Milestone 3.2: Macroeconomic impact analysis updated

Authors: Kalliopi Petrinoli, Sevastianos Mirasgedis, Nikos Mihalopoulos

Work package no	WP3
Deliverable no.	MS3.2
Lead beneficiary	NOA
Deliverable type	X R (Document, report) ☐ DEC (Websites, patent fillings, videos, etc.) ☐ OTHER: please specify .....
Dissemination level	X PU (public) ☐ CO (confidential, only for members of the Consortium, incl. Commission)
Estimated delivery date	M18
Actual delivery date	29/12/2021
Version	Final
Reviewed by	Eija Juurola
Accepted by	Eija Juurola
Comments	

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Contents

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

1. Introduction

ACTRIS Research Infrastructure is a pan-European initiative that unites the observations and related research of aerosols, clouds, and trace gases amongst European partners to provide high-quality research infrastructure services to a wider user community. Integrating European ground-based stations equipped with advanced atmospheric probing instrumentation, ACTRIS will have the essential role to support building of new knowledge as well as policy issues on climate change, air quality, and long-range transport of pollutants. The ESFRI Roadmap 2016 identified ACTRIS as a new important pan-European research infrastructure for the European scientific community. With ESFRI-status, ACTRIS shall further develop its organizational and operational framework, and long-term strategic goals. In this context, the ACTRIS Implementation Project (ACTRIS IMP) aims at taking ACTRIS into a new level of maturity and will set the needed structures for the implementation actions, both at the national and European level. ACTRIS IMP builds on three main pillars: securing the long-term sustainability, implementing of ACTRIS functionalities and positioning ACTRIS in the national, European, and international science and innovation landscape.

In general, ACTRIS, as any other research infrastructure, creates positive socio-economic effects through different impact pathways:

- At consortium level, as research institutes, universities, companies, etc., involved in the development, maintenance and operation of the infrastructure in question will benefit through knowledge creation, technological developments, human capital enhancement, creation of new jobs, etc.
- To the wider research community, as research teams, organizations and programs utilizing the outcomes provided by ACTRIS will improve their modelling, satellite data calibration / validation and atmospheric climate services and products.
- To the society, as local authorities, environmental protection agencies, industries, ministries, international organizations, weather services, etc., will utilize ACTRIS outcomes to optimize their environmental strategies and improve their decision-making processes.

The socio-economic impacts associated with ACTRIS implementation and operation, were initially estimated in the context of the preparation phase of ACTRIS research infrastructure (project ACTRIS PPP). The analysis undertaken provided a set of Key Performance Indicators (KPIs) to facilitate the effective monitoring and quantification of various type of socio-economic impacts, including the impacts on human capital creation, scientific activity, innovation, economy and society. The work plan envisaged in the context of ACTRIS IMP aims at updating and further investigating selected types of the above-mentioned societal impacts, namely the macroeconomic effects of ACTRIS implementation and operation as well as the impacts on society through a Contingent Valuation Study. The present short technical note updates the macroeconomic impact analysis of ACTRIS infrastructure using the most recent EU and Member States data together with the ACTRIS cost book on the required costs for the development and operation of ACTRIS.

The present technical note is structured as follows:

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Chapter 2 provides a brief description of the input-output analysis framework that has been used to estimate the macroeconomic effects associated with ACTRIS implementation and operation for Central and National Facilities.

Chapter 3 presents the results of the analysis. A number of KPIs has been identified and quantified on the basis of data collected for past activities in the context of ACTRIS as well as on projections made by national teams for future developments of ACTRIS in each participating country.

Finally, in *Chapter 4* the main findings of the study are summarised, and conclusions are drawn.

2 Estimation of macro-economic effects through input – output analysis

2.1 Overview

As already mentioned, in the present study, the macroeconomic implications associated with the development and operation of the ACTRIS infrastructure will be updated. The analysis is done for the whole European economy, as analysis at national level requires more detailed data and a determination of the percentage of expenditures incurred domestically in each country, which is quite difficult given the dispersion of this infrastructure and the strong partnerships of the participating groups.

As a large-scale investment, ACTRIS contributes directly to the economy through direct payments, taxes, creation of employment, etc. In addition, the realization of the activities associated with the research infrastructure development, maintenance and operation requires the purchase of goods and services such as construction materials and equipment, maintenance tools, and supplies as well as manpower essentials such as food, clothing, spares, safety equipment, etc., enhancing further the economic development at both local, national and regional level (indirect economic effects). Furthermore, as those engaged directly or indirectly in these activities will increase their available income for spending, additional economic effects are expected due to the increased consumption for purchasing goods and services (induced economic impacts). In the context of this analysis, we have analysed all the direct, indirect and induced macroeconomic effects associated with ACTRIS development, maintenance and operation activities, namely:

- Contribution to GDP through changes in Gross Value Added (GVA),
- Employment effects,
- Changes in available income.

The quantification of these effects is based on input-output analysis, which is shortly presented in Section 2.2. The multipliers that can be derived from input-output tables and used for estimating the impacts on GDP, employment and other macroeconomic parameters are presented in Section 2.3.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

2.2 Input – output analysis

Input-output analysis is a methodological approach, which can evaluate the effects of an investment on key socio-economic variables taking into account the inter-sectoral linkages in the economy where the investment in question is realized. Specifically, input-output tables provide a complete overview of the monetary flows representing the exchange of goods and services in an economic system for a given year, either between producers and consumers or among economic sectors. The standard representation of the input-output model in matrix notation is defined in the following Equation, which allows constructing disaggregated multipliers in order to estimate the direct, indirect and induced impacts of a project (Leontief, 1966; Eurostat, 2008):

$$X = (I - A)^{-1} Y \quad (1)$$

where,

X: is the vector of output of the economy in question (all elements of the vector are expressed in €).

Y: is the vector of final demand of the economy (all elements of the vector are expressed in €).

I: is the identity matrix.

A: is a n × n matrix of technical coefficients. A technical coefficient a_{ij} is defined as the amount of production of sector i used by sector j in order for the latter to produce one unit of output. Through these coefficients one can estimate the direct impacts from an increase in final demand for a particular commodity on the various economic sectors.

The $(I-A)^{-1}$ is the n × n matrix of input–output multipliers, or the Leontief inverse. The rows and columns of the Leontief inverse matrix are the sectors of the economy and each element b_{ij} of this matrix shows the total required increase in the production of sector i to meet an increase of one unit in the final demand of sector j. The sum of all the elements of the j column of the Leontief inverse matrix gives the output multiplier of the sector j, which shows the total change in gross output (or sales) of the entire economy created by a change in the final demand of sector j by 1 €.

There are two types of Leontief inverse matrices, where each one of them provides a different type of multiplier. The first named Type I, includes the relationship among various economic sectors and is used to estimate the indirect economic effects. The second one named Type II, includes additionally the effect of households' consumption (by expanding the matrix with one column, namely the households' expenditure and one row, namely the compensation of employees) and is used in combination with Type I Leontief inverse to estimate the induced effects of a policy or project.

It is also worth mentioning that the input-output analysis is based on certain assumptions/prerequisites (Trewin, 2000), namely homogeneity (i.e., each sector produces a single output, has a single input structure and there is no substitution between the products of different sectors), proportionality (i.e., the change in output of a sector will lead to proportional changes in the quantities of its intermediate and primary inputs), and no existence of externalities (i.e., the production process of each sector does not affect the production activities of any other sector). Even though these assumptions are far from being realistic given the multiplicity and variability of processes in modern economies, input–output

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

analysis is still considered as an attractive and powerful tool that is capable of adequately capturing the inter-linkages within an economic system. Since radical changes in economic structure can be assumed to occur relatively slowly, the results derived from such models can remain robust for many years.

2.3 The framework for estimating the macroeconomic effects

Input-output tables can be used to estimate several of the macro-economic effects associated with a policy or an investment. These comprise impacts on employment, GVA, wages, taxes on products and production, etc. To this end, the total investment in question is disaggregated to a number of distinct economic sectors, which are included in the input-output table. It is assumed that the marginal change MX_j in the activity of sector j caused by the realization of the project in question incurs an analogous change in the level of various macro-economic parameters (i.e., employment, GVA, wages, taxes on products and production) that can be approximated by the following simple formula:

$$ME_j = MX_j \cdot \frac{E_j}{X_j} \qquad (2)$$

Where ME_j is the marginal change of the macroeconomic parameter E, which characterizes sector j, from the marginal change MX_j of the output (X) of sector j. Thus, the direct effects on employment, GVA, wages, taxes on products and production, etc., from ACTRIS development and operation result as the sum of all marginal changes estimated in all sectors of the economy affected by the project in question.

The indirect and induced effects on these macro-economic parameters can also be estimated exploiting the input-output table through appropriate multipliers. As in the case of output, there are two types of macro-economic multipliers. Specifically:

- The Type I multiplier of the macro-economic parameter E ($M_{I,E}$) calculates the increase of E in the whole economy (direct and indirect effects) due to a unit direct increase of E in sector j:

$$M_{I,E,j} = \sum_{i=1}^{n} \frac{e_i \cdot b_{ij}}{e_j} \qquad (3)$$

  where $M_{I,E,j}$ is the Type I multiplier for the macro-economic parameter E and sector j, e_i (or e_j) is the corresponding macroeconomic effect creating in sector i (or j) per €1 of total output per sector i (or j) and $b_{i,j}$ is the Leontief coefficient which depicts direct and indirect impacts on the demand for the output of sector i as a result of changes in the demand of sector j.

- The Type II multiplier of the macro-economic parameter E ($M_{II,E,j}$) measures the ratio of direct, indirect and induced effects on E to the direct change of E in sector j:

$$M_{II,E,j} = \sum_{i=1}^{n} \frac{e_i \cdot b'_{ij}}{e_j} \qquad (4)$$

  where $b'_{i,j}$ is the Type II Leontief coefficient.

By implementing this accounting framework, the macroeconomic effects attributed to the investments under examination per sector of economic activity can be estimated for the entire lifetime of a project or

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

a policy in question. The results will be more reliable for the first years of the analysis while uncertainties increase in the long-run as the structure of the economy changes.

A key assumption for the analysis is to what extent the necessary equipment for developing and maintaining the infrastructure as well as the additional expenditures due to the increased income, occurs in the economy considered or elsewhere abroad. In the latter case, the estimation of the associated macroeconomic impacts should be based on this part of the expenditures that are spent inside the economy in question.

2.4 Implementation for ACTRIS

The macroeconomic impact analysis carried out in the context of this analysis takes into account:

- The implementation and operation of Central Facilities.
- The implementation and operation of National Facilities.
- The additional research funding that can be attracted by utilizing the research infrastructure in question.

The analysis is based on specific technological and economic data for the ACTRIS research infrastructure that have been collected through:

- The 5-year financial plan for Central Facilities approved by the Interim ACTRIS Council in its 15th meeting.
- A survey of ACTRIS participants, which collected data on the implementation and operation of the ACTRIS research infrastructure in each country, as well as on the additional funding attracted.

These data provide the essential background information for estimating the direct impacts of the reference infrastructure on economic development and on employment. The indirect and induced macroeconomic implications of the project on value added, employment and available income have been analysed through Input–Output multipliers, taking into account the inter-sectoral linkages of the European economy.

3. Results

3.1 Design of the survey

The analysis of the macro-economic impact of ACTRIS associated with the development and operation of National Facilities was based on a field survey and the completion of a properly designed questionnaire by the project participants.

The questionnaire was designed by National Observatory of Athens (NOA) and was distributed to the national ACTRIS contact persons in each country participating in ACTRIS, as defined in the ESFRI Roadmap (2016). Consequently, each participating country in the context of the ACTRIS IMP had to fulfill

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

one questionnaire, providing aggregated data at national level by including all organizations of the country engaged in development, operation, and maintenance of ACTRIS infrastructure.

The time available to the national contact persons to complete the questionnaire was initially 2 months (1 June to 31 July 2021), however some completed questionnaires were received by the end of October 2021.

The developed questionnaire is presented in Appendix and it is organized in three sections:

- Section I comprises introductory questions such as the name and affiliation of the responsible for completing the questionnaire, the Institutes in each country that participate in ACTRIS research infrastructure and their role, etc.
- Section II deals with the macroeconomic effects attributed to the implementation and operation of ACTRIS, collecting information and background data on the economic and human resources attributed to the development and operation of ACTRIS infrastructure in each country.
- Section III explores the influence of ACTRIS infrastructure on research activities of the participating Institutions, focusing on the funds attracted by utilizing the RI in question.

In total it comprises 25 questions, collecting various data that will allow a quantitative analysis of the macro-economic impacts of ACTRIS RI. Data were completed for two periods, namely 2021-2025 and 2026, covering future developments of the infrastructure in question in the context of ACTRIS IMP (2021-2025), as well as an indicative year (2026) of full operation of the infrastructure in question.

Eight countries completed the questionnaire out of a total of 23 participating in the ACTRIS IMP. Specifically, responses were received from Germany, Spain, Finland, Romania, Italy, France, Austria and Greece, covering the activities of 67 organizations engaged in ACTRIS development and operation. It is also worth mentioning that this sample constitutes a significant part of the ACTRIS community as the countries responded to the questionnaire have approximately a 70% share of the budget in the context of ACTRIS IMP.

3.2 Macroeconomic effects

As already mentioned, in the context of ACTRIS IMP we have attempted to update the analysis of the macroeconomic effects associated with the development, operation, maintenance and upgrading of the ACTRIS research infrastructure taking into account the spending required and the funds that will be attracted during the period 2021-2025 (implementation phase) and for the year 2026 (indicative year of full operation). The analysis is undertaken for the entire European economy through input – output analysis. To this end, the input - output table covering the 28 EU Member States was used, while the estimated macroeconomic impacts are calculated at EU level. Specifically, the analysis is based on the input – output table of the European Union (EU-28) for 2018, which is available from the Eurostat database.

Knowing the total spending for developing, maintaining, upgrading, and operating the research infrastructure in question as well as its sectoral decomposition is essential for estimating its

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

macroeconomic impacts and performing the input-output simulation. The total amount of spending for all the above-mentioned activities during the period 2021-2025 and 2026 was collected at national level through the questionnaires and for Central Facilities through the ACTRIS 5-year Financial Plan. Furthermore, estimates on the research funds expected to be attracted by national teams due to the utilization of ACTRIS infrastructure were also collected through the questionnaires. For an average year of the period 2021-2025, the total spending was estimated at € 110 million, of which 12% concern the implementation and operation of Central Facilities, 52% the implementation and operation of National Facilities and 36% funds attracted through research projects, etc. (Table 3.1). Correspondingly, for the year 2026, the total spending was estimated at € 77 million, 16% of which concern the Central Facilities, 34% National Facilities, and the remaining 50% funding related to the implementation of various research programs and scientific activities (Table 3.2). It is considered that for the year 2026, the groups participating in the ACTRIS infrastructure will attract the same amount for research funds as in the period 2021-2025, which is a rather conservative assumption given that it is reasonable to expect that the full operation of the infrastructure in question will result in increased funding for research activities. As some countries did not respond to the survey, the total spending associated with the research infrastructure in question over the period considered is expected to be even higher.

A critical issue for the analysis is to what extent these expenditures will be undertaken domestically (i.e., inside the European economy) or some of the equipment / materials will be imported from abroad, influencing the volume of money that will be spent domestically. Given that the analysis is undertaken for the entire European economy and the specialized equipment and services that require these projects, we consider that all expenditures related to ACTRIS infrastructure are made within the European Union. However, an analysis at national level can significantly differ from these results taking into account only the domestic expenditures.

It is worth mentioning that the development, maintenance and upgrading activities of research infrastructures are not included as distinct sectors in the input – output table, while only the use of the infrastructure could be considered that is covered by the sector “Scientific research and development services”. Therefore, as described in the proposed methodological framework in Section 2, the analysis is undertaken by disaggregating the expenses associated with the implementation, operation and upgrading of the research infrastructure in question to the predefined economic sectors included in the input–output table. Aiming at facilitating the disaggregation of the expenditures made for the development and operation of ACTRIS infrastructure, the 65×65 input–output table of the European economy has been chosen for the quantitative analysis. Tables 3.1 and 3.2, summarize the analysis of spending for the implementation, operation and research activities of ACTRIS for an indicative (average) year of the period 2021-2025 and 2026, further disaggregated to Central and National Facilities respectively. To a large extent the distribution of total spending to various economic sectors are based again on data provided through the questionnaires and information included in ACTRIS 5-year Financial Plan as well as on expert judgements, since some countries did not provide the relevant information, or the disaggregation covered only part of the total spending.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Table 3.1: Sectoral decomposition of the expenditures undertaken for an average year of the period 2021-2025 for implementation, operation and research projects of ACTRIS, Central and National Facilities.

	Implementation				Operation				Research Activities		Total spending	
	Central Facilities		National Facilities		Central Facilities		National Facilities					
Economic sectors	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*
Computer, electronic and optical products	1.50	27.6 %	12	31.2%	0.51	6.50 %	2.04	10.00%			16.05	14.60%
Electrical equipment	0.10	1.80%	1	2.60%	0.07	1.00%	0.29	1.40%			1.46	1.30%
Machinery and equipment n.e.c.	0.20	3.60%	2	5.20%	0.11	1.40%	0.44	2.00%			2.75	2.50%
Constructions and construction works	0.50	9,20%	4	10.40%							4.50	4.10%
Architectural and engineering services; technical testing and analysis services	0.10	1.80%	1	2.60%	0.04	0.60%	0.15	0.70%			1.29	1.20%
Scientific research and development services	3.00	56.00%	18	47.00%	7.00	90.50%	17.00	86.00%	39.00	100.00%	84.00	76.30%
Total	5.56	100%	38	100%	7.79	100%	19.74	100.00%	39.00	100.00%	110.09	100.00%

Table 3.2: Sectoral decomposition of the expenditures undertaken during 2026 for operation and research projects of ACTRIS, Central and National Facilities.

	Operation				Research Projects		Total spending	
	Central Facilities		*National Facilities*					
Economic sectors	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*	*Spending (in € millions)*	*Percentage (%)*
Computer, electronic and optical products	1.65	6.5 0%	2.40	10.00%			4.05	5.30%
Electrical equipment	0.24	1.00%	0.34	1.40%			0.58	0.80%
Machinery and equipment n.e.c.	0.35	1.40%	0.52	2.00%			0.87	1.10%
Constructions and construction works								
Architectural and engineering services; technical testing and analysis services	0.12	0.60%	22.00	0.70%			22.12	28.80%
Scientific research and development services	10.00	90.50 %	0.17	86.00%	39.00	100.00%	49.17	64.00%
Total	12.47	100%	25.63	100.00%	39.00	100.00%	76.79	100.00%

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

In Tables 3.3 and 3.4, the impact per effect (direct, indirect and induced) attributed to the implementation, operation and research activities of ACTRIS infrastructure on the value added (in million €), employment (in full-time equivalent person-years) and available income (in million €) are presented.

For an average year of the period 2021-2025 the ACTRIS infrastructure is expected to contribute to an increase of the Valued Added of the European economy by € 153 million. About 35% of this value added was created directly, 26% indirectly and 39% is induced. In addition, 12% of these effects are associated with implementation and operation activities in Central Facilities, 51% with the corresponding activities in National Facilities and 37% with the research activities undertaken in the infrastructure. Also, for the average year of this period the total effects on employment were estimated at 1,974 person-years of which 20% is created directly, 32% is created indirectly and 48% is induced. Approximately 35% of the created employment is associated with research activities developed in ACTRIS infrastructure. No matter the type of employment created, the activities undertaken for the implementation, operation and research projects of ACTRIS infrastructure have resulted in an increased available income by € 80 million/year.

For 2026 the ACTRIS infrastructure is expected to contribute in an increase of the Valued Added of the European economy by € 110 million, of which 35% is created directly, 25% indirectly and 40% is induced. For the same period the total effects on employment were estimated at 1,369 person-years of which 18% is created directly, 31% is created indirectly and 51% is induced. Approximately 51% of the created employment is associated with research activities developed in ACTRIS infrastructure. The activities undertaken for the operation and research projects of ACTRIS infrastructure is expected to result in an increased available income by € 57 million during 2026.

Table 3.3: Estimated macroeconomic effects associated with the implementation, operation and research projects of ACTRIS, Central and National Facilities during the period 2021-2025.

Type of impact	Implementation		Operation		Research Projects	Total
	Central Facilities	National Facilities	Central Facilities	National Facilities		
Impact on Gross Value Added (in € millions)						
Direct	3	17	4	10	20	54
Indirect	2	14	3	7	14	40
Induced	3	19	4	11	22	59
Total	8	50	11	28	56	153
Impact on Employment (in person-years)						
Direct	22	156	26	66	123	393
Indirect	33	225	43	110	215	626
Induced	47	310	70	174	355	956
Total	102	691	139	350	693	1975
Impact on Income (in € millions)						

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Direct	1	9	2	6	12	31
Indirect	1	8	1	4	8	22
Induced	1	9	2	5	10	27
Total	3	26	5	15	30	80

Table 3.4: Estimated macroeconomic effects associated with the operation and research projects of ACTRIS, Central and National Facilities during 2026.

Type of impact	Operation		Research Projects	Total
	Central Facilities	National Facilities		
Impact on Gross Value Added (in € millions)				
Direct	6	13	20	39
Indirect	5	9	14	28
Induced	7	14	22	43
Total	18	36	56	110
Impact on Employment (in person-years)				
Direct	42	85	123	250
Indirect	70	143	215	428
Induced	109	227	355	691
Total	221	455	693	1369
Impact on Income (in € millions)				
Direct	4	7	12	23
Indirect	2	5	8	15
Induced	3	6	10	19
Total	9	18	30	57

Tables 3.5 and Table 3.6 present the estimated macroeconomic effects associated with ACTRIS activities for an average year of the period 2021-2025 and for 2026 adjusted on a per € 1 million spending. The indicators presented in both tables, provide a sound basis for calculating the macroeconomic effects of the infrastructure, subject to availability of more detailed data about past activities, but also in order to calculate the impact attributed to future developments of the infrastructure.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Table 3.5: Estimated macroeconomic effects associated with the development, maintenance and operation of ACTRIS research infrastructure per € 1 million spending for an average year of the period 2021-2025.

Type of impact	Implementation		Operation		Research Projects	Total
	Central Facilities	National Facilities	Central Facilities	National Facilities		
Impact on Gross Value Added (in € millions/ € 1 million spending)						
Direct	0.54	0.45	0.51	0.50	0.51	0.49
Indirect	0.36	0.37	0.39	0.35	0.36	0.36
Induced	0.54	0.50	0.51	0.56	0.56	0.54
Total	1.44	1.32	1.41	1.42	1.44	1.39
Impact on Employment (in person-years/ € 1 million spending)						
Direct	3.96	4.11	3.34	3.34	3.15	3.57
Indirect	5.93	5.92	5.52	5.57	5.51	5.69
Induced	8.45	8.16	8.99	8.81	9.10	8.67
Total	18.34	18.18	17.84	17.73	17.77	17.93
Impact on Income (in € millions/ € 1 million spending)						
Direct	0.18	0.24	0.26	0.30	0.31	0.28
Indirect	0.18	0.21	0.13	0.20	0.21	0.20
Induced	0.18	0.24	0.26	0.25	0.26	0.25
Total	0.54	0.68	0.64	0.76	0.77	0.73

Table 3.6: Estimated macroeconomic effects associated with the operation and research projects of ACTRIS research infrastructure per € 1 million spending during 2026.

Type of impact	Operation		Research Projects	Total
	Central Facilities	National Facilities		
Impact on Gross Value Added (in € millions/ € 1 million spending)				
Direct	0.48	0.51	0.51	0.51
Indirect	0.40	0.35	0.36	0.36
Induced	0.56	0.55	0.56	0.56
Total	1.44	1.40	1.44	1.43
Impact on Employment (in person-years/ € 1 million spending)				

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Direct	3.36	3.32	3.15	3.26
Indirect	5.61	5.58	5.51	5.58
Induced	8.74	8.86	9.10	9.00
Total	17.72	17.75	17.77	17.83
Impact on Income (in € millions/ € 1 million spending)				
Direct	0.32	0.27	0.31	0.30
Indirect	0.16	0.20	0.21	0.20
Induced	0.24	0.23	0.26	0.25
Total	0.72	0.70	0.77	0.74

Finally, Tables 3.7 and 3.8 present a sector distribution of the estimated employment effects associated with ACTRIS activities for an average year of the period 2021-2025 and for 2026, highlighting those economic sectors that will mainly benefit. These results have been derived by taking into account the estimated direct impact on employment by sector of economic activity and the components of the employment multipliers estimated for these sectors as described in equations 3 and 4 in Section 2.3. Having done the analysis for each economic sector in which direct employment is created, then the results obtained are summed up by sector of economic activity. As expected, direct results are concentrated in the sectors where the majority of spending takes place, namely "Computer, electronic and optical products", "Scientific research and development services" for both periods and "Construction and construction works". The indirect and induced effects of the expenditures under consideration are transmitted, to a certain extent, to all the sectors of the economy. Specifically, during the period 2021-2025, the indirect effects are mostly concentrated in "Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services" (9% of indirect employment), "Wholesale trade services, except of motor vehicles and motorcycles" (7% of indirect employment), and "Legal and accounting services; services of head offices; management consultancy services" (8% of indirect employment). Regarding induced employment effects the most significant economic sectors are "Retail trade services, except of motor vehicles and motorcycles", "Accommodation and food services" and "Products of agriculture, hunting and related services". During 2026, the indirect employment effects are mostly concentrated in "Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services", "Legal and accounting services; services of head offices; management consultancy services", "Employment Services" and "Wholesale trade services, except of motor vehicles and motorcycles ". At the same time, the induced employment effects are mostly concentrated in "Retail trade services, except of motor vehicles and motorcycles", "Accommodation and food services" and "Products of agriculture, hunting and related services". This distribution is mainly influenced by the ways that households consume their available income as well as from the employment intensities of the various sectors of the European economy.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Table 3.7: Analysis of the employment effects attributed to ACTRIS infrastructure during an average year of the period 2021-2025 per industry (in person-years of full time jobs).

	Direct	Indirect	Induced	Total
Products of agriculture, hunting and related services	0	11	65	76
Products of forestry, logging and related services	0	2	2	4
Fish and other fishing products; aquaculture products; support services to fishing	0	0	1	1
Mining and quarrying	0	2	2	4
Food, beverages and tobacco products	0	4	35	39
Textiles, wearing apparel, leather and related products	0	3	12	15
Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	0	4	3	7
Paper and paper products	0	3	3	6
Printing and recording services	0	5	3	8
Coke and refined petroleum products	0	0	1	1
Chemicals and chemical products	0	6	4	10
Basic pharmaceutical products and pharmaceutical preparations	0	1	1	2
Rubber and plastic products	0	11	6	17
Other non-metallic mineral products	0	6	4	10
Basic metals	0	8	2	10
Fabricated metal products, except machinery and equipment	0	26	8	34
Computer, electronic and optical products	60	8	2	70
Electrical equipment	9	9	4	22
Machinery and equipment n.e.c.	14	11	3	28
Motor vehicles, trailers and semi-trailers	0	9	9	18
Other transport equipment	0	2	1	3
Furniture and other manufactured goods	0	3	8	11
Repair and installation services of machinery and equipment	0	7	4	11
Electricity, gas, steam and air conditioning	0	4	8	12
Natural water; water treatment and supply services	0	1	3	4
Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; remediation services and other waste management services	0	5	6	11
Constructions and construction works	35	24	22	81
Wholesale and retail trade and repair services of motor vehicles and motorcycles	0	11	26	37
Wholesale trade services, except of motor vehicles and motorcycles	0	45	45	90
Retail trade services, except of motor vehicles and motorcycles	0	31	141	172
Land transport services and transport services via pipelines	0	24	35	59
Water transport services	0	0	1	1
Air transport services	0	1	2	3
Warehousing and support services for transportation	0	12	13	25
Postal and courier services	0	10	8	18
Accommodation and food services	0	14	101	115

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Publishing services	0	3	3	6
Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services	0	2	3	5
Telecommunications services	0	4	6	10
Computer programming, consultancy and related services; Information services	0	22	9	31
Financial services, except insurance and pension funding	0	10	17	27
Insurance, reinsurance and pension funding services, except compulsory social security	0	1	6	7
Services auxiliary to financial services and insurance services	0	5	9	14
Real estate services excluding imputed rents	0	4	21	25
Legal and accounting services; services of head offices; management consultancy services	0	50	28	78
Architectural and engineering services; technical testing and analysis services	11	21	8	40
Scientific research and development services	264	10	0	274
Advertising and market research services	0	7	5	12
Other professional, scientific and technical services and veterinary services	0	12	8	20
Rental and leasing services	0	5	3	8
Employment services	0	40	20	60
Travel agency, tour operator and other reservation services and related services	0	1	4	5
Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	0	56	36	92
Public administration and defence services; compulsory social security services	0	3	26	29
Education services	0	1	24	25
Human health services	0	2	12	14
Residential care services; social work services without accommodation	0	2	10	12
Creative, arts, entertainment, library, archive, museum, other cultural services; gambling and betting services	0	4	5	9
Sporting services and amusement and recreation services	0	2	3	5
Services furnished by membership organisations	0	2	30	32
Repair services of computers and personal and household goods	0	1	32	33
Other personal services	0	7	8	15
Services of households as employers; undifferentiated goods and services produced by households for own use	0	24	25	49
Total	393	626	955	1974

Table 3.8: Analysis of the employment effects attributed to ACTRIS infrastructure during 2026 per industry (in person-years of full time jobs).

	Direct	Indirect	Induced	Total
Products of agriculture, hunting and related services	0	9	47	55
Products of forestry, logging and related services	0	1	2	3
Fish and other fishing products; aquaculture products; support services to fishing	0	0	1	1
Mining and quarrying	0	1	2	3
Food, beverages and tobacco products	0	3	26	29
Textiles, wearing apparel, leather and related products	0	2	9	11

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	0	2	2	5
Paper and paper products	0	2	2	4
Printing and recording services	0	4	2	6
Coke and refined petroleum products	0	0	0	1
Chemicals and chemical products	0	4	3	7
Basic pharmaceutical products and pharmaceutical preparations	0	1	1	2
Rubber and plastic products	0	7	4	12
Other non-metallic mineral products	0	3	3	5
Basic metals	0	5	1	7
Fabricated metal products, except machinery and equipment	0	16	6	22
Computer, electronic and optical products	15	4	2	21
Electrical equipment	3	5	3	8
Machinery and equipment n.e.c.	4	7	2	13
Motor vehicles, trailers and semi-trailers	0	7	6	14
Other transport equipment	0	1	1	2
Furniture and other manufactured goods	0	2	6	8
Repair and installation services of machinery and equipment	0	5	3	8
Electricity, gas, steam and air conditioning	0	3	6	9
Natural water; water treatment and supply services	0	1	2	3
Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; remediation services and other waste management services	0	4	4	8
Constructions and construction works	0	12	16	27
Wholesale and retail trade and repair services of motor vehicles and motorcycles	0	8	19	27
Wholesale trade services, except of motor vehicles and motorcycles	0	28	32	60
Retail trade services, except of motor vehicles and motorcycles	0	20	102	122
Land transport services and transport services via pipelines	0	17	25	42
Water transport services	0	0	1	1
Air transport services	0	1	1	2
Warehousing and support services for transportation	0	8	9	18
Postal and courier services	0	7	6	13
Accommodation and food services	0	10	73	83
Publishing services	0	2	2	4
Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services	0	2	2	4
Telecommunications services	0	3	5	7
Computer programming, consultancy and related services; Information services	0	16	7	23
Financial services, except insurance and pension funding	0	7	13	19
Insurance, reinsurance and pension funding services, except compulsory social security	0	1	5	6
Services auxiliary to financial services and insurance services	0	4	7	10
Real estate services excluding imputed rents	0	3	15	18

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Legal and accounting services; services of head offices; management consultancy services	0	36	20	56
Architectural and engineering services; technical testing and analysis services	3	14	6	23
Scientific research and development services	225	9	0	234
Advertising and market research services	0	5	4	9
Other professional, scientific and technical services and veterinary services	0	9	6	15
Rental and leasing services	0	3	2	5
Employment services	0	28	14	42
Travel agency, tour operator and other reservation services and related services	0	0	3	4
Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	0	41	26	67
Public administration and defence services; compulsory social security services	0	2	19	21
Education services	0	1	17	18
Human health services	0	1	9	10
Residential care services; social work services without accommodation	0	2	7	9
Creative, arts, entertainment, library, archive, museum, other cultural services; gambling and betting services	0	3	3	6
Sporting services and amusement and recreation services	0	1	2	3
Services furnished by membership organisations	0	2	22	23
Repair services of computers and personal and household goods	0	0	23	23
Other personal services	0	5	6	11
Services of households as employers; undifferentiated goods and services produced by households for own use	0	19	18	37
Total	250	429	691	1369

4. Concluding remarks

The ACTRIS Research Infrastructure is a pan-European initiative that unites the observations and related research of aerosols, clouds, and trace gases amongst European partners to provide high-quality research infrastructure services to a wider user community. Undoubtedly, ACTRIS constitutes a major investment and consequently an analysis of the socio-economic outcomes associated with its development and operation is of particular importance.

The socio-economic impacts associated with ACTRIS implementation and operation, were initially estimated in the context of the preparation phase of ACTRIS research infrastructure (project ACTRIS PPP). The analysis undertaken provided a set of Key Performance Indicators (KPIs) to facilitate the effective monitoring and quantification of various type of socio-economic impacts, including the impacts on human capital creation, scientific activity, innovation, economy and society.

This report presents an update of the macroeconomic impact analysis of the research infrastructure in question by utilizing updated estimates on the spending planned in the upcoming years for developing

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

and operating ACTRIS. To macroeconomic effects were estimated by implementing the input – output analysis framework for the economy of the entire European union (EU-28).

Table 4.1 summarizes the results of this analysis for an indicative year of the period 2021-2025 and Table 4.2 for 2026.

We found that for every € 1 million spending in developing, maintaining and operating ACTRIS infrastructures the European economy has benefited through an increase of the value added by € 1.39 million and the creation of 17.93 person-years of new employment during the period 2021-2025 and an increase of the value added by € 1.43 million and the creation of 17.83 person-years of new employment for 2026.

Table 4.1: Summary of the socio-economic effects of ACTIS infrastructure at consortium level during an average year of the period 2021-2025.

KPIs	Total impact on the organizations participated in the survey	Impact per €1 million spending
Macroeconomic effects		
Direct impact on GVA (in € millions)	54	0.49
Direct impact on employment (person-years of full time jobs)	393	3.57
Direct impact on income (in € millions)	31	0.28
Total impact on GVA (in € millions)	153	1.39
Total impact on employment (person-years of full time jobs)	1975	17.93
Total impact on income (in € millions)	80	0.73

Table 4.2: Summary of the socio-economic effects of ACTIS infrastructure at consortium level in 2026.

KPIs	Total impact on the organizations participated in the survey	Impact per €1 million spending
Macroeconomic effects		
Direct impact on GVA (in € millions)	39	0.51
Direct impact on employment (person-years of full time jobs)	250	3.26
Direct impact on income (in € millions)	23	0.30
Total impact on GVA (in € millions)	110	1.43
Total impact on employment (person-years of full time jobs)	1369	17.83
Total impact on income (in € millions)	57	0.74

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

References

European Strategy Forum on Research Infrastructures (ESFRI), 2016. Strategy report on research infrastructures – Roadmap 2016. Technical Report, available on line: http://www.esfri.eu/roadmap-2016

Eurostat 2008. Eurostat Manual of Supply, Use and Input-Output Tables. European Commission ISSN 1977-0375.

Florio M and Sirtori E, 2014. The evaluation of research infrastructures: a cost-benefit analysis framework. Working paper, European Investment Bank.

Griniece E, Reid A, and Angelis J, 2015. Evaluating and Monitoring the Socio-Economic Impact of Investment in Research Infrastructures. Technical Report. Technopolis Group. Available on line: http://www.technopolis-group.com/31627/

Leontief W, 1966. Input–Output Economics. Oxford University Press, New York.

Markandya A, 1998. The indirect costs and benefits of greenhouse gas limitations. Economics of Greenhouse Gas Limitations: Handbook Reports, UNEP Collaborating Centre of Energy and Environment, Riso National Laboratory, Denmark 1998.

Soutukorva A and Hasselström L, 2015.Initial socio-economic impact assessment of ACTRIS. Technical Report prepared by ENVECO.

Trewin D, 2000. Australian system of national accounts: concepts, sources and methods. Technical report, Australian Bureau of Statistics, ISBN 0 642 54212 0.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Appendix

1st Questionnaire of Task 3.3

EVALUATING THE MACROECONOMIC EFFECTS OF ACTRIS IR

Information about this survey

The Research Infrastructure ACTRIS is a pan-European initiative that unites the observations and related research of aerosols, clouds, and trace gases amongst European partners to provide high-quality research infrastructure services to a wider user community. The ESFRI Roadmap 2016 identified ACTRIS as a new important pan-European research infrastructure for the European scientific community. With ESFRI-status, ACTRIS shall further develop its organizational and operational framework, and long-term strategic goals. In this context, the ACTRIS Implementation Project (ACTRIS IMP) aims at taking ACTRIS into a new level of maturity and will set the needed structures for the implementation actions, both at the national and European level. ACTRIS IMP builds on three main pillars: securing the long-term sustainability, implementing of ACTRIS functionalities, and positioning ACTRIS in the national, European, and international science and innovation landscape.

The purpose of this survey is to collect, through the completion of a questionnaire, the necessary data for updating the macroeconomic impacts associated with ACTRIS implementation and operation, which were initially estimated in the context of ACTRIS PPP. The research will help to better understand the economic benefits generated to organizations and institutions that participate in the development, operation, and maintenance of a large research infrastructure like ACTRIS. Furthermore, it will provide useful insights for evaluating the social return of the investment required for implementing and operating ACTRIS infrastructure.

The questionnaire should be completed by the national ACTRIS contact persons in each country participating in ACTRIS, as specified in the ESFRI Roadmap 2016 (one questionnaire per participating country). It is organized in three sections.

The deadline for answering the questionnaire is July 31, 2021. Your participation in the survey is voluntary.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Your Participation and Informed Consent

Your participation in this survey will consist of a completion of a questionnaire. You will be asked a series of questions about the participation of the Organization(s) of your country in ACTRIS research infrastructure, the expenditures planned to develop and operate the National Facilities of the infrastructure, estimates for possible funds that will be attracted due to the ACTRIS infrastructures, and the potential macroeconomic impacts generated. Please feel free to co-operate with colleagues when answering the questionnaire, if you think it is necessary. Your participation in the survey is fully voluntary, and you may pass on any question that makes you feel uncomfortable. You are encouraged to ask questions or raise concerns at any time about the nature of the study or the methods used.

The only personal details that will be asked from you will be your name and position in your organization. Insights gathered by you and other participants will be used in writing a research report about the macroeconomic impacts of ACTRIS infrastructure. All gathered information will be aggregated at the ACTRIS level such that no personal data will be traceable from the end product. The individual answers and informed consent forms will be stored by NOA until the end of the project. All of your information and responses to the questionnaire will be kept confidential.

By signing below, I acknowledge that I have read and understood the above information. You can either print and sign this page or add a digital signature. Please send the signed document (i.e., a scanned copy or its digital version) to the e-mail address below.

Signature_____ Date_____

If you have any questions, please contact Prof. Nikos Mihalopoulos (nmihalo@noa.gr, +30 210 8109121)

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

I. INTRODUCTORY DATA

I.1 What is your name:

_____

I.2 Affiliation and country (please also indicate your Institute):

_____

_____

_____

_____

I.3 Please indicate all the Institutes and/or Organizations of your country that participate in ACTRIS:

_____

_____

_____

_____

_____

_____

_____

_____

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

II. MACROECONOMIC EFFECTS

The data required in this section aims at helping us to estimate the macroeconomic impacts attributed to development and operation of ACTRIS.

The structure of the following Tables and the required information (i.e., expenditures of National Facilities) is similar to those included in 5-year Financial Plan for the Central Facilities. However, **this questionnaire concerns National Facilities only.** The expenditures concerning Central Facilities will be included in the analysis and will be received from the 5-year Financial Plan.

Please provide aggregated data for the estimated expenditures (in €) and the personnel hired (in full time equivalent jobs) of all National Facilities of your country included under ACTRIS infrastructure. The expenditures estimated for the **Implementation**[1] and **Operation**[2] of the facilities will be reported separately in the two tables below.

Implementation	**2021**	**2022**	**2023**	**2024**	**2025**
Personnel - Full time equivalent jobs - Expenditures (in €)					
Equipment (in €) [1]					
Travel (in €)					
Other Costs (in €) [2]					
Total Cost (in €)					

[1] Please specify the type of equipment purchased (i.e., mechanical, electric, electronic, computers, etc.) and a distribution of the corresponding expenditures.

_____

_____

_____

_____

[2] Please provide some details on what the other costs included concern.

_____

_____

_____

[1] All the activities undertaken for the development of the infrastructure are categorized under **implementation**.
[2] All the activities related to the typical services and operations provided by the infrastructure are categorized under **operation**.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

Operation	2021	2022	2023	2024	2025
Personnel - Full time equivalent jobs - Expenditures (in €)					
Equipment (in €) [1]					
Travel (in €)					
Other Costs (in €) [2]					
Total Cost (in €)					

[1] Please specify the type of equipment purchased (i.e., mechanical, electric, electronic, computers, etc.,) and a distribution of the corresponding expenditures.

[2] Please provide some details what the other costs included concern.

Grand Total Costs (Implementation + Operation)	2021	2022	2023	2024	2025
Total Costs					

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115

III. IMPACT ON INNOVATION

Please provide data and estimates on how ACTRIS infrastructure influences innovation and related business opportunities at your country.

Identify and report research projects of your Institutions that predominantly or partially utilize the research infrastructure in question.

If a project is extending in several years of the refence period, please mention it in all corresponding years. In this case, please allocate the total budget of the project to the corresponding years according to the expected payments.

Indicators	2021	2022	2023	2024	2025
Number of R&D projects commissioned by European Commission or other international funding Agencies to the Research Groups involved in ACTRIS RI. Total volume of funding (in millions €)					
Number of R&D projects commissioned by National Authorities to the Research Groups involved in ACTRIS RI. Total volume of funding (in millions €)					
Number of R&D projects commissioned by private sector to the Research Groups involved in ACTRIS RI. Total volume of funding (in millions €)					
Number of start-ups and/or spin-offs operating utilizing products or expertise gained from the RI in question. Estimated total turnover (in millions €) [1] Estimated total earnings (in millions €) [1]					

[1] Provide aggregated figures for all companies and for the corresponding years.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2018-2020, Grant Agreement number: 871115