Initial socio-economic impact assessment of ACTRIS

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CONTENTS

LIST OF ACRONYMS

ACTRIS	EU FP7 Aerosols, Clouds, and Trace gases Research InfraStructure Network, Grant Agreement n. 262254 (2011-2015)
CLOUDNET	EU FP5 Development of a European pilot network of stations for observing cloud profiles (2001-2005)
CLRTAP	Convention of Long-range Transboundary Air Pollution - United Nations Economic Commission for Europe
EARLINET	EU FP5 European Aerosol Research Lidar NETwork to establish an aerosol climatology
EMEP	Co-operative programme for monitoring and evaluation of the long range transmission of air pollutants in Europe
GAW	WMO Global Atmosphere Watch
GCOS	Global Climate Observing System. A joint undertaking of WMO, ICSU, IOC, UNEP, and UNESCO
GRUAN	GCOS Reference Upper Air Network
ICON-model	Icosahedral non-hydrostatic model
ICP IM	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
IPCC	Intergovernmental Panel on Climate Change
PEGASOS	EU FP7 Pan-European Gas-Aerosol-Climate Interaction Study, Grant Agreement n° 265148 (2011-2014)
RTD	Research, Technology and Development
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VOLCEX	Volcanic Ash Exercise
WMO	World Meteorological Organization
WMO-GAW	The Global Atmosphere Watch (GAW) programme of WMO

1 INTRODUCTION

1.1 Background and scope of study

Funded under the EU FP7 ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) is a European Project aiming at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. 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 purpose of this pre-study is to shed light on the socio-economic impacts of ACTRIS on society as a whole. It may for example be about facilitation of research (incl. research outside ACTRIS), technological development, creation of human capital, generation of new jobs and local business development and innovation, and in the medium-long term positive impacts on e.g. human health, climate resilience, protection from environmental hazards, visibility.

Given the pre-study character of the study, focus at this stage is on *identifying* as many impacts as possible, which is a necessary first step if a full cost-benefit analysis is to be carried out subsequently.

Chapter 2 gives a brief methodological introduction to a step-by-step procedure for carrying out a socio-economic assessment, and discusses what the different steps implies for an assessment of ACTRIS. The chapter briefly mentions a framework for cost-benefit analysis of research infrastructures discussed by Florio and Sirtori (2014), and focuses mainly on the broad types of positive and negative impacts suggested in that paper. In the chapter is also described the design of a questionnaire survey that was distributed to and answered by partners of ACTRIS in order to collect necessary information on positive and negative socio-economic impacts, again with a focus on the types of benefits suggested by Florio and Sirtori, 2014. Chapter 3 presents the results. Chapter 4 provides overall conclusions.

2 METHOD

2.1 Step-by-step procedure

A socio-economic impact assessment can be described as a step-wise procedure with the objective to answer the question "what is the net social benefit?" of a given project, programme of measures, proposal etc. If the size of the total positive impacts "benefits (B)" exceeds the size of the total negative impacts "costs (C)", a project is socially profitable. However, it is rarely the case that all positive and negative impacts of a project are possible to express in monetary terms. This makes comprehensive, qualitative descriptions of identified impacts important.

The socio-economic assessment carried out for ACTRIS at this stage is not a full-scale cost-benefit analysis. The analysis of this pre-study roughly follows the step-wise procedure illustrated in Box 1 below, mainly focusing on step 5 "identify the impacts of the project", especially what is exemplified under "other types of impacts". This exercise gives crucial information for a full cost-benefit analysis, if that is to be undertaken further ahead.

Broadly in line with the suggestions by Florio & Sirtori (2014), the benefits of the research infrastructure are assumed to belong to the following main categories:

- Knowledge outputs (e.g. scientific papers, books, research contracts granted)
- Technological development (e.g. patents granted, license deals, spinoffs created)
- Human capital creation (e.g. number of Master and Ph.D. students)
- Other types of benefits (the infrastructure may also provide benefits to other users, such as industry, local authorities, environmental protection agencies, meteorological agencies, etc.)

Employment effects are often viewed as a positive socio-economic impact. However, from a cost-benefit analysis perspective, employment is an input to a project (just like man made capital) rather than an output - and consequently a cost. In this report employment effects are still presented as a positive type of outcome of the research infrastructure. The impacts of employment may certainly be positive from the perspective of local economies, especially if new jobs are generated at sites with high levels of unemployment. If the kind of jobs created are primarily highly specialized tasks for experts "coming from outside" the positive impacts on local economies are much smaller. A full cost-benefit analysis would have to take these issues regarding employment into account.

Box 1. Step-by-step procedure for carrying out a socio-economic impact assessment, and brief descriptions of what each step may entail for assessment of ACTRIS. Source: Based on Swedish Environmental Protection Agency (2014), report 6628 [in Swedish only].

Step 1. Formulation of problem

ACTRIS: Difficulties to maintain European coordination without a binding project - risk for fragmentation, decreased capacity, lost synergies and decreased quality of data.

Step 2. Formulation of purpose

ACTRIS: To secure future atmospheric research, long-term provision of data etc.

Step 3. Describe reference alternative

ACTRIS: The situation today with no project (further funding). This is the point of comparison to which project consequences are assessed.

Step 4. Identify and describe "the project"

ACTRIS: ACTRIS to become part of the ESFRI roadmap.

Step 5. Identify the impacts of the project

- Impacts on the environment

ACTRIS: Medium-long term direct and indirect environmental impacts related to air-quality and climate change which can be linked to ACTRIS achievements.

- Impacts on human health

ACTRIS: Medium-long term direct and indirect health impacts related to air quality and climate change which can be linked to ACTRIS achievements.

- Other types of impacts

ACTRIS: Direct and indirect impacts on society, e.g. investment and operation costs, knowledge outputs, technological development, human capital creation, benefits to other users and also employment effects, business opportunities, new innovations.

Step 6. Summary of the impacts of the project

ACTRIS: Summary of positive and negative impacts primarily in qualitative terms.

CONTROL STATION: IS THE PROJECT WELL DEFINED?

Step 7. If "yes", estimate the benefits and costs of the project, if "no" try to redefine the project.

Step 8. Distribution analysis

ACTRIS: Which groups in society are affected by the research infrastructure, e.g. researchers, general public, local business?

Step 9. Sensitivity analysis

ACTRIS: If a monetized cost-benefit analysis is subsequently carried out, a sensitivity analysis could be done for example by changing interest rate levels and making alternative assumptions regarding the size of costs.

CONCLUSION: IS THE PROJECT SOCIALLY PROFITABLE?

ACTRIS: A full-scale monetized cost-benefit analysis would answer whether or not the project is socially profitable. Here, qualitative indications are given on the positive and negative impacts.

Step 10. If "no", evaluate if a revised project may become profitable. If so, try to redefine the project.

2.2 Design of questionnaire survey

The method to efficiently collect relevant information for the socio-economic assessment was to design and distribute a questionnaire survey. The questionnaire was designed in co-operation with the University of Helsinki, the Finnish Meteorological Institute and the National Research Council of Italy and sent out to ACTRIS partners and other key individuals representing the 21 participating countries of ACTRIS.

Given that the study deals primarily with step 5 "identify the impacts of the project" (see Box 1), the questionnaire focuses on what the respondents perceive as societal impacts of ACTRIS – both in retrospect and looking ahead to a situation with or without further funding. As already mentioned, the impacts of interest here are primarily ones that may/will occur in the relatively short term, e.g. investment and operation costs of atmospheric stations, generation and dissemination of knowledge, technological development, creation of human capital, employment effects, stimulation of local business life, business opportunities related to innovation etc. In the medium-long term however there will also be benefits related to improved environment and human health. These are briefly discussed but not further analyzed here.

The main contents of the questionnaire are listed below, and the complete questionnaire can be found in Annex 1.

- Introductory questions (name, affiliation, role in ACTRIS)
- Questions related to positive and negative societal impacts of ACTRIS so far
    - Which groups in society are affected?
    - How/to what extent has ACTRIS contributed to/caused the impacts?
- Good examples of what ACTRIS has achieved in society, e.g. related to local industries, innovation activity, the environment, the local community.

- Good examples of research findings that have partly or fully been dependent on ACTRIS data
- Future (looking ahead to 2025) societal positive and negative impacts if and if not ACTRIS will be continued in any common form
- Detailed questions about direct and indirect creation of jobs since 2006 as well as future creation of jobs (looking ahead to 2025)
- Opinions about the linkages between research infrastructure -> research findings/networks/etc. -> societal benefits. Experiences from different countries.

3 SOCIO-ECONOMIC IMPACTS OF ACTRIS

This chapter presents positive and negative impacts of ACTRIS so far, and also the impacts if/if not the project will continue to exist. Since it can be expected that, apart from investment and operating costs, only few (if any) other impacts are possible to monetize at this stage, it is important to provide qualitative assessments of as many impacts as possible. Of interest is to find out more about the linkages between the research infrastructure - > research findings/networks -> societal benefits (see Figure 1). Research carried out during the last years have reduced the level of uncertainty regarding these links (see IPCC (2014), 5th Assessment report, WG 1 & 2) and ACTRIS is part of this positive development. Evidently, one major challenge is to assess to which extent ACTRIS has had a positive effect, i.e. to decide ACTRIS's share of the total impact. In the chapter is indicated and exemplified where links exist and how ACTRIS has contributed to society.

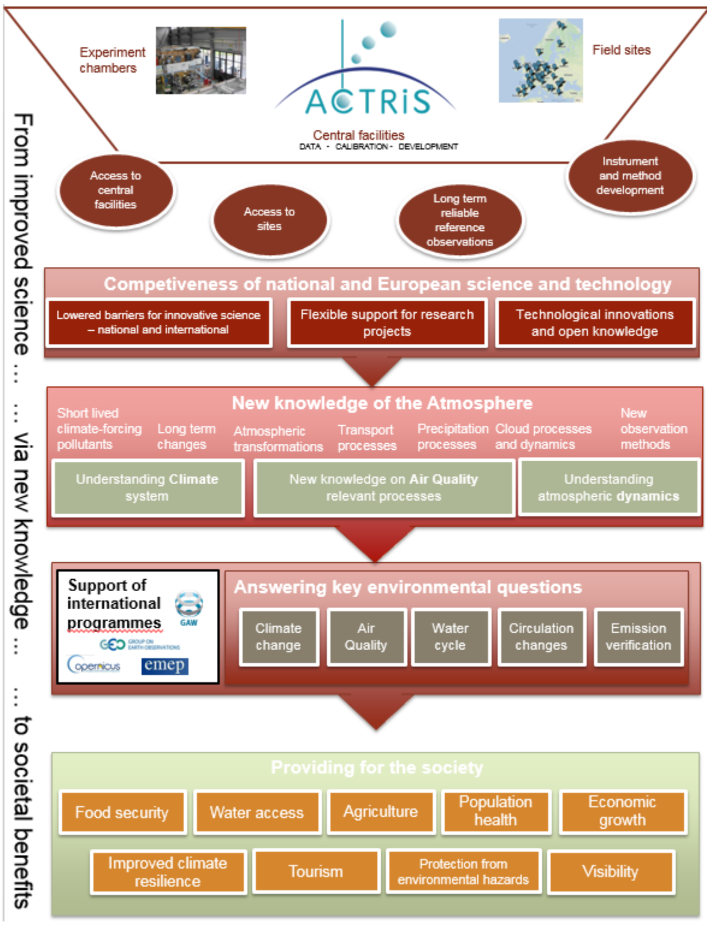

Figure 1. Going from improved science to societal benefits. Source: ACTRIS RI coordination team.

3.1 Positive impacts (benefits)

The positive socio-economic impacts (benefits) of ACTRIS are primarily assessed based on the findings from the questionnaire. Given the short amount of time available for the study the reliance upon input provided by the partners is high and the results must be interpreted with some care. The respondents (representing the research community) were asked to describe the societal impacts of ACTRIS for their respective countries. For each of the positive direct and indirect impacts identified the respondents described further who is affected (e.g. general public, local community, research community, organization x and y), and how/to what extent ACTRIS in the respective countries has contributed to the impacts. A next step would be to also reach out to other actors in society, e.g. local businesses in different countries, general public and other researchers, in order to learn more about their opinions.

Again, it is assumed that the impacts belong to the four main types of benefits suggested by Florio & Sirtori (2014); knowledge outputs (e.g. scientific papers, books, research contracts granted), technological development (e.g. patents granted, license deals, spinoffs created), human capital creation (e.g. number of Master and Ph.D. students), other types of benefits (e.g. the infrastructure may also provide benefits to other users, such as industry, local authorities, environmental protection agencies, meteorological agencies). In addition to these are discussed the effects on employment and on business and innovation.

3.1.1 Knowledge creation, technological development and human capital creation

Table 1 summarizes positive impacts that have been numerically estimated related to knowledge creation and dissemination, technological development and human capital creation during the last ten years (2005-2015). The respondents were further asked to look ahead (2015-2025) and consider whether the positive impacts identified would remain, increase or decrease given continued funding for the research infrastructure. All the respondents state that they judge that the positive impacts identified will increase during the coming ten years.

Regarding knowledge creation and dissemination Table 1 shows that in a time period of roughly ten years ACTRIS has resulted in approximately 1000 scientific papers, 50 books and more than 500 research contracts in the 21 participating countries. The technological development that has taken place implies for the same time period that approximately 10 patents have been granted, 2 license deals have been signed, 4 spinoffs have been created, 40 technologies have been transferred and 60 prototypes developed. As for creation of human capital around 850 Masters and Ph.D. students are estimated to have carried out research at the research infrastructure. The figures in Table 1 are extrapolated based on a limited sample of respondents and must therefore be interpreted with care.

Table 1. Positive impacts on society from ACTRIS, approximate estimates for the 21 participating countries in total, 2005-2015. Note: the figures are extrapolated based on a limited sample of respondents and must therefore be interpreted with care.

Impacts	Numerical estimates
Knowledge creation and dissemination	
…number of scientific papers	1 000
…number of books published	50
…number of research contracts	510
Technological development	
…number of patents granted	10
…number of license deals	2
…number of spinoffs created	4
…technologies transferred	40
…number of prototypes developed	60
Human capital creation	
…number of Masters and Ph.D. students carrying out research at the research infrastructure	850

Further stated qualitative observations made by the respondents regarding knowledge output, technological development and creation of human capital are discussed below.

Knowledge creation and dissemination

The knowledge creation and dissemination generated by ACTRIS is basically about improved quality and access to atmospheric data, which will primarily benefit the research community inside and outside ACTRIS, industry as well as the general public and policy makers.

Long-term investigations carried out on aerosols, clouds, trace gases on continental scale benefit the scientific community and have resulted in many publications on air pollution, Saharan dust, volcanic emissions, long-range transport, cloud-aerosol interaction etc. ACTRIS has played an important role in implementing monitoring strategies of international programs like EMEP and GAW. Also, air quality studies, source apportionment and trend analysis are examples of positive impacts for the general public, which ACTRIS have contributed to by production of scientific publications, work with media and support to policy making. By providing high quality data for improved knowledge on climate, air quality, environment and security the research community benefits directly and the general public indirectly due to improved understanding and quantification of climate and air pollution relevant effects.

The open data policy of ACTRIS means positive impacts for the research community (inside and outside ACTRIS) but also for industry as it provides enabling data and knowledge. ACTRIS has acquired the data through its observation programmes and has made these data available and discoverable for industrial partners. Also, knowledge to correctly and effectively use the data has been provided. Affected by these efforts are for example SMEs (small and medium enterprises) and consultancies in the fields of instrument technology, wind energy, solar energy, air quality and water management.

The most important reasons for the positive impacts linked to knowledge creation and dissemination to increase given continued funding is that the research communities will have the availability of the right platform to conduct state of the art research in the atmospheric field. This will help to improve the quality of research, acquire new knowledge and strengthen the cooperation at international level. For example, it can be expected that the long-term continental wide and global availability of data is secured and research communities and fostering of multi-disciplinary cooperation will increase.

Technological development

The contributions of ACTRIS to technological development is in terms of technologies, automation, remote access to instruments and data improvements of abilities, harmonizations and standardizations as well as new patents. The groups in society that benefit from these achievements are primarily the research community, industry and policy makers. The way ACTRIS has contributed to the positive development is by providing opportunities for knowledge transfer, development of new methods, exchange of expertise, development of Q/A standards and data protocols and by creating a scientific environment which promotes innovation.

The most important reasons for technological development to increase if the project continues is that a sustained availability of the infrastructure will establish a reliable platform for new technology development. The demand for observation stations for more accurate measurements will promote innovative ideas and simultaneously ACTRIS observatories will serve as testbed of new technology and techniques. It is foreseen by the respondents that the stations will be steadily improved by equipment with best and newly emerging technologies, more automated systems with remote control will be available, the research infrastructure will make the “European voice” stronger in ISO procedures to mention a few impacts.

Human capital creation

ACTRIS has facilitated creation of human capital by providing an environment that gives training opportunities and favors exchange of expertise and mobility of researchers. The research infrastructure can be described as a place for networking with people in Europe facing identical issues. More specifically, ACTRIS has provided training of a great number of Masters and Ph.D. student and researchers, also in developing countries. The groups who benefit directly of this are students and the scientific research community these students join. Indirectly some industrial sectors and the general public also benefit. In developing countries young scientists, the research community and general public benefit via provision of human capital in form of well-educated and trained scientists in the field of atmospheric chemistry and physics.

As for creation of human capital, it is foreseen by the respondents that if the project continues the long-term existence of ACTRIS will reinforce capacity building, that data produced in the infrastructure will increasingly be used in teaching and graduation of students (master and Ph.D. theses), that interaction with the general public will increase and also knowledge transfer and education of scientists from developing countries. The enlargement of the research community would mean that more projects are carried out and that the number of people educated in the field will increase.

3.1.2 Other types of benefits

This section discusses other types of benefits of the research infrastructure. These benefits are primarily related to what the research findings can be used for "in practice", also by actors in society outside the research community. Examples of groups that benefit are the general public, the research community, aviation industry and policy makers at different scales.

Support for better predictions of topics related to climate change, air quality, extreme events and atmospheric hazards

- European-wide and global observations contribute to a better understanding of climate-related processes, allow better climate prediction and support to climate protection initiatives, but also provide information for predictions related to air quality, extreme events and atmospheric hazards. The volcanic eruption crisis (see Box 2) clearly illustrated the need for atmospheric monitoring and how ACTRIS was almost the unique way for civil aviation authorities to obtain information on the state of the atmosphere.

- Climate research projects have been the basis for climate adaptation and mitigation strategies that have been implemented (using public funds) to the benefit of society.

- There are examples of ACTRIS-stations keeping long term records of concentration of short-lived reactive gases and of particulate matter concentration and properties which can be used for supporting abatement strategies. Aerosol (especially Saharan dust) and pollutant source-apportionment studies support decision making and regulatory development and compliance at both regional (sub national) and national levels.

- ACTRIS facilities and data are frequently used by other research projects. One example in Germany is the HD(CP)² project (High Definition Clouds and Precipitation for Climate Prediction) focusing on the development of the new German community model ICON which will be used for global climate modeling as well as numerical weather prediction. Observations from ACTRIS supersites serve for model evaluation and validation. The high-resolved model is expected to provide improved weather forecast and future-climate prediction, which would benefit society.

Support for local, national, international policy making and planning

- ACTRIS contributes to better policies by providing quality assured measurements. The improvement of knowledge through high quality long-term observations and monitoring of extreme events is also important.
- ACTRIS contributes to efficient planning of investments in the "administrative sector" (e.g. municipalities, water boards) by providing data which is used for construction of climatologies and underpinning of climate scenarios. This information is needed for the administrative sector to plan investments in environmental policies and infrastructure developments, which are necessary due to adaptation and mitigation actions to climate change.
- ACTRIS facilitates planning and negotiation in policy making concerning environmental and infrastructure issues by providing data which is used for construction and underpinning of climate scenarios. Policy makers will gain from this, e.g. ministries of environment, infrastructure and finance.
- The state-of-the art observations provided by the infrastructure, combining remote sensing and in-situ instrumentation, along with modeling at several scales, is a necessary tool to rapidly provide information about severe aerosol events, such Saharan dust, volcanic ash, smoke plumes. These are highly relevant for society, for example in terms of human and animal health, aviation safety and civil alerts.
- Increasingly, research efforts are taken advantage of in policy making (e.g. IPCC, UNEP). State of the art atmospheric data are expected to contribute to future air and climate policies (CLRTAP, EU, UNFCCC) when development of techniques and technologies for long-term, quality assured observations can be transferred and support monitoring networks. ACTRIS contributes to the needs of these international programs by addressing air quality and climate change. The efforts rely on active involvement from both

scientists/data providers as well at central facilities to operate the necessary infrastructures.

Support for increased public awareness, knowledge and debate

- Climate research and communication thereof has created the needed societal awareness, acceptance and support of climate adaptation and mitigation strategies. Also, it plays a significant role in the societal debate about climate change (and other environmental issues).

- Research carried out in ACTRIS is published in peer-reviewed publications and increasingly also in public media. The scientific findings contribute to improving both weather and climate predictions, which benefit society directly.

- The dialogue between climate researchers and societal parties has led to a better understanding of what is needed from the science community to translate the climate knowledge to what is needed at practical level and vice versa.

3.1.3 Employment impacts

The respondents were asked about the number of jobs that have been created directly and indirectly due to ACTRIS since 2006, and also what they estimate future (2015-2025) job creation to be. Table 2 presents direct and indirect generation of jobs for the time period 2006-2015. The figures are extrapolated based on a limited sample of respondents and must therefore be interpreted with care.

Table 2. Direct and indirect generation of jobs, 2006-2015. Approximate numerical estimates for the 21 participating countries of ACTRIS in total. Note: the figures are extrapolated based on a limited sample of respondents and must therefore be interpreted with care.

Type of jobs	Numerical estimates
Directly generated	
Setting up the physical infrastructure (e.g. stations, surrounding infrastructure)?	220
Maintenance and daily operation of the research infrastructure?	160
Data collection and quality control of data?	170
Indirectly generated	
ACTRIS research?	390
Other research relying on data from ACTRIS infrastructure?	460
Businesses and services surrounding the infrastructure (e.g. hotels, restaurants)?	50
Business related to innovation?	70
Tot:	***~1 500***

Table 2 shows that most jobs created in the time period 2006-15 have been generated indirectly by ACTRIS research and other research relying on data from the ACTRIS infrastructure. Altogether the research infrastructure has generated around 1500 jobs since 2006, of which 64 % have been indirectly created. More specifically ACTRIS has contributed to generation of jobs by setting up and running the infrastructure, supporting the development of new stations outside Europe, by providing financial support, scientific attractiveness and by increasing the employability of trained people. Trained people in turn contribute to the strengthening of the research community, of some industrial sectors and potentially also by a positive cascade effect on employment in general.

Table 3 shows that also future jobs (2015-2025) are estimated to occur primarily related to ACTRIS-research and other research carried out relying on data from the ACTRIS infrastructure. The total number of expected new jobs in the coming ten years is estimated to around 1700, of which 68 % are expected to be indirectly generated.

The respondents stated reasons for jobs to be generated by ACTRIS also in the future is that the provision of a sustainable infrastructure will require permanently employed personnel, data availability will create new projects involving new staff, in particular specialists will be needed. The extent to which new jobs will be created is however strongly dependent on the number of activities carried out, i.e. if these increase so will also the need for support and research.

Table 3. Direct and indirect future generation of jobs, 2015-2025. Approximate numerical estimates for the 21 participating countries of ACTRIS in total. Note: the figures represent extrapolations based on a limited sample of respondents and must therefore be interpreted with care.

Type of jobs	Numerical estimates
Directly generated	
Setting up the physical infrastructure (e.g. stations, surrounding infrastructure)?	200
Maintenance and daily operation of the research infrastructure?	170
Data collection and quality control of data?	160
Indirectly generated	
ACTRIS research?	480
Other research relying on data from ACTRIS infrastructure?	450
Businesses and services surrounding the infrastructure (e.g. hotels, restaurants)?	50
Business related to innovation?	70
Tot:	***~1 700***

One important conclusion regarding creation of jobs in the past and also when looking ahead is that around two thirds of the total effect on employment has occurred/will occur indirectly due to ACTRIS.

3.1.4 Stimulation of local business life and opportunities related to innovation

This section briefly discusses and exemplifies the respondents views on the impacts of ACTRIS on local business life and opportunities related to innovation, today and also looking ahead.

Stimulation of local business life
Generally, the way in which ACTRIS stimulates local business life is by activities in SMEs, technological clusters and the tourism sector (accommodation, restaurants etc.). More specifically, ACTRIS provides support to development of new products, new technologies, physical access to the research infrastructure and so on.

One example of how business life locally may benefit from the presence of people participating in scientific research campaigns is from Spain where some sites in the present infrastructure (Instituto Nacional de Técnica Aeroespacial (INTA’s) El

Arenosillo station, Agencia Estatal de Meteorología (AEMET's) Izaña Center of Atmospheric Research in Tenerife Island, Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC's) Montseny and Montsec stations) host national and international intercomparison exercises of atmospheric instruments. Participants (researchers, technicians, students etc.) contribute to the local business life in the tertiary sector. Barcelona Supercomputing Center (BSC) participates also in national and transnational access programs with a similar effect on local business life, although more diluted in the Barcelona metropolitan area. The construction and running of the sites of Montseny and Montsec has reverted around 50 000 Euro to local companies, and their maintenance amounts to 10 000 Euro/year.

Another example is that the existence of the infrastructure has promoted the organization of conferences (e.g. European Aerosol Conference 2012), with has had a positive effect on local business life.

If ACTRIS continues local business life will benefit directly from the improvement and maintenance of the infrastructure which will involve local business partners. Moreover the establishment of a long-term research infrastructure will imply a direct improvement of the innovation potential with impact also at local scale. Involved local territories can be expected to have the opportunity to use the European dimension for improving own strengths, for both research and innovation aspects, in line with the European Smart Specialization Strategy. Future improvement and maintenance of the infrastructure can be foreseen which will involve local business partners, increased maturity of the infrastructure in terms of innovation platform and increased number of physical accesses to infrastructure facilities. One of the respondents states: *"It is expected that ACTRIS stations and central facilities will be poles of activities, both scientifically and commercially related".*

Business opportunities related to innovation
Already mentioned, knowledge generation and access to the infrastructure is expected to give rise to innovative business opportunities. Small and medium-sized businesses will have a benefit in terms of new opportunities for increased competitiveness at different scales (local, national, international) by development of new services and/or technological products in the environmental field.

One example is from Spain where CSIC has integrated jointly with a private company an A31 aethalometer with a high volume sampler. Another example from the Netherlands is the existence of start-ups in the field of high resolution forecasts for wind and solar power generation and companies related to weather radars for urban rainfall.

The groups in society who will benefit from this positive development are the industrial sector (for example R&D branch of SMEs), technological clusters, big enterprise, and indirectly also the general public through the products and services developed. Such smart services and products may include information about the environmental status, specific extreme events and hazards. ACTRIS has contributed for example by new patents, provision of data that enables service and support for development of innovative products etc.

If ACTRIS continues the respondents judge ACTRIS-fostered technologies and ACTRIS-provided observation products to create new business opportunities, also standards and norms are an important area of market development. The infrastructure is expected to make the "European voice" stronger in ISO procedures. Examples of companies relying on ACTRIS are the German Metek (cloud radars, wind lidars) and Radiometer Physics (microwave profilers), as well as the Greek company Raymetrics for lidar. In Finland ACTRIS measurements have initiated one spinoff company. In addition to this should also be mentioned that novel measurement technologies are pursued by the researchers funded by TEKES, which is a Finnish funding agency for innovation providing potential breakthroughs that could be relevant to the wider scientific community.

3.1.5 Good examples of societal benefits and research findings

There are many examples of societal benefits and research findings that ACTRIS has contributed to. This section describes some of them.

Box 2. ACTRIS contribution to improved knowledge about volcanic aerosol detection- the Eyjafjallajökull volcanic eruption

The Eyjafjallajökull volcanic eruption in Iceland in 2010 caused the closure of airspace over many countries affecting the travel arrangements of hundreds of thousands of people in Europe and elsewhere. It was estimated a total loss for the airline industry around €1.3 billion and a loss for airports of about €95 million. During the eruption, the ACTRIS lidar component (EARLINET) was the only operational observing system that was able to react immediately and provide Near-Real-Time observations of the volcanic plume. A report summarizing relevant information about the dispersion of the ash-cloud was updated on a daily basis and provided to the VAAC, as an additional source of information. For example, the arrival and the spread of the ash cloud over Germany could be observed by making use of the distribution of ACTRIS lidar stations from northern to southern Germany. The presence of dangerous concentration levels of ash could be documented.

The improvement of knowledge acquired about volcanic aerosol detection gained at the RI was of particular relevance for the Volcanic Ash Scientific Advisory Group VASAG of the WMO. In this context ACTRIS/EARLINET contributed to the new definition of thresholds for air flight security conditions. This has also a significant positive socio-economic impact (less cancelled flights and improvement of air traffic security, airline industry, airports budget, tourism).

Furthermore, important contributions to the scientific literature resulted from this event. The four-dimensional (4-D) distribution of the Eyjafjallajökull volcanic cloud in the troposphere over Europe as observed by ACTRIS/EARLINET during the entire volcanic event was provided and made freely available to all potential users (Pappalardo et al., 2013). Lidar data for the volcanic eruption were fundamental for the evaluation of transport model and of satellite detection algorithm for volcanic particles [Matthias et al., 2012, Dacre et al., JGR, 2011, SACS2 project final report, 2014]. These RI findings could significantly impact the effectiveness of air closure planning and therefore all related aspects of society as already mentioned, i.e. security, tourism, business etc.

Romanian ACTRIS facilities participated in the first European and North Atlantic volcanic ash exercise (VOLCEX14/01) which was organized by the International Civil Aviation Organization – EUR/NAT Office in Paris. The National R&D Institute for Optoelectronics (INOE's) ACTRIS facility was responsible to install a sodar system at the "Henri Coanda" airport in Bucharest, to detect the low-level wind shears in order to avoid incidents during take-offs and landings.

Moreover, the abilities of ACTRIS led to the initiation of the setup of new observing capabilities by the German Meteorological Service, based on ACTRIS technologies and collaboration. Analogues initiatives also exist in the UK (Met Office), France (Meteo France) and Italy (CNR and Air Force).

Box 3. Provision of long-term observations of desert dust with positive impacts on aviation and security

The research infrastructure provides long-term observation of desert dust distributed over Europe. This database of high quality, harmonized, centralized information is fundamental for the evaluation of desert dust forecast models. First evaluation studies show the effectiveness and limits of the most used forecast models [Mona et al., 2014, Binietoglou et al. 2015]. The evaluation of desert dust forecast models have an impact on aviation and security in regions as Middle East, and potential effects on air quality management over Europe.

Our understanding of long-range transport of aerosols, such as Saharan dust, forest-fire smoke or volcanic missions, across Europe became only possible through the dense network of remote-sensing stations distributed over the whole continent. There has been a tremendous gain of knowledge in this field of research since the establishment of the European Aerosol Research Lidar Network, now part of ACTRIS, in the year 2000. This knowledge is important, e.g., for the quantification of inter-continental and cross-border transport and its influence on local air quality and visibility. This work resulted in about 40 scientific publications under German first-authorship.

Box 4. Other positive impacts of research carried out in ACTRIS related to air quality, climate change topics, human health

Cooperation with epidemiological department of Local Environmental Agency for a study on the impact of air quality (in particular during Saharan dust events) on mortality and morbidity.

Chamber experiments significantly improved our quantitative understanding concerning the influences of aerosols, and the processes they undergo, in both climate and air quality. Specifically this holds for the topics of secondary organic aerosol formation, aerosol particle hygroscopic growth, and the formation and freezing of cloud droplets. Moreover, a number of these chamber experiments concerning the activation behavior of atmospheric aerosol particles and the formation of secondary organic aerosols have been motivated through measurements and data from ACTRIS field sites. These are examples how new knowledge could be created by making use of both ACTRIS field and laboratory observations. The work resulted in about 35 scientific publications at the Leibniz Institute for Tropospheric Research.

An intensive observation campaign was organized by the Romanian ACTRIS facilities in 2010 at Rovinari power plant in SW Romania, to quantify the level of pollution in the surroundings. Remote sensing measurements were carried out as independent validation of the values calculated from the emission inventory. Results showed critical values of PMs and SO_2 especially early morning, in correlation with a low PBL, and a clear underestimation of the emissions. A major technological upgrade of the Rovinari power plant is now planned to reduce the emissions and consequently the effects on the inhabitants' health.

Improved skills of weather forecast models through better parameterizations of clouds (Cloudnet). Data from the ACTRIS Czech Republic infrastructure has been repeatedly used for development of the utility models of new sampling devices. This research can be translated into more practical applications as improvement of the weather forecast models, especially in predictions of the rain and storm events or research connected to renewable energies (solar, wind power). Meteorological measurements conducted at the tall tower of the AS Křešín u Pacova serve also the steel construction sector, especially in the area of dynamics and statics of tall slender constructions. In case of new lidar acquisition in the future, it may serve as a basis of a warning system for air traffic in cases like Eyafjalajökul eruption.

Coordinated observations by the Spanish part of the infrastructure have provided insight on aerosol transport phenomena, properties and radiative transfer effects in the western Mediterranean basin, which has an impact on the improvement of air quality forecast models.

Clear impact on the determination of trends that helped to understand how efficient regulation is for air quality in Europe.

Identification of sources of pollutants giving information on the regional background of pollution in Europe

Box 5. ACTRIS contribution to progress in measurement techniques

The progresses in measurement techniques achieved at the research infrastructure contributed to the definition of instruments, measurements and data format standards. In particular, the RI contributed to the definition within the Global Aerosol Watch

(GAW) program of the WMO of criteria for harmonizing the in situ and vertical profile data. This harmonization will assure a world-wide consistent approach with positive impact for security, hazards, air pollution and climate applications.

Policy makers and society have an interest in knowing about which effect emission reduction has on actual pollution. Due to the harmonization of measurements and due to a wider network of measurement stations, it has been shown that emission reductions of vehicles led to the reduction of black carbon and ultrafine particles in Germany. This could only be achieved due to the harmonization and quality assurance of these measurements within ACTRIS. Our findings positively influenced the discussions on low-emission zones in the public media.

Other aspects of the effects of emission reduction are the long-range transport of pollutants, the influence of secondary formation processes and the interaction with meteorology. By investigating ACTRIS measurements at rural background and urban polluted sites, the influence of long-range transport under high-pressure situations with easterly flows on the local pollution level within the city of Leipzig has been quantified. In this way, the limits of local emission reduction on air quality could also be shown.

The EC-funded PEGASOS project measured aerosol particles and trace gases onboard a Zeppelin. This provided an eye-opener for the general public in relation to importance of air quality. Finland (Hyytiälä) was used as a reference for clean conditions.

Box 6. ACTRIS contribution to technical definition of ISO standard

The RI contributes to the ISO standard, i.e. the technical definition of requirements, for performing atmospheric lidar measurements. The infrastructure laboratories have been visited by a number of high-school students and general public. This represents a great opportunity to disseminate the most updated ACTRIS scientific findings directly into society.

Box 7. Contribution to international collaboration and capacity building

The Cabo Verde Atmospheric Observatory is an excellent example how ACTRIS contributes to international collaboration and education of local people in developing countries. For the future a stronger scientific cooperation is planned with the University of Cabo Verde.

ACTRIS supports national obligations to conventions and programmes like EMEP (under UNECE CLTRAP) and GAW (WMO). Support include efficient and harmonized methodologies and procedures to be used by these networks. Capacity building in numerous countries, also outside Europe for long-term harmonized measurements to detect atmospheric change, and impact of climate change.

The Biogenic Aerosols – Effects on Clouds and Climate (BAECC) project (US DOE funded) brought a suite of active remote sensing instruments to Hyytiälä in Finland (value 10 million USD) for 8 months. This activity enabled research collaboration between US and Europe. It also improved the capacity of Hyytiälä station to host demanding campaigns and provided additional long-term measurement capacity.

ACTRIS in Czech Republic plays an important role in education of students. This capacity has been exploited by the Research Centre for Toxic Compounds in the Environment (RECETOX), for more than two decades. A week-long practical course focusing on various aspects of ecology and environmental quality is organized at the station for all students on an annual basis. The annual practical courses of on-line measurements and sampling techniques are taught as well as practical courses of the international summer school of environmental chemistry and ecotoxicology. Some 500 hundred participants from one hundred countries worldwide participated in the summer school (and visited the RI) during the last decade. The employees of the RI also participated in the RECETOX EDUCATION project of the Operational Programme Education for Competitiveness contributing significantly to development of the new courses, improvement of the practical training, and bringing the education closer to the applied practice. The long-term integrated monitoring programme executed in the RI in frames of EMEP for almost three decades in the close collaboration of RECETOX and the Czech Hydrometeorological Institute (CHMI) has created a platform for many diploma and dissertation theses and joint publications on environmental and analytical chemistry and environmental modelling.

3.2 Negative impacts (costs)

Information on the negative socio-economic impacts (costs) of ACTRIS is based on available project budget overview (personal communication, Niku Kivekäs FMI Finland). The total estimated cost of upgrading and running existing ACTRIS facilities in all of Europe (2015-19) is ~70 million Euro (upgrading) and ~120 million Euro (running), in total 190 million Euro.

None of the respondents to the questionnaire reported negative direct or indirect impacts such as for example that the infrastructure is perceived as visually disturbing among certain stakeholders[1], or that there are negative environmental impacts from construction, maintenance, etc. However, one country reported a potential risk that networks in charge of regulation on air quality may see ACTRIS as duplicating their efforts, which would mean that some stakeholders are under the impression that they need to fund the same activity twice. This risk can be avoided by underlining the role of ACTRIS as RI in supporting these agencies/networks. Another potential negative impact could be related to the misuse of near real time and not perfectly quality checked data. This risk can be avoided by establishing a clear data policy and by providing support and full documentation on the quality of the data for different time releases.

[1] Groups outside the research community were not directly targeted by the questionnaire for this study, thus their opinions are not reflected here.

3.3 Impacts looking ahead if ACTRIS will not continue

This section presents the impacts on the research infrastructure, research and society if ACTRIS will not continue in the future (looking ahead to 2025) in any common form.

Difficulties to maintain European coordination without a binding project –fragmentation, decreased capacity, lost synergies and decreased quality of data

The respondents expect that there will be major difficulties to maintain a European coordination without a binding project. Central facilities may fall apart and services may not be implemented due to the existence of a short term perspective only. A lack of suitable platform for atmospheric research, coordinated efforts/fragmentation and critical mass implies a risk for decreased capacity and competitiveness, both related to research and innovation. A loss of capacity for future development is likely to occur despite investments already made at different levels (national, EU). Also, a considerable synergy between the observing stations and the central facilities is associated with the ACTRIS infrastructure. If no overall structure is given, the effectiveness of the research will be less.

- Cross-cutting issues such as new technological solutions for continuous operation (lidar), aerosol-clouds interaction, in situ – remote sensing – models synergy or data assimilation will likely not be tackled because the instrumentation will not be up-to-date
- Research conducted based on ACTRIS generated data, technology and knowledge benefit from the standards that ACTRIS provides. The central facilities are essential to make the data and related products well discoverable and accessible to the community at large
- Continuous and quality assured data records are needed in different regions in order to be able to improve knowledge and understanding of (atmospheric) processes through models. Short or discontinuous and inhomogeneous data records cannot reduce uncertainties.
- Establishment of long time series with required quality for detection of climate change and change in atmospheric composition will suffer. Continued quality assurance and follow up is crucial, and this will immediately be reduced. Many sites are totally depending on interaction with the ACTRIS community and data center to provide data with a quality and precisions that is necessary to draw conclusion about long term changes. Furthermore, data management with collection, archiving and curation requires continuous focus. Follow up data flow from all sites require large effort, good procedures but also extensive personal contact on regular bases (weekly-monthly) with the data providers. Thus, collection of data and access to data from the suite of sites will be reduced.

Loss of human capital and invested capital in general

There is a risk for considerable loss of expertise (human capital) and invested capital. Also, higher costs for research projects can be expected when data provided by the research infrastructure will have to be produced by the Research, Technology and Development (RTD) project itself, hence with lower quality/reliability.

Reduced European expertise and capabilities concerning climate topics and air quality

ACTRIS is one of the major environment-related European infrastructures, which has already improved and, in case of continued funding, will continue to improve our understanding of climate and air-pollution-related processes. These efforts require both an overall coordinated structure and continuous funding. If these prerequisites are not provided, in other words if ACTRIS and related projects are not continued, European expertise and capabilities concerning a better understanding of climate and air pollution will be significantly reduced. This holds in general as well as for the RI in particular. The consequences would be:

- Losing the control over the quality of the data
- Losing the partners operating the infrastructures and providing the data
- Losing the high level of successful cooperation in research in Europe
- Lowering the benefit for the society due to inferior understanding of the changing environment in a changing climate

Moreover, there would be a lack or suitable platform to support innovation in the environmental field

Loss of information for future generations

An example of a long-term risk is loss of information for future generations. As one respondent puts it “we have lost almost all information from campaigns before 2000”. It is an open question who would take care of global storage of information. Data records will be discontinued and homogeneity of climate records cannot be guaranteed. Without continuous data series, topics such as aerosol climatology, Cal/Vals of satellite instruments and data products and air quality trends will not be properly addressed.

Loss of services and international cooperation

- Loss of potential services (i.e. weather hazards, improvement of forecasts, air pollution; development of adaptation and mitigation to climate change)

- Great loss also for the international networks like CLRTAP (EMEP, ICP-IM), Stockholm Convention (GMP) and WMO (GAW) as ACTRIS provides an important technical contribution and support also for observations outside Europe. There would also be a reduced capability to carry out long-term programs of scientific research and satellite validation in a key region as the Mediterranean Sea. This will affect in particular the EU capability to obtain high quality inter-calibrated measurements of aerosol and trace gases in Europe. Due to the large diversity of institutions acting in Europe, this is expected to have an impact on the capability to develop accurate assessments on the environment in Europe, and to direct political decisions.

- The UNFCCC-ERT (expert review team) calls the attention that the possible closure of the Cabauw Experimental Site for Atmospheric Research could affect important activities of the global climate observing activities at international and European level, as this center provides information to GRUAN and GCOS at international level and to ACTRIS at European Level

Finally, one of the responding countries state that:

"Probably some of the components of ACTRIS would survive in some form, but the motivation and synergies would lose momentum lacking common goals and coordination. Research would no doubt continue, but, without the positive impact of ACTRIS as a common infrastructure, many synergetic effects would disappear or be weakened, which would result in a decrease in research efficiency. This would translate in longer time for the benefits of research to reach the society".

4 CONCLUDING SUMMARY

The socio-economic impacts of ACTRIS are assessed in this pre-study. Largely based on the results of a questionnaire to partners of the project the study focuses on what respondents perceive as societal impacts of ACTRIS – both in retrospect and looking ahead to a situation with or without further funding. The main focus is to assess impacts of a continued project compared to a situation if the project will not continue.

The impacts of most interest here are primarily ones that may/will occur in the relatively short term, e.g. investment and operation costs of atmospheric stations, generation and dissemination of knowledge, technological development, creation of human capital, employment effects, stimulation of local business life, business opportunities related to innovation etc. In the medium-long term however there will also be positive impacts on e.g. human health, climate resilience, protection from environmental hazards, and visibility. A thorough assessment of these are out of scope for this study.

Broadly in line with the suggestions by Florio & Sirtori (2014), the benefits of the research infrastructure are assumed to belong to the following main categories:

- Knowledge outputs (e.g. scientific papers, books, research contracts granted)
- Technological development (e.g. patents granted, license deals, spinoffs created)
- Human capital creation (number of Master and Ph.D. students)
- Other types of benefits (e.g. the infrastructure may also provide benefits to other users, such as industry, local authorities, environmental protection agencies, meteorological agencies)

The total estimated cost of upgrading and running existing ACTRIS facilities in all of Europe (2015-19) is ~70 million Euro (upgrading) and ~120 million Euro (running), in total 190 million Euro (personal communication with Niku Kivekäs FMI Finland). What are the positive socio-economic outcomes of this major investment?

So far (2005-2015) and looking ahead (2015-2025) ACTRIS have resulted/is estimated to result in the following positive socio-economic impacts:

Knowledge output so far (2005-2015) and looking ahead (2015-2025) if ACTRIS continues

During the last ten years ACTRIS has resulted in approximately 1000 scientific papers, 50 books and more than 500 research contracts in the 21 participating countries.

The positive impacts in terms of knowledge creation and dissemination are expected to increase, the most important reasons being that the research communities will have the availability of the right platform to conduct state of the art research in the atmospheric field. This will help to improve the quality of research, acquire new knowledge and strengthen the cooperation at international level. For example, it can be expected that the long-term continental wide and global availability of data is secured and research communities and fostering of multi-disciplinary cooperation will increase.

Technological development so far (2005-2015) and looking ahead (2015-2025) if ACTRIS continues

During the last ten years ACTRIS-related technological development implies that approximately 10 patents have been granted, 2 license deals have been signed, 4 spinoffs have been created, 40 technologies have been transferred and 60 prototypes developed.

The positive impacts relating to technological development are expected to increase, the most important reasons being that a sustained availability of the infrastructure will establish a reliable platform for new technology development. The demand for observation stations for more accurate measurements will promote innovative ideas and simultaneously ACTRIS observatories will serve as testbed of new technology and techniques. It is foreseen that the stations will be steadily improved by equipment with best and newly emerging technologies, more automated systems with remote control will be available, the research infrastructure will make the “European voice” stronger in ISO procedures to mention a few impacts.

Human capital creation so far (2005-2015) and looking ahead (2015-2025) if ACTRIS continues

During the last ten years around 850 Masters and Ph.D. students have carried out research at the research infrastructure.

The positive impacts relating to human capital creation are expected to increase since the long-term existence of ACTRIS will reinforce capacity building, data produced in the infrastructure will increasingly be used in teaching and graduation of students (master and Ph.D. theses), interaction with the general public will increase and also the knowledge transfer and education of scientists from developing countries. The enlargement of the research community would mean that more projects are carried out and that the number of people educated in the field will increase.

Employment effects looking ahead (2015-2025) if ACTRIS continues

Future jobs (2015-2025) are estimated to occur primarily related to ACTRIS-research and other research carried out relying on the infrastructure. The total number of expected new jobs in the coming ten years is estimated to around 1700, of which nearly 70 % are expected to occur indirectly due to ACTRIS.

ACTRIS generated jobs in the coming ten years can partly be explained by the fact that the provision of a sustainable infrastructure will require permanently employed personnel, but primarily by the fact that data availability will create new projects involving new staff, in particular specialists will be needed.

Stimulation of local business life looking ahead (2015-2025) if ACTRIS continues

Generally, the way in which ACTRIS stimulates local business life is by activities in SMEs, technological clusters and tourism sector (accommodation, restaurants etc.). More specifically, ACTRIS provides support to development of new products, new technologies, physical access to the research infrastructure and so on.

If ACTRIS continues, local business life will benefit directly from the improvement and maintenance of the infrastructure involving local business partners. Moreover the establishment of a long-term research infrastructure will imply a direct improvement of the innovation potential with impact also at local scale. Involved local territories can be expected to have the opportunity to use the European dimension for improving own strengths, for both research and innovation aspects, in line with the European Smart Specialization Strategy. Future improvement and maintenance of the infrastructure can be foreseen which will involve local business partners, increased maturity of the infrastructure in terms of innovation platform and increased number of physical accesses to infrastructure facilities. One of the respondents states: *"It is expected that ACTRIS stations and central facilities will be poles of activities, both scientifically and commercially related*".

Business opportunities related to innovation looking ahead (2015-2025) if ACTRIS continues

Knowledge generation and access to the infrastructure is expected to give rise to innovative business opportunities. Small and medium-sized businesses will have a benefit in terms of new opportunities for increased competitiveness at different scales (local, national, international) by development of new services and/or technological products in the environmental field. The groups in society who will benefit from this positive development are the industrial sector (for example R&D branch of SMEs), technological clusters, big enterprise, and indirectly also the general public through the products and services developed. Such smart services and products may include information about the environmental status, specific extreme events and hazards. ACTRIS has contributed for example by new patents, provision of data that enables service and support for development of innovative products etc.

If the project continues it can be judged that ACTRIS-fostered technologies and ACTRIS-provided observation products will create new business opportunities, also standards and norms are an important area of market development. The infrastructure is expected to make the "European voice" stronger in ISO procedures. Examples of companies relying on ACTRIS are the German Metek (cloud radars, wind lidars) and Radiometer Physics (microwave profilers), as well as the Greek company Raymetrics for lidar. In Finland ACTRIS measurements have initiated one spinoff company. In addition to this should also be mentioned that novel measurement technologies are pursued by the researchers funded by TEKES, which is a Finnish funding agency for innovation providing potential breakthroughs that could be relevant to the wider scientific community.

Other types of impacts

These impacts are primarily related to what the research findings can be used for "in practice", also by actors in society outside the research community. Three main types of positive impacts of ACTRIS have been identified;

- support for better predictions of topics related to climate change, air quality, extreme events and atmospheric hazards;
- support for local, national, international policy making and planning; and
- support for increased public awareness, knowledge and debate.

Examples of groups that will benefit are the general public, the scientific community, aviation and policy makers at different scales.

REFERENCES

Binietoglou, S. Basart, V. Amiridis, L. A. Arboledas, A. Argyrouli, J. M. Baldasano, D. Balis, L. Belegante, J.A. Bravo-Aranda, P. Burlizzi, V. Carrasco, A. Chaikovsky, A. Comerón, G. D'Amico, M. Filioglou, M. J.Granados-Muños, J. L. Guerrero-Rascado, P. Kokkalis, A. Maurizi, F. Monti, C. Muñoz, D. Nicolae, S. Nikcovic, A. Papayannis, G. Pappalardo, S. N. Pereira, M. R. Perrone, A. Pietruczuk, M. Posyniak, A. Rodriguez, M. Sicard, N. Siomos, A. Szkop, E. Terradellas, A. Tsekeri, U. Wandinger, and J. Wagner: Application of the Lidar/photometer algorithm: dust model evaluation, AMTD, 2015. [submitted]

Dacre, H. F., Grant, A. L. M., Hogan, R. J., Belcher, S. E., Thomson, D. J., Devenish, B. J., Marenco, F., Hort, M. C., Haywood, J. M., Ansmann, A., Mattis, I., and Clarisse, L.: Evaluating the structure and magnitude of the ash plume during the initial phase of the 2010 Eyjafjallajökull eruption using lidar observations and NAME simulations, J. Geophys. Res., 116, D00U03, doi:10.1029/2011JD015608, 2011.

Florio, M., Sirtori, E., 2014. The evaluaiton of reserach indrastructures: a cost-benefit analysis framework. Working paper, European Investment Bank.

FP7 PEGASO project. Grant agreement no: 244170. http://www.pegasoproject.eu/

IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. 5th Assessment report, working groups 1 and 2.

Kriström, B., Bonta Bergman, M., 2014. Samhällsekonomiska analyser av miljöprojekt – en vägledning. Naturvårdsverket, rapport 6628.

Matthias V., Aulinger, A., Bieser, J., Cuesta, J., Geyer, B.,Langmann, B., Serikov, I., Mattis, I., Minikin, A., Mona,L., Quante, M., Schumann, U., and Weinzierl, B.: The ash dispersion over Europe during the Eyjafjallajökull eruption– comparison of CMAQ simulations to remote sensing and air-borne in-situ observations, Atmos. Environ., 48, 184–194, doi:10.1016/j.atmosenv.2011.06.077, 2012.

Mona, L., Papagiannopoulos, N., Basart, S., Baldasano, J., Binietoglou, I., Cornacchia, C., and Pappalardo, G.: EARLINET dust observations vs. BSC-DREAM8b modeled profiles: 12-year-long systematic comparison at Potenza, Italy, Atmos. Chem. Phys., 14, 8781-8793, doi:10.5194/acp-14-8781-2014, 2014.

Pappalardo, G., Mona, L., D'Amico, G., Wandinger, U., Adam, M., Amodeo, A., Ansmann, A., Apituley, A., Alados Arboledas, L., Balis, D., Boselli, A., Bravo-Aranda, J. A., Chaikovsky, A., Comeron, A., Cuesta, J., De Tomasi, F., Freudenthaler, V., Gausa, M., Giannakaki, E., Giehl, H., Giunta, A., Grigorov, I., Groß, S., Haeffelin, M., Hiebsch, A., Iarlori, M., Lange, D., Linné, H., Madonna, F., Mattis, I., Mamouri, R.-E., McAuliffe, M. A. P., Mitev, V., Molero, F., Navas-Guzman, F., Nicolae, D., Papayannis, A., Perrone, M. R., Pietras, C., Pietruczuk, A., Pisani, G., Preißler, J., Pujadas, M., Rizi, V., Ruth, A. A., Schmidt, J., Schnell, F., Seifert, P., Serikov, I., Sicard, M., Simeonov, V., Spinelli, N., Stebel, K., Tesche, M., Trickl, T., Wang, X., Wagner, F., Wiegner, M., and Wilson, K. M.: Four-dimensional distribution of the 2010 Eyjafjallajökull volcanic cloud over Europe observed by EARLINET, Atmos. Chem. Phys., 13, 4429-4450, doi:10.5194/acp-13-4429-2013, 2013.

SACS-2/SMASH – VALIDATIONREPORT ON THE EYJAFJALLAJÖKULL & GRIMSVÖTN ERUPTIONS, February 20, 2014. http://sacs.aeronomie.be/Documentation/LAP-AUTH-SACS-ValidationReport_FINAL.pdf.

VOLCANIC ASH Exercise VOLCEX 14/01. ICAO 2014. http://www.icao.int/EURNAT/Pages/METEOROLOGY/VA_Exercice/VOLCEX_14_01.aspx

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ANNEX 1. QUESTIONNAIRE

Q1. What is your name (s):

Q2. Affiliation and country:

Q3: How would you describe your role in ACTRIS research: (please, tick one or more boxes)

☐ Data user
☐ Data provider
☐ Infrastructure user
☐ Infrastructure provider
☐ Infrastructure manager
☐ Research scientist
☐ Other (specify):

Q4. So far, what have been the <u>positive</u> direct and indirect impacts on society from the ACTRIS research (infrastructure) in your country? Please fill out the relevant fields: (tick one or more boxes and try to give numeric estimates when asked for)

☐ 1. Knowledge creation and dissemination
number of scientific papers:
number of books published:
number of research contracts:

☐ 2. Technological development
number of patents granted:
number of licence deals:
number of spinoffs created:
technologies transferred:
number of prototypes developed:

☐ 3. Human capital creation
number of Masters and Ph.D. students carrying out research at the research infrastructure:

☐ 4. Employment effects

☐ 5. Contributions to policy guidance that later resulted in environmental improvement

☐ 6. Stimulation of local business life

☐ 7. Business opportunities related to innovation

☐ 8. Other (specify):

Q5. For each of the positive direct and indirect impacts you just identified in Q4, try to describe also who is affected (e.g. general public, local community, research community, organization x and y), and provide some reflections on how ACTRIS in your country has contributed to this.

Positive impacts (please, write your answer directly in the table, the numbers 1-8 refer to the alternatives in Q4)

Brief narrative of positive impacts	Who is affected by this?	How/to what extent has ACTRIS contributed to this?
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

Q6. If you find it relevant, please fill out the table below in a corresponding way for any negative direct and indirect impacts.

For example, maybe the infrastructure is perceived as visually disturbing among certain stakeholders, or there are negative environmental impacts from construction, maintenance, etc. Try to be specific in terms of relating these impacts to the facilities in your country.

(Note that we already have data on maintenance and investment costs. Here, we are interested in other types of negative impacts)

☐ Relevant (fill out table below)
☐ Irrelevant (go to Q7)

Negative impacts (please write your answer directly in the table)

Brief narrative of negative impacts	Who is affected by this?	How/to what extent has ACTRIS caused this impact?
1.		
2.		
3.		
4.		
5.		

Q7. Could you provide one or several good example(s) of what ACTRIS has achieved in society that is especially interesting/communicable?

For example, this might be about positive effects related to local industries, innovation activity, the environment, the local community, etc. You might have mentioned this above, in that case explain in narrative here. Please also include numeric estimates, if possible. (These examples can be used in the ESFRI proposal directly).

Q8. Could you also provide one or several good example(s) of research findings that have partly or fully been dependent on ACTRIS data?

If possible, focus on giving examples that have a close link to societal benefits, such as improved health, improved environment, air quality, etc. Please also include numeric estimates, if possible. (These examples can be used in the ESFRI proposal directly).

Q9. When answering Q4 to Q8, what time perspective did you have in mind?

Q10. Looking ahead (to 2025): Given continued funding for the research infrastructure, do you expect the positive direct and indirect impacts you identified in Q4-Q5 to remain/increase/decrease? Motivate your answer and write directly in the table. Please also include numeric estimates, if possible.

Positive impacts	Remain, why?	Increase, why?	Decrease, why?
1. Knowledge creation and dissemination			
2. Technological development			
3. Human capital creation			
4. Employment effects			
5. Contributions to policy guidance that later resulted in environmental improvement			
6. Stimulation of local business life			
7. Business opportunities related to innovation			
8.Other, namely:			

If you filled out negative impacts in Q6, please answer Q11 below. Otherwise move on to Q12.

Q11. Looking ahead (to 2025): Given continued funding for the research infrastructure, do you expect the negative direct and indirect impacts you identified in Q6 to remain/increase/decrease? Motivate your answer and write directly in the table. Please also include numeric estimates, if possible.

Identified negative impacts (see Q6)	Remain, why?	Increase, why?	Decrease, why?
1.			
2.			
3.			
4.			
5.			
6.			
7.			

Q12. Looking ahead (to 2025): If ACTRIS will not be continued in any common form, what would be the impacts to the research infrastructure, research and society? Answer freely. Motivate your answer.

Below follow a number of more detailed questions concerning the infrastructure in your country. Try to answer in an as detailed way as possible.

First, we need some information about job creation. Please answer the questions below by giving numeric estimates. Feel free to add any clarifications if needed.

Q13. Since 2006, approximately how many jobs have been generated related to …

a) setting up the physical infrastructure (e.g. stations, surrounding infrastructure)?

b) maintenance and daily operation of the research infrastructure?

c) data collection and quality control of data?

Apart from the jobs generated through a-c above, there might also be job opportunities generated indirectly. Since 2006, approximately how many jobs have been generated related to…

d) ACTRIS research?

e) other research relying on data from ACTRIS infrastructure (we know this one is particularly difficult to answer but please try your best)?

f) businesses and services surrounding the infrastructure (e.g. hotels, restaurants)?

g) business related to innovation

Q14. Looking ahead (to 2025): Approximately how many jobs do you estimate will be generated during the construction phase and when the research infrastructure is operational related to…

a) setting up the physical infrastructure (e.g. stations, surrounding infrastructure)?

b) maintenance and daily operation of the research infrastructure?

c) data collection and quality control of data?

Apart from the jobs generated through a-c above, there might also be job opportunities generated indirectly. Looking ahead (to 2025), approximately how many jobs do you estimate will be generated related to…

d) ACTRIS research?

e) other research relying on data from ACTRIS infrastructure (we know this one is particularly difficult to answer but please try your best)?

f) businesses and services surrounding the infrastructure (e.g. hotels, restaurants)?

g) business related to innovation

Q15. We are particularly interested in the linkages between research infrastructure -> research findings/networks/etc. -> societal benefits. If you have anything to add related to this in your country (or in general), please add here!

Q16. Is there anything you would like to add? If so, write here.

Research, consulting and teaching for a sustainable future

Enveco Environmental Economics Consultancy is well-established in the environmental economics research community. We offer analysis, research, education and training in environmental economics and ecological economics. Our clients are in the private, non-profit and public sectors. We are located in Stockholm and Göteborg but work nationwide as well as internationally.

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