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## ETO-Civil Engineering Roadmap for Phase 1

### Abstract

This document is intended to contribute to the definition of the Einstein Telescope (ET) Roadmap Deliverables in relation to the preparation of the WBS (Work Breakdown Structure) and will only focus on the Civil Engineering activity in Phase 1. The text outlines the key areas involved in designing an underground civil project, starting from the major field deliverables or products that are expected to be prepared by the end of Phase 1 by the different stakeholders engaged in the civil engineering feasibility studies.

### KeyWords

ET Roadmap, Phase 1, civil engineering feasibility design, site investigation, technical systems, environmental assessment, modelling, cost and risk assessment

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## **1 Acronyms**

ET – Einstein Telescope

ETO – Einstein Telescope Organization

ETC – Einstein Telescope Collaboration

ET-PP – Einstein Telescope Preparatory Phase

WBS – Work Breakdown Structure

PBS – Project Breakdown Structure

WP – work package

CE – civil engineering

ED – engineering department

PO – project office

TDR – technical design report

LT – local team

TETI – Team for Einstein Telescope in Italy

EMR – Euregio Meuse-Rhine

## 2 Introduction

This document is intended to contribute to the Einstein Telescope (ET) Roadmap definition and to the preparation of the WBS (Work Breakdown Structure) that will be produced by the Einstein Telescope Organization (ETO). It is only focused on Phase 1 civil engineering major deliverables or products that are expected to be delivered by the end of Phase 1. Phase 1 ends with site selection and principal approval for construction. Assuming that the local teams' studies are concluded, comparisons have been done, and report is writing in the preliminary TDR which is originally expected to be by the end of 2026. This document serves ETO as a reference for:

- identifying and accessing essential information necessary for developing and aligning the civil engineering design roadmap in the overall framework of activity in Phase 1
- identifying potential gaps and defining responsibility roles for deliverables
- assisting in coordinating activities with local teams involved in the site studies. The documents must be shared with and approved by local teams for their content.

In alignment with ETO activities, additional documents may be developed to offer more detailed information on the elements outlined in this document.

The following are the key categories in which the deliverables are organized:

1. Standards and Formats for Site Studies
2. Technical studies for subsurface assessment and risk analysis
3. Design and Construction Feasibility Assessment
4. Cost and Time Estimation
5. Environmental impact assessment, permits, and noise mitigation measures
6. Safety and security plan
7. Technical Infrastructure (underground and surface)

Each deliverable is linked to key information, including the responsible unit for tasks or WPs, target delivery dates, necessary intermediate actions, prerequisites/required inputs, and its correspondence with the potential WBS element (work in progress in PO).

Target dates are not final and subject to change as new information regarding the timelines of ETO, ET-PP, and the local teams are agreed upon.

### 3 Einstein Telescope Deliverables related to Civil Engineering for Phase 1

#### 3.1 Standards and Formats for Site Studies

Standards and Formats for Site Studies						
Deliverable		Responsible Unit-Dept	Target Delivery Date	Intermediate actions	Prerequisite / Input	Corresponding WBS Element
3.1.1	Standards for data exchange formats, BIM Modelling guidelines, and ET Modelling Coordination including process for model changes and updates <sup>1</sup>	ETO-CE	Q4 2024	Consultation with ET-PP WP8	Confirmed alignment with ET-PP WP8	3
3.1.2	Model-based analysis methods (Cost estimation/verification, GIS-BIM combination, Take offs, ...)	ETO-CE	Q1 2025?	?	?	2.2
3.1.3	Validation procedures/review procedures <sup>2</sup>	ETO-PO, ETC (science case)	Q2 2025?	Consultation and approval from ETO needed before delivering any docs	ETO approval and ETC	3
3.1.4	Cost standards and validation methodology (CE related only) <sup>3</sup>	ETO-CE	Q4 2024	Ref.doc on methodology	- CERN-CE MOU	7

<sup>1</sup> The purpose of this document is to establish a comprehensive set of guidelines for the ET-Engineering group to standardize the modelling work methodology. These guidelines are intended to streamline the modelling process, ensuring smooth collaboration across teams, and to prevent issues related to model compatibility and coordination.

<sup>2</sup> This deliverable has a high priority/urgency, since it is a bottleneck in the delivery process of any other document from ETO

<sup>3</sup> It is necessary to identify a common methodology for attributing the maturity level of the CE design and, consequently, associate it to a cost class. In Phase 1, this action should be adapted to what will be decided to deliver to have the principal approval of construction. Local teams are required to understand and follow the steps and best practices applied within ETO for cost estimating and assessment.

Standards and Formats for Site Studies						
Deliverable		Responsible Unit-Dept	Target Delivery Date	Intermediate actions	Prerequisite / Input	Corresponding WBS Element
					<ul style="list-style-type: none"> <li>- Additional CERN agreement (in preparation)</li> <li>- alignment with ETO-PO</li> </ul>	
3.1.5	Risk standards and validation methodology (CE related only)	ETO-PO	Q2 2025?	Ref.doc on methodology	<ul style="list-style-type: none"> <li>- CERN-CE MoU specifically for geohazards?</li> <li>- local &amp; intl. code compliant</li> </ul>	10, 5
3.1.6	Preliminary TDR CE underground infrastructure (from PBS ?)	ETO- CE	Q4 2026	Overall agreement on the methodology is needed	<ul style="list-style-type: none"> <li>- PBS is fully reviewed sept. 24</li> <li>- CERN-MOU</li> </ul>	2.2
3.1.7	Reference schedule for preparation, construction, and implementation of CE works (ROADMAP)	ETO-PO and ETO-CE	Q4 2024	From timeline of LT	<ul style="list-style-type: none"> <li>LT acceptance</li> <li>Timeline alignment?</li> </ul>	3
3.1.8	Process for changes request of detector configuration	ETO-PO	Q4 2024	On-going informally	ETC-ISB approval	3
3.1.9	ET reference detector layout(s) <sup>4</sup>	ETC and ETO	Ref. detector layout -	Ref. Detector layout in collaboration with ETC	Ref. optical layout, ETC collaboration	2.2, 9

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Standards and Formats for Site Studies						
Deliverable	Responsible Unit-Dept	Target Delivery Date	Intermediate actions	Prerequisite / Input	Corresponding WBS Element	
		triangle: Q4 2024?  2L: Q1 2025?				
3.1.10	ETO	Baseline civil infrastructure layout Q4 2026?	Ref. Technical Infrastructure layout	ETC input, configuration decision has been made	2.2, 9	

### 3.2 Technical Studies for Subsurface Assessment and Risk Analysis

Technical Studies for Subsurface Assessment and Risk Analysis						
Deliverable	Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element	
3.2.1	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs with WP4 coordination	Input from WP4	8.2	

- Triangle and/or 2L, depending on when the configuration decision is made
- Detector layout is the responsibility of ETC and ETO, coordination is currently being done by ETO
- To be used as the baseline design for ET. Local teams bidding for ET are free to exploit the configuration flexibilities while ensuring the detector performance is not reduced
- Triangle and/or 2L, depending on when the configuration decision is made. Preferably the decision has been made by this time to avoid unnecessary work
- To be used as the baseline design for ET. Local teams bidding for ET are free to exploit the configuration flexibilities while ensuring the detector performance is not reduced



Technical Studies for Subsurface Assessment and Risk Analysis						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
3.2.2	Borehole campaigns at potential vertex locations	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs with WP4 coordination	Input from WP4	8.2
3.2.3	Borehole campaigns at potential tunnel locations	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs with WP4 coordination	Input from WP4	8.2
3.2.4	Prospection and laboratory testing report	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs with WP4 coordination	Input from WP4	8.2
3.2.5	3D geological and hydrogeological model	LT	Q4 2025(TETI) / Q4 2026(EMR), 02/2026 (WP4)	Conducted by LTs with WP4 coordination	Input from WP4	8.2
3.2.6	Geotechnical Interpretive Report <sup>6</sup>	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs with WP4 coordination	- Input from WP4	8.2

<sup>6</sup> Geotechnical Interpretive Report (GIR) or equivalent: A factual report on geophysical and geotechnical site investigation along with the data interpretation, and the associated field investigations and laboratory tests. In this case, it acts as a summary and conclusion of the previous deliverables within this section.

- Presentation of performed geotechnical, geophysical, and geohydrological investigations
- Introduction to the regional geology and a description of the local ground conditions and soil/rock types
- Brief introduction to the parameters needed for the design methodology
- Presentation of the methodology for interpreting soil/rock engineering properties and classification
- Determination and derivation of geotechnical parameters related to the interpreted soil/rock units, including description of methodologies applied
- Presentation of the methodology for preparation of design profiles and soil/rock parameters
- Presentation of the methodology and the results for constructing the visualised 3D engineering geological model and hydrogeological model with detailed localization of ET Infrastructure
- Maps and drawing compatible with GIS/CDE/PLM system,
- Raw data in digital format (e.g. .AGS or .CSV).

Technical Studies for Subsurface Assessment and Risk Analysis					
Deliverable	Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
				- General ET layout - Reviewed by CERN?	

### 3.3 Design and Construction Feasibility Assessment

Design and Construction Feasibility Assessment						
Deliverable	Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element	
3.3.1	Report on positioning/Location Scenarios of underground design (Triangle and 2L) <sup>7</sup>	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	Requirements, General ET layout	2.2, 9
3.3.2	Drawings and conceptual design <sup>8</sup> of underground structure (including resulting surface structures) for: 1. Caverns, 2. Tunnels, 3. Intersurface connections (access tunnels/shafts, boreholes, etc.), 4. Technical rooms, 5. Dewatering, 6. Emergency exits, 7. Monitoring systems, 8. Other auxiliary structures	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	Requirements, ET reference layout, defined requested	2.2, 9

<sup>7</sup>

- Compliant with all relevant standards and best practice (CERN specification?)
- Reaching a level of details to fulfil all requirements needed to obtain local authorizations
- Demonstrate that fully accomplished site-specific conditions to mitigate potential geohazards and environmental impacts.
- Include measures to minimize risks during construction, operation and decommissioning.

<sup>8</sup> 2D and 3D drawings in standard formats (e.g. IFC) to be shared in a common data environment (e.g. CDE).

Design and Construction Feasibility Assessment						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
					minimum level of detail	
3.3.3	Report on optimised construction solutions for the underground facility <sup>9</sup>	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	Requirements, General ET layout	2.2, 9
3.3.4	Logistics plan during construction including: 1. Layout of the construction site(s), 2. Personnel, 3. Flow of equipment and material, 4. Transportation of structural components from surface to underground site level	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	ED input needed	2.2, 9
3.3.5	Construction risk assessment <sup>10</sup>	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	ETO inputs	2.2, 3.5, 9, 10
3.3.6	Specific reports on the feasibility of construction solutions able to mitigate level of noise	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	ISB input needed, SPB	2.2, 9

### 3.4 Cost and Time Estimation

Cost and Time Estimation						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
3.4.1	Cost estimation report for the construction of underground and surface facilities	LT, WP4	Q4 2025(TETI) / Q4 2026(EMR), 07/2026 (WP4)	Conducted by LTs with WP4 coordination	Defined requested minimal	7.4

<sup>9</sup> Including explanation and justification for changes made to the reference layouts released by ETC/ETO.

<sup>10</sup> Including structural monitoring plan during construction and during operation

Cost and Time Estimation						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
					level of detail	
3.42.	Scheduling for construction underground and surface facilities (preparation, construction and implementation)	LT, WP4	Q4 2025(TETI) / Q4 2026(EMR), 07/2026 (WP4)	Conducted by LTs with WP4 coordination	Roadmap defined	3
3.43	Scheduling for civil works permitting (authorizations, expropriations, and easements)	LT, WP4	Q4 2025(TETI) / Q4 2026(EMR), 07/2026 (WP4)	Conducted by LTs with WP4 coordination	Ref. ET-PP WP4	3

### 3.5 Environmental Impact Assessment, Permits, and Noise Mitigation Measures

Environmental Impact Assessment, Permits, and Noise Mitigation Measures						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
3.5.1	Land development strategy accomplishing local urban planning and land use/zoning	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	Bid book defined	6
3.5.2	Excavation material treatment and management plan (feasibility)	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	ET-PP WP9 strategy	6
3.5.3	Cultural heritage preservation report	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	Bid book defined	6
3.5.4	Assessment of noise levels and mitigation strategy (e.g. construction typologies, buffer zones)	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	SPB input	6
3.5.5	Environmental impact assessment and management (water treatment, gas emission, habitats, and ecosystems protection)	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	ET-PP WP9 strategy	6

Environmental Impact Assessment, Permits, and Noise Mitigation Measures						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
3.5.6	Strategy for connections to public networks & utilities	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs		6
3.5.7	Environmental risk assessment	LT/ETO	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs & ETO	ET-PP WP9 strategy	6
3.5.8	Legal studies for site construction permitting	LT	Q4 2025(TETI) / Q4 2026(EMR)	Conducted by LTs	ET-PP WP4	6
3.5.9	Long term assessment and sustainability plans, including: 1. Lifespan evaluation, 2. Resilience and Climate Adaptation, 3. Maintenance costs analysis (structural), 4. Plan to accommodate potential future upgrades	ETO	Q4 2025(TETI) / Q4 2026(EMR)	CERN model	ET-PP WP9	6

### 3.6 Safety and Security Plan

Safety and Security Plan						
Deliverable		Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element
3.6.1	Strategy on safety and security during construction	LT	Q4 2025(TETI) / Q4 2026(EMR)	LT prepare site-dep. plan	ED defines standards	5
3.6.2	Strategy on safety and security during operation	ETO-ED	Q4 2026	LT prepare site-dep. plan		5
3.6.3	Risk assessment and mitigation (impact on performance, cost, schedule)	LT	Q4 2025(TETI) / Q4 2026(EMR)	LT prepare site-dep. plan	ED defines standards	10
3.6.4	Planning of mitigating measures	LT	Q4 2025(TETI) / Q4 2026(EMR)	LT prepare site-dep. plan	ED defines standards	5, 10

### 3.7 Technical Infrastructure (Underground and Surface)

Technical Infrastructure (Underground and Surface) <sup>11</sup>						
Deliverable	Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element	
3.7.1 Cooling and ventilation: Design and integration – technical reports and drawings <ul style="list-style-type: none"> <li>- Design technical solution for HVAC of surface and underground;</li> <li>- Design technical solution for (water) cooling of surface and underground;</li> <li>- Integration with the infrastructure design;</li> <li>- Underground installation plan;</li> <li>- CFD simulations and fluid flow analysis.</li> </ul>	ETO	Q4 2026?	LTs to adjust for local solution/layout	CERN MOU	2.2	
3.7.2 Electrical Engineering: Design and integration – technical reports and drawings: <ul style="list-style-type: none"> <li>- First Single Line Diagram design (HV / MV / LV distribution);</li> <li>- Develop AC grid solution, evaluation DC option (if necessary);</li> <li>- Study compact surface sub-stations;</li> <li>- Study connection to public HV grid;</li> <li>- Study energy storage requirements regarding renewable energy supply and networks stability;</li> <li>- First integration model for underground and surface areas;</li> <li>- Cabling and FO routing;</li> <li>- CAPEX / OPEX modelling.</li> </ul>	ETO	Q4 2026?	LTs to adjust for local solution/layout	CERN MOU	2.2	

<sup>11</sup> Technical Infrastructure (TI) layout and Preliminary TDR made in agreement with CERN. Further details regarding the technical infrastructure will be in a separate document. Expected by Q4 2026, meanwhile there is a possibility that the 2 local teams currently bidding to host ET in their region will have concluded their contracts by that date.

Technical Infrastructure (Underground and Surface) <sup>11</sup>						
Deliverable	Responsible Unit	Target Delivery Date	Intermediate actions	Prerequisite /Input	Corresponding WBS Element	
3.7.3	Access and Alarms: Design and integration – technical reports: <ul style="list-style-type: none"> <li>- Identify all the prevention and mitigation barriers or systems to be implemented;</li> <li>- Document safety requirements;</li> <li>- Document safety solutions.</li> </ul>	ETO-ED	Q4 2026?	LTs to adjust for local solution/layout	CERN MOU	2.2, 3.5, 5.3, 10
3.7.4	Occupational Health and Safety: Design and integration – technical reports: <ul style="list-style-type: none"> <li>- Underground risk assessment</li> <li>- Fire Safety Concept report: Partitioning and smoke extraction;</li> <li>- Smoke / leak detection report</li> <li>- Evacuation concept report;</li> <li>- Implosion risk assessment report.</li> </ul>	ETO-ED	Q4 2026?	LTs to adjust for local solution/layout	CERN MOU	2.2
3.7.5	Evaluation of requirements related to technical infrastructure technical report	ETO-ED	Q4 2026?		CERN MOU	2.2
3.7.6	Validation of cost, planning, and risks for technical infrastructure technical report	ETO-ED	Q4 2026?		CERN MOU	3.5, 5, 7.4, 10
3.7.7	Preliminary Technical Infrastructure TDR, including (but not limited to): <ul style="list-style-type: none"> <li>- HVAC chapter</li> <li>- Electrical chapter</li> <li>- Access and Alarms chapter</li> <li>- Safety chapter</li> </ul>	ETO-ED	Q4 2026?		CERN MOU	2.2

## 4 References

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- Procurement guide on the European tender under the open procedure for: Civil Engineering Feasibility phase Einstein Telescope Euregio Meuse-Rhine. Document number: P2.1\_019\_V1.0.
- “Studio Propedeutico Allo Sviluppo Del Progetto Di Fattibilità Tecnica Ed Economica Dell’osservatorio Di Onde Gravitazionali Einstein Telescope Nella Regione Sardegna, In Diverse Configurazioni, Comprensivo Della Esecuzione Delle Indagini E Dei Sondaggi E Della Valutazione Preliminare Di Impatto Ambientale, Per Le Opere Infrastrutturali, In Sotterranea E In Superficie, Edili E Impiantistiche” - Cig\_9760848a93. Document numbers: ETIC\_WP6\_0-A00 to ETIC\_WP6\_5-A06.
- Einstein Telescope EMR Region <https://indico.ego-gw.it/event/710/contributions/6386/>
- Sardinia (TETI) Update <https://indico.ego-gw.it/event/710/contributions/6387/>
- Urso, D., Walk, W. *WP4 Report*. 25 October 2024.



## 5 Appendix

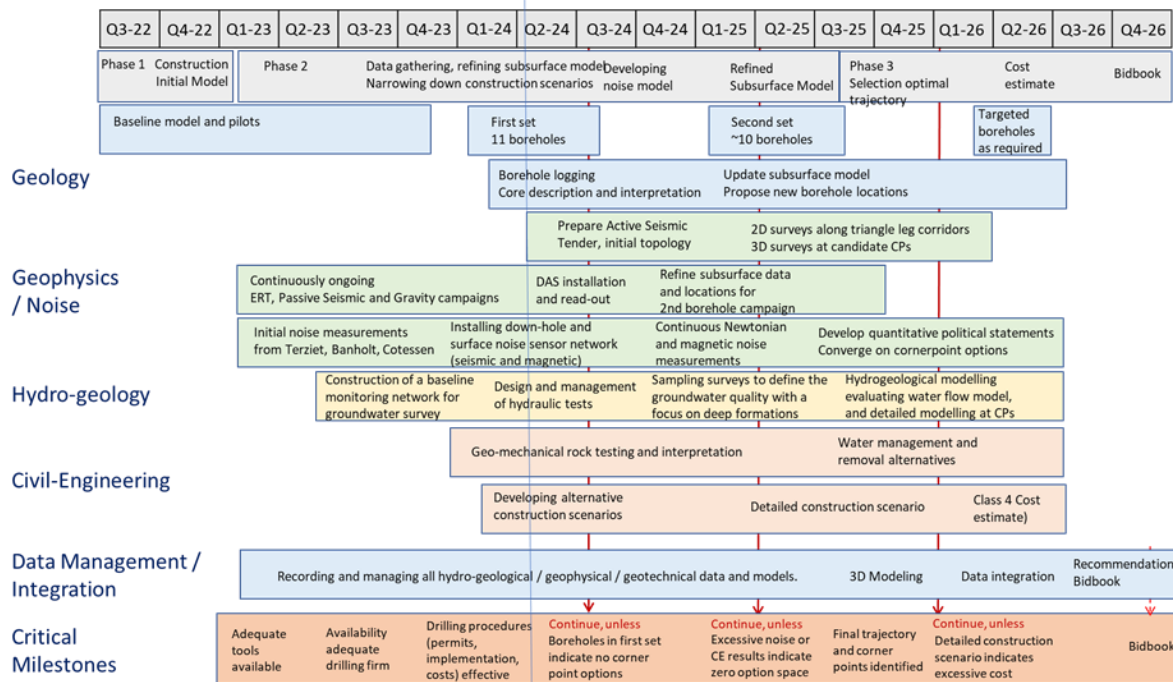
### 5.1 Current knowledge of the timeline of activities of both local teams

In this section, we show the current known timelines of two local teams working on the Einstein Telescope project. During the XIV Einstein Telescope Symposium, held from May 6 to May 10, 2024, both local teams gave presentations that provided information regarding updates on their progress and adjustments to their respective time schedules. This comparison aimed to highlight the differences in their project schedules, which may impact the overall project execution and delivery of the Einstein Telescope.

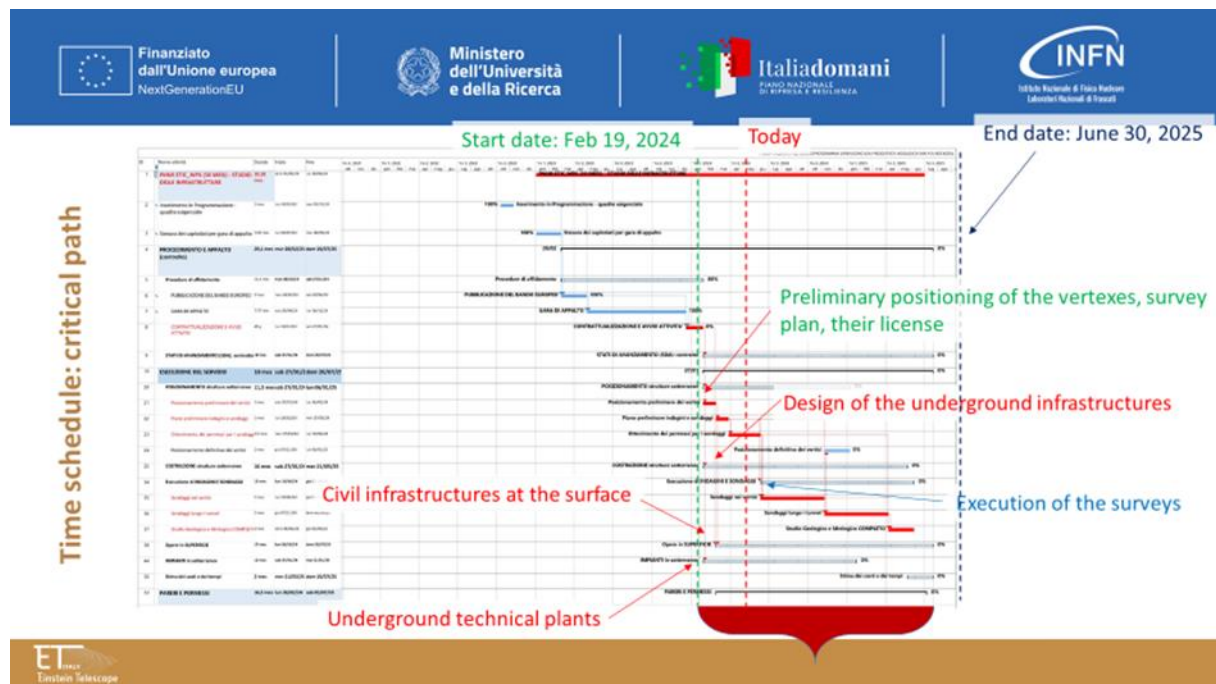
The following table summarizes the interpreted time schedule for both teams:

Timeline		Dur (m)	2022		2023				2024				2025				2026				
Activities			Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	
<b>EMR (Update May 2024)</b>																					
Construction Initial Model																					
Data gathering, refining subsurface model																					
Narrowing down construction scenarios																					
Developing noise model																					
Refined subsurface model																					
Selection optimal trajectory																					
Cost estimate																					
Bidbook defined																					
<b>TETI (Update May 2024)</b>																					
PNNR ETIC_WP6 (30 MONTHS) - INFRASTRUCTURE STUDY		22																		extend?	
Programming - Requirements Framework		1																			
Drafting of Tender Documents		2																			
PROCEDURE AND PROCUREMENT (control)		31																		extend?	
Assignment Procedures		12																			
STATES OF PROGRESS (SDA): contract		19																		extend?	
EXECUTION OF THE SERVICE		19																		extend?	
POSITIONING underground structures		12																			
CONSTRUCTION underground structures		17																			
Carrying out INVESTIGATIONS AND SURVEYS		13																			
SURFACE Works		18																		extend?	
Underground SYSTEMS		13																			
Estimation of Costs and Schedule		2																		extend?	
OPINIONS AND PERMISSIONS		18																		extend?	

Time schedule of the EMR team, taken from the presentation shown during the XIV ET Symposium (10 May 2024):



Time schedule of TETI, taken from the presentation shown during the XIV ET Symposium (10 May 2024):



## 5.2 Current knowledge of the timeline of ET-PP WP4

Within ET-PP WP4, there were a number of milestones and deliverables as described as deliverable names along with the date (in months, months from ET-PP start date, Sept. 1st 2022). In October 2024 an update timeline was given.

The milestones and original planned timeline are described as following:

- M4.1 – M3 : Document detailing the site-specific characteristics that impact ET sensitivity and its duty cycle
- M4.2 – M10 : Common methodology to estimate impact of site characteristics on ET sensitivity and operation and, if required, a scheme to compensate it

The deliverables and original timeline along with the new dates are as following:

- D4.1- M10: Scan of legal procedures, permitting and land acquisitions, i.e. the steps to be taken prior to starting excavations  
Update: Achieved. Expected an updated version at the end of ET-PP.
- D4.2 - M15: Updated socio-economic impact studies. Scan of accessibility, quality of life etc.  
Update: exp. 12/2024
- D4.3 - M28: Complete quantification of all the aspects impacting the ET performance for each site.  
Update: exp. 07/2026
- D4.4 - M30: Report on 3D geology, hydrology, etc. model with localisation of the ET infrastructure.  
Update: exp. 02/2026
- D4.5 - M42: Updated cost and schedule estimates of the excavations, including, if necessary: instrumentation for Newtonian Noise cancellation; costs of debris removal; costs of land acquisition, permitting, etc..  
Update: exp. 07/2026

Time schedule of ET-PP WP4, as shown during in the WP4 update (25 Oct 2024):

