Socio-economic impact of the Einstein Telescope

Executive summary - ET-0001A-20

1. Introduction

This executive summary is provided for the application of the Einstein Telescope (ET) to the ESFRI Roadmap 2021. The case is based on three ex-ante impact studies as attached (Technopolis, 2018; Cide-Socran & HEC Liège, 2019; Atzeni et al., 2019). Considering that the project is in its design phase, the studies show some level of unpredictability. They differ on the 10s of percent level in terms of the absolute value of the socio-economic impact of ET and this is due to different assumptions regarding operating and construction costs. Such differences are conceptually physiological, due to the fact that there is still a substantial degree of uncertainty about such costs, given that the technical design of the infrastructure is still preliminary. To this extent, differences across studies should be interpreted as different scenarios. Importantly, and coherently with such interpretation, all studies display a good level of agreement in terms of multiplier effects on output, value added and employment, which measure the impact per unit of expenditure.

We will start with an overall view on the different kinds of opportunities the ET will bring. After that, the impact is presented overall and split out for three project phases (preparation, implementation and operation). Lastly the impact is generally projected on both proposed ET sites and referenced to their level of development and qualitative differences. These are Sardinia and the Euregion Meuse-Rhine. The Euregion Meuse-Rhine is an European high-tech region located between Aachen (Germany), Eindhoven (Netherlands) and Liège (Belgium).

Info-Box: Definitions of metrics for socio-economic impact

The economic impact of the ET stems from initial demand of goods and services necessary for the construction and the operation of the infrastructure. Such initial demand induces further multiplicative effects along the supply chain, and also due to workers' induced expenditure. In the executive summary the following definitions of '*Total output (TO), value added (VA), and employment (FTE) generated per unit of initial expenditure'* will be used.

TO measures the increase of the volume of economic activity induced by the project. VA measures the new value generated by the project, i.e. its contribution to the GDP, net of the duplication effects due to the production of intermediate goods and services along the supply chain.

2. Overall view

Acting upon the opportunity of the Einstein Telescope will bring about direct and lasting benefits in (1) science, (2) technology and (3) society. In the overall view these different kinds of impacts of the Einstein Telescope will be reviewed.

- *Stronger science communities (impact science & society)*

Observations of ET will enable discoveries in many scientific fields such as astronomy, astrophysics, cosmology, nuclear physics and particle physics. The Einstein Telescope will therefore serve as a focal point for collaboration and communication of knowledge workers, to connect different fields of study which would not or have less collaborated with each other. Already the ET community is building further towards a stronger network between universities and institutes and as a consequence strengthens its scientific position and reputation in the world. The increase of scientists by about 150-200 each year in the gravitational waves (GW) community being a signal of success and attraction towards this field. Scientists in the field of gravitational waves are already cooperating and 786 scientists to this day have indicated to support the ET project by signing the "Letter of Intent for the Einstein Gravitational Wave Telescope (ET) collaboration".

Almost all (92%) of them are from Europe, about a quarter is from Italy and about another quarter from the Euregion Meuse-Rhine countries.

· *Developing skills and attracting talent (impact science and society)*

The wealth of cutting edge technological developments and scientific progress associated with Einstein Telescope will not only attract existing talent and knowledge, but it will also speak to the imagination of young people as to choose for a study in the fields of Science, Technology, Engineering and Mathematics (STEM). As a result of this attraction, participating universities shall create new faculties especially for these fields. Such is already happening in Maastricht with the coming of the faculty of science and engineering.

· *R&D and innovation clustering (impact science and technology)*

The ET will attract scientists, knowledge workers and technology driven economic activity. It will become the nucleus for cluster formation, realizing a regional ecosystem where new technologies are developed and new companies are started. The Einstein Telescope pushes technologies beyond the current state of the art in a variety of fields. The European Commission has defined Key Enabling Technologies (KETs), which provide the basis for innovation in a range of products across all industrial sectors. Technology development for ET overlaps five of the six defined KETs, i.e.: photonics, advanced materials, nanotechnology, micro and nanoelectronics, and advanced manufacturing technologies. Examples from the Einstein Telescope context include amongst others: ultra-stable lasers, low-loss thin films, high power optical fibres, squeezed light techniques, high-efficiency photo-detectors, new thin-film materials and innovative coating procedures, ultra-pure silicon and low-absorption fused silica for large substrates (100s of kilograms and around 50cm diameter), nanostructured and controlled surfaces, advanced realtime control systems and ultra-low noise electronics, innovative production techniques for optical components and the vacuum system.

· *The effects of technology and innovation at Einstein Telescope (impact technology and society)*

The R&D and innovation originating from the ET will result in attracting business and creating spin-offs based on the key technologies for relevant high tech and life, sciences & wealth sectors. For instance, the extension of the laser wavelength can be applied to the welding of special plastics, spectroscopic measurements in medical applications and the crushing of gallstone (cholelithotripsy). It will also create a state-of-the-art technological ecosystem in many other fields of activity such as mechanics, astronomy and construction underground. All companies involved in the project would be marked with a label of technological excellence, which would increase their attractiveness and individual competitiveness.

· *Branding (impact society)*

A proper branding strategy, high visibility and related international exposure will not only be beneficial to the regions in forms of tourism, but it has been recognised that the Einstein Telescope will facilitate in bringing science and society closer together.

· *Jobs for both high- and low-tech (impact society)*

Ranging from scientists and engineers to maintenance workers and support staff, a broad range of professionals is needed during the construction and operation of the Einstein Telescope. A list of the potential professions needed in direct connection with ET is provided below.

- (High value-added) employees such as technical sales staff, project managers, administrative staff, team leaders, physicists, engineers, automation engineers, electromechanical engineers, safety experts, fire safety engineers, precision optics engineers, civil engineers, electronics engineers, mechanical engineers, hydraulic engineers, machine programmers and surveyors.

- (High value-added) workers such as technicians, mechanics, welders, pipefitters, instrumentalists, machinists, industrial painters, laborers, construction workers, millers, turners, optical technicians, technicians programmers, workers specialized in underground, mechanical heads and tunnel operators.

2. Impact of the preparation phase

Currently the preparation phase of the ET is underway. In the preparation phase it is determined what the specs of the ET will be, where it will be located and how it will be administratively run (governance). These choices determine to a large extent the impacts later in the process, and where these impacts are likely to land. It is a process of scientific and technological development which will result in the best design for the telescope to achieve its scientific ambitions and with it, it's socio-economic impact. The initial design activity was realised through a conceptual design funded by European Commission in FP7, but nowadays updated with the contribution of external companies, specialised in large underground infrastructure design, and thanks to the large experience acquired with the Advanced GW detectors currently in operation and the KAGRA detector.

The essential technologies that will be developed are key enabling technologies with a very broad application potential further down the innovation pipeline. The results of the research in key enabling technologies will enable further insights to estimate the costs of the ET.

Furthermore, the needed adaptation to be able to perform the research will improve the local R&D infrastructure. There will be testing of technologies which will be interesting for (new) companies. Several companies have stated that the spillover in economic activity and innovation and entrepreneurship is more important for them than the direct impacts of working on the ET. Even though they cannot predict what kind of spin-offs will occur and how economic activity will develop, they trust that more activity will lead to innovation that will benefit them and they indicate they want to be involved. Especially since all technologies that need to be developed have an innovation part.

As a result of working together on the development of technologies, it is strengthening the collaboration between science and industry in the preparation phase, as there is a need for organisation. When companies are interested and the cooperation between the countries and different knowledge fields goes well, this strengthens the consortium for the ET. This will put scientific and industrial players from the regions in a good position to optimise their returns from building and developing the telescope, by showing that the expertise and knowledge needed for the ET is present in the regions, and that willingness to cooperate within ET exists.

3. Impact of implementation

With the impact of implementation we look at the construction phase of the Einstein Telescope. The overall expected budget will be around 1,700 M€. As detailed in answer to 3.1, conducted modelling in the three impact studies suggest that the multiplier effects per Euro of initial expenditure are as follows: (1) 3.6 in TO terms, meaning that 1 Euro of expenditure generates a TO of 3.6 €; (2) between 1.4 and 1.55 in VA terms; (3) between 18 and 21 workers person-year (py) per M€ in terms of employment. These multipliers translate to an overall estimated TO of 6,100 M€; an overall VA between 2,400 M€ and 2,600 M€ and an estimated overall employment effect of about 34,000 py over the construction period (about 1,500 construction site workers and the remaining 32,500 are jobs created along ET supply-chain). Around 50% of this budget is location bound for it will be used for the development of the site and other low-tech expenses. The remaining 50% is an approximation for the high-tech expected investments for development in science, technology and innovation.

High costs per unit make high-tech production elsewhere viable, but special consideration is given by and between investing partners for agreeing on procurement rules. So that every party involved gets a fair share that fits their capabilities and needs. As described before, key technologies that will be part of the development of the ET are optics, ultra-stable lasers, cryogenics, seismic isolation, material science, quantum technologies, vacuum systems, precision metrology, electronics and control systems, data handling and management, as well as adaptive control techniques and machine learning.

4. Impact of operation

In the ET cost book the annual costs of the operation phase are estimated to be 37 M€. These relate to the employees' wages and the provision of goods and services other than labor, including IT equipment, software maintenance, consumables, security, electricity, etc. The annual TO being 133

M€, the VA outcome ranging between 52 and 57 M€ and overall estimated employment of about 883 py of which 163 is the ET staff and 720 are jobs created along ET supply-chain.

The operational costs have been evaluated considering the actual costs of two large RIs 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 also been compared with the initial costs of the KAGRA observatory. The costs of the two RIs 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 build a prediction for ET. The overall amount has not included (data analysis) computing costs because shared resources will be used and because the low level of predictability of the computing costs in 2033.

5. General projection of the impact on the region

Lastly the impact is generally projected on both proposed ET sites with reference to their level of development and qualitative differences.

In the Sardinia region the ET will be a key element, together with the other existing regional research infrastructures in the development of the aerospace sector that falls within one of the targeted sectors of the region’s Smart Specialisation Strategy. The reorientation of the mine site that will host ET, other than being in line with the strategies pursued by the regional government, has a long-term socio-economic impact due to the re-use of the site which will be able to provide higher long-term returns. Also the Sardina region has been recognised as ‘Less Developed’ region (objective I) within the EU cohesion policy framework 2021-27, which will be a plus since there is robust evidence that large public research infrastructures generate a bigger impact in less developed regions compared to more developed ones.

ET can promote the internationalization and aggregation of scientific policy for regions bordering the western Mediterranean, including through Interreg or similar tools.

The Euregion Meuse-Rhine has a strong base in (knowledge) infrastructure, high-tech industry and a very favorable international business- and living climate. A European region with great innovation potential (OECD, 2013) and innovation leadership (European innovation scoreboard). These are the ingredients for a good anchoring, with it a unique way to connect these forces and the optimal impact of the ET as an 'infrastructural magnet'. Also there is an opportunity to connect economically separated regions across borders by means of science (in line with the EU ERA strategy) and innovative cooperation in order to also connect the various development stages/speeds within the Euroregion (EU cohesion strategy).