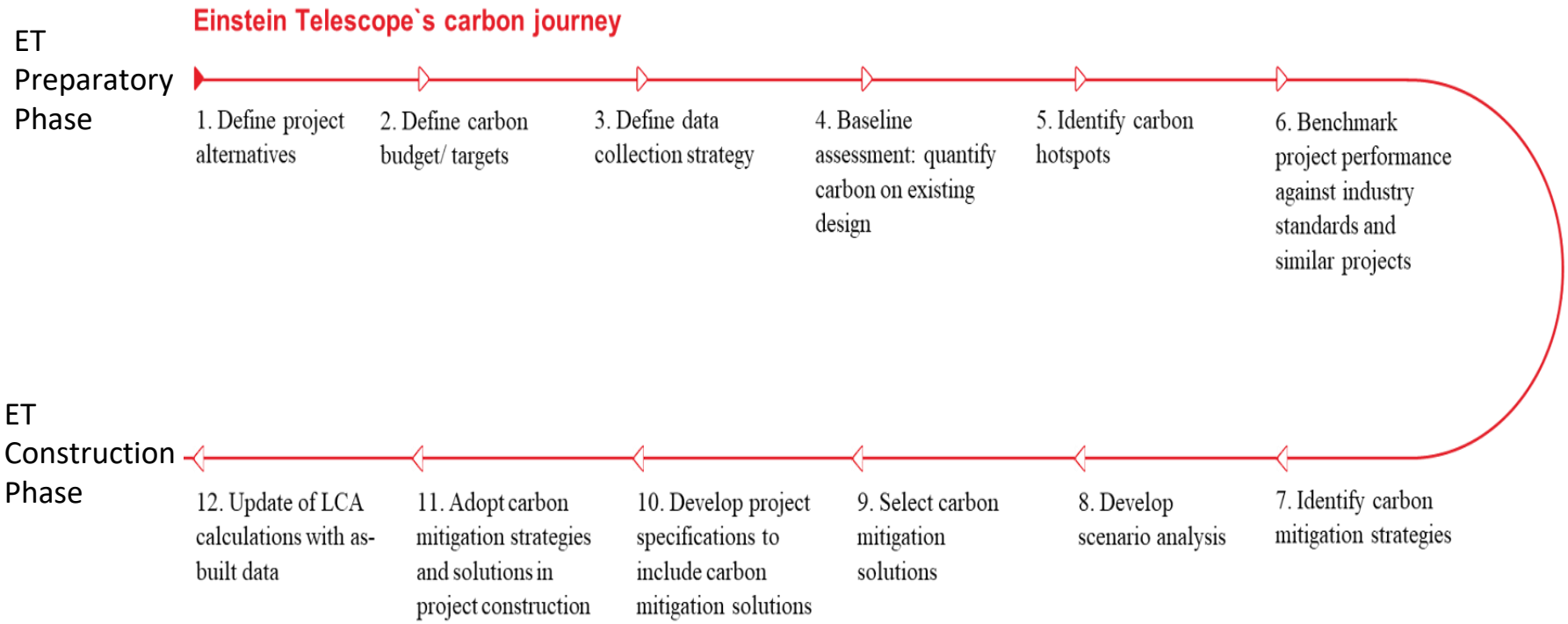
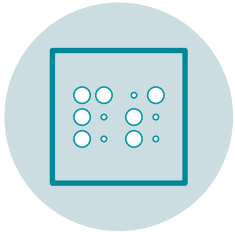
Key Steps for the Life Cycle Assessment during ET Phases

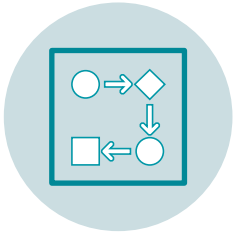


ET Sustainable Development Implementation Strategy - Opportunities

Addressing the path toward sustainability is crucial and can be prioritized proactively rather than reactively.



It can serve as a guide for decision-making in various sectors.



An iterative process is being conducted to determine the technologies to be used, sizing, geometry, financial aspects, and environmental impact.

We are in a preparatory phase (ESFRI roadmap), which involves pre-feasibility studies managed by candidate sites as part of the preparation of the technical and economic proposal for candidacy.