

## Einstein Telescope preliminary cost book

### Preamble

The evaluation of the costs of the Einstein Telescope Research Infrastructure uses as starting point the Conceptual Design Study funded by the European Commission during FP7 (GA 211743). In the Conceptual Design Report (CDR) an over-simplified underground infrastructure has been sketched and the cost of a single detector (two interferometers) has been evaluated, rather than the complete 3-detectors design defined in this ESFRI proposal.

The current evaluation is based on an updated design of the underground research infrastructure, evolved over two years of design activity and interactions with two external companies, leaders in Europe in designing large underground infrastructures and facilities. These two companies have evaluated the excavation cost independently and the results match at 10% level, excellent matching level considered the slightly different requirements used in input to these evaluations.

The other costs result from an updated and detailed cost estimation performed over two years by a multidisciplinary team of experts (the ET steering committee).

**Nota Bene:** in the questionnaire and in this document, the cost evaluation is made without using the “Discounted cash flow method” described in the Str-ESFRI document “Guidelines on Cost Estimation of Research Infrastructures” ([https://www.esfri.eu/sites/default/files/StR-ESFRI2\\_STUDY\\_RIs\\_COST\\_ESTIMATION.pdf](https://www.esfri.eu/sites/default/files/StR-ESFRI2_STUDY_RIs_COST_ESTIMATION.pdf)).

**Nota Bene:** VAT is not included.

### Design phase

The initial design activity has been realised through a conceptual design funded by the European Commission in FP7. For this document, the design of ET is updated with contributions from external companies, specialised on large underground infrastructure design, and thanks to the large experience acquired with the Advanced GW detectors currently in operation and the KAGRA detector. The ET design will be detailed in more detail in the coming two years (2020-2021)

Activity	Cost [M€]	Note
Conceptual Design	3,6	Conceptual design activity.
Underground RI Design	0,6	Update of the underground RI design. Collaboration with external companies.
Surface RI Design	0,4	Update of the design of the technical and civil infrastructures on the surface. Collaboration with engineers' departments of the involved institutions.
Preliminary detector design update	0,1	Update of the detector specifications in the CDR, thanks to the experience gained with Advanced Virgo, Advanced LIGO and KAGRA.
Cost Evaluation	0,2	Update of the cost tables.
<b>Tot</b>	<b>4,9</b>	

### Preparation phase

The different project phases for a large research infrastructure like ET aren't fully separated, because of the complexity and the modularity of the project. Whereas the design activities of some specific elements of ET is continuing, the preparation phase is already started. The preparatory phase consists of several technical

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and management activities, as described in the following table. Technical activities are mainly addressed to the qualification and selection of the site and, when selected, to the realisation of the operative design, passing through different levels of detail. Management activities are addressing the governance, management and financial frameworks of the project.

Activity	Cost [M€]	Start	End	Note
Site Qualification	15	2019	2023	Complex series of activities, going in parallel in the two candidate sites, aiming to the qualification of the sites (compliance with the stringent ET requirements).
Funding schemes for the two sites	0	2019	2023	Definition of the two funding schemes for the two candidate sites. Interaction and negotiation between countries.
Site Comparison	1	2023	2024	Evaluation of the two candidatures, using also external panels, experts and companies.
RI Technical documentation completion	38	2024	2026	Completion of the technical documentation needed for the construction (legally defined as preliminary project, definitive and operative project) by specialised external companies.
Governance definition -ERIC	1	2020	2025	Study and definition of the governance structure of ET.
Land acquisition	19	2024	2027	Acquisition of the land for the excavation and for the realisation of the surface infrastructures.
Technology development	95	2019	2030	R&D activity addressed to the development of the technologies needed for ET. This activity is already started since years and it is partially based on the technology developed for the upgrades of the current detectors.
Detector project completion	2	2023	2026	Completion of the detector project after the selection of the site.
<b>Tot</b>	<b>171</b>			

Site qualification activity is composed by a series of tasks to be accomplished in parallel at the two sites candidate to host the infrastructure, according to the following table

Task	Cost [M€]	Site
Seismic, acoustic, magnetic measurements in Sardinia	2,2	S
Enlargement and implementation of the laboratory underground	3,5	S
Boreholes at the other two corners	2,0	S
Characterisation of the other two corners	2,4	S
Report writing	0,03	S
Euregio Meuse-Rhine drill hole + sensor	1,3	E
Socio-economic study	0,02	E
Detailed geology study (more boreholes, seismic campaigns, etc.)	3,4	E

The Research Infrastructure Technical design completion is a complex activity realised with the major contribution of one or more external companies, to be selected with a European call for tender. This important activity spans over a few years and it is composed by at least three main phases: (1) preliminary design, (2) Definitive design and (3) Operative design. According to private external experts, the overall cost is expected to be about the 4% of the RI construction cost (excavation, services and surface buildings).

Technology Development includes all the activities addressed to design and develop the technologies for ET. There is a certain overlap between the technologies needed for the upgrades of the current detectors and the technologies addressed to ET; this facilitates a progressive development and constitutes a de-risking for ET. Medium/large facilities (laboratories and R&D centres like ETpathfinder) will be realised to develop ET technologies and the costs for these national and regional labs are included.

### Implementation phase

The implementation phase consists of the excavation of the underground infrastructure, the implementation of the technical infrastructures (services), the realisation of the detectors and their installation, as listed in the following table. It is worth to note that the last phases of the detector installation overlaps with the initial operative phase of the RI and a certain overlap with the running costs must be considered.

Activity	Cost [M€]	Start	End	Note
<b>Infrastructure costs</b>	<b>932</b>			
Excavation	781	2027	2033	Excavation of the underground tunnels with TBMs and of the caverns. Cost based on the evaluation by two independent external companies.
Direction of the civil works	9	2026	2034	Evaluation based on the 1% of the underground and surface infrastructures realisation cost.
Civil works on the surface	98	2028	2033	Realisation of the technical and civil infrastructures on the surface. Cost evaluation based on the Conceptual Design study.
Services underground (ventilation ...)	44	2030	2033	Technical infrastructures serving the underground facilities and apparatuses.
<b>Detector costs</b>	<b>804</b>			
Vacuum system	566	2026	2032	Vacuum plant, pumps and pipes.
Optics and Laser	125	2027	2032	Main mirrors, auxiliary optics and lasers.
Suspension system	48	2027	2032	Filtering and suspension systems.
Cryogenics	45	2026	2032	Cryogenic plants.
ET installation	20	2032	2035	Contracts and activities for the installation of the ET components.
<b>Total</b>	<b>1736</b>			

The excavation cost has been computed through two preliminary evaluations committed to external private companies. To their estimations, following the normal practice in this kind of civil works, has been added a 15% percentage of contingency; about 40 M€ have been considered for the treatment of the excavated land. It is worth to mention that these costs are heavily dependent on the geology and on the characteristics of the selected site and a large variability must be taken in account.

The component production cost is based on our best estimate, considering the ET CDR and recent updates hereof. In the ET plan are scheduled design activities and development activities that surely will have impact on this estimate. We expect to have a refined evaluation at the end of 2023 and a definitive evaluation by the beginning of 2026.

### Operational Phase

Operational costs have been evaluated considering the actual costs of two large R.I. that have, separately, the two main aspects of ET (to be underground and to be a GW observatory): The largest Astroparticle underground laboratory (INFN-LNGS) and the largest European GW observatory (EGO-Virgo); it has been also

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compared with the initial costs of the KAGRA observatory. The costs of the two R.I. have been analysed, a unique set of cost entries has been realised by the logical union of the two independent sets and it has been scaled item per item in order to obtain a prediction for ET. The overall amount has been actualised at 37M€/year. This is not including (data analysis) computing costs because shared resources will be used and because the low level of predictability of the computing costs in 2035.

### Termination phase

It is quite difficult to evaluate in detail the termination cost of ET, considering its multi-decade expected lifetime. We can make some guess based on the costs to secure the underground infrastructures and the amount of work needed to dismount the main parts of the detectors. Being ET realised on hard rock, the main activity to be implemented to secure the infrastructure consists in the dismounting the services (ventilation, electric power, ...) and in closing the accesses to the infrastructure. Considering the number of accesses to the infrastructure and some reference cost provided by the mine company in the Sardinia site, this activity is estimated to cost a few M€.

The dismounting of the detector components is evaluated to cost about one year of running cost of ET. We don't evaluate the recycling cost of the detector components because no polluting, contaminant or radioactive components will be used in ET and the recycling costs will be compensated by the value of the metals and materials.

In total, we expect a termination cost of about 40 M€.