Deloitte Access Economics

Evaluation of CSIRO's research impacts

AuScope Case Study

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

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Executive Summary

Introduction

Deloitte Access Economics (DAE) was commissioned by CSIRO to recommend, test and validate an appropriate framework and methodologies for the ex-post impact evaluation of CSIRO research. In Stage 1 of the project, DAE presented an ex-post impact evaluation framework, while Stage 2 focused on applying and validating the framework across diverse case studies. CSIRO, with the assistance of DAE, has selected four impact case studies to test the framework and undertake the ex-post impact evaluation. This report presents the 'AuScope' impact case study.

Impact case study: AuScope

The Minerals Down Under Flagship developed tools to generate and process deposit data for mineral exploration, such as the Satellite ASTER Geoscience Map of Australia, a Laterite and Calcrete atlas and HyLogger. The data is made available through the AuScope portal, which integrates distributed heterogeneous datasets. These tools jointly aim to improve the efficiency of mineral resource exploration. Cost savings in exploration and new minerals discoveries brought forward are the main economic impacts identified and assessed in this case study. Environmental impacts were considered, but are not substantial in this sector.

The progress in the adoption of these technologies can be observed in specific applications, such as the Laterite geochemical database launched in 2008 for the West Yilgarn Craton, Western Australia.

The following impacts of the package of work undertaken under AuScope were estimated in monetary terms:

- **Cost saving in exploration:** Given an annual expenditure on mineral exploration of $1.4 billion across Australia (not including petroleum, iron ore and coal), likely 15% target market penetration at full maturity and assuming a cost reduction of 17.5%, total cost savings associated with AuScope as a result of the improved availability and accessibility of comprehensive geoscientific data and thus a more targeted exploration effort are $35.8 million per annum at maturity.
- **New minerals discoveries brought forward:** Assuming that CSIRO research is used on approximately 20% of current gold discoveries across Australia and given a current market value of the gold industry of $14 billion per year, out of which 57% is value added to the economy, the impact of new mineral resource discoveries brought forward by five years as a result of CSIRO research is valued at $458.1 million per annum at maturity for gold discoveries alone.
- **Reduced emissions:** Given that 2.4% of the expenditure in the 'Exploration and Mining Support Services' sector is used on petroleum products and assuming all of this represents consumption of fuel oil, a reduction of 1,888 tonnes of CO_2 can be achieved from avoided exploration activities. Similarly, 0.04% of the exploration expenditure is on electricity, which reduces indirect emissions of 62 tonnes of CO_2. If $24.15 per tonne is assumed as the value of reduced carbon emissions, this research would lead to savings to society of $45,597 per annum at maturity.

Other impacts identified but not estimated in monetary terms include increased investment in mining activities and positive externalities in relation to providing data for use in other sectors, such as meteorology, the environmental sector and primary industries.

Assuming 90% attribution to CSIRO, the ex-post impact evaluation indicated that the value of the impacts generated by the package of work undertaken under AuScope that are attributable to CSIRO research is $444.5 million per annum at maturity.

Major uncertainties affecting the estimates relate to underlying assumptions around the market penetration and the reduction in exploration costs at maturity, the share of gold discoveries in which CSIRO research has been used, benefits being brought forward by five years and the attribution of CSIROs role versus other inputs required to make the impacts possible.

Even though this case study appears to be the one with the largest impact in monetary terms – because of its broad impact across such a large part of the Australian economy in terms of both direct and spillover benefits - it is also the case study where quantification of impacts was most challenging because of a paucity of sound starting point numbers to inform an analysis.

Evaluation of research impacts: AuScope

1. Project context

Deloitte Access Economics (DAE) was commissioned by CSIRO to recommend, test and validate an appropriate framework and methodologies for the ex-post impact evaluation of CSIRO research. In the first stage of the project, DAE developed an ex-post impact evaluation framework in collaboration with CSIRO stakeholders and the Performance and Evaluation Team. Appendix A provides an overview of that framework, including the different framework steps and key considerations.

The second stage of the project focused on applying and validating the framework across diverse case studies. CSIRO, with the assistance of DAE, selected four impact case studies to test the framework and undertake the ex-post impact evaluation. This report presents the 'AuScope' impact case study.

2. Background: AuScope

CSIRO's Minerals Down Under Flagship works across the minerals value chain to grow Australia's resource base, increase the productivity of the minerals industry and reduce its environmental footprint, both in Australia and globally. The Flagship goal is to deliver science and technology options for the discovery and efficient development of Australia's mineral resource endowment that will lead to $1 trillion in-situ value by 2030 and enable flow-on benefits to the wider national economy.

Under the AuScope project, a partnership of 23 participants including CSIRO, Geoscience Australia, 11 universities, and state government agencies, CSIRO undertook research to improve the availability and accessibility of comprehensive geoscientific data to encourage investment in mining by improving the perception of prospectivity.

There are five types of outputs from this package of work, which work together to deliver the information that is needed to enhance mineral exploration success:

- **Satellite ASTER Geoscience Map of Australia:** The ASTER geoscience map of Australia is a set of digital geoscience products generated from satellite ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data. The ASTER geoscience maps of Australia represent the first continent-scale maps of the Earth's surface mineralogy, focusing on important rock forming minerals such as iron oxides, clays carbonates, quartz, muscovite and chlorite.
- **Laterite and Calcrete geochemistry:** Calcrete and laterite samples can be used to identify potential mineral deposits. CSIRO discovered that the presence of subterranean gold is correlated with the chemical composition of laterite and calcrete soils that are found on the earth's surface above gold deposits. This correlation led to a

new mineral exploration method whereby geologists can identify potential subterranean gold deposits by sampling and testing soils gathered by hand from the surface of the earth rather than undertaking expensive drilling campaigns which require additional licences and environmental approvals. The benefit to exploration companies from utilising this methodology is that it significantly reduces the time, cost and environmental impact of mineral prospecting.

- **National Virtual Core Library (NVCL) and HyLogger:** The National Virtual Core Library creates an innovative earth science research network building a high resolution picture of the mineralogy and composition of the upper 1 to 2 km of the Australian continent based on the legacy of drill samples already held, and to be acquired by State agencies and industry in the future. HyLogger, a robotic, automated spectroscopic machine, can be used to scan drill cores held or collected by the NVCL and provide detailed data in a consistent and objective manner.
- **AuScope portal:** Seamless access to Australian geoscience data at atomic to continental scale within and between geological surveys and their clients.
- **Spatial Information Services Stack (SISS) platform:** CSIRO developed the SISS, which is an architecture and suite of tools which enables spatial data interoperability using the Open Geospatial Consortium (OGC) standards, Geography Markup Language (GML) application schema development and registries. SISS is deployed in organisations such as State and Territory surveys to translate their datasets from proprietary mark-up languages into the interoperable OGC standard which can then be integrated by portals such as AuScope. CSIRO drew on expertise in software architecture, services science, computer science and their deep understanding of the application domain to deliver a high-quality, scalable and long term solution to the complex integration of geological data. SISS solves a complex research challenge and enables Australia's e-Research infrastructure to federate nationally distributed datasets. The platform provides access to current data holdings in a standards based web service for 24/7 client self-service, thereby providing a higher quality, timely service at less cost.

CSIRO was instrumental in the research of all five components. While research for the technologies is completed, the use of the various technologies for data collection and sharing is not yet business-as-usual.

3. Purpose and audience for the evaluation

The evaluation was undertaken to assess the outcomes and impacts derived from a range of CSIRO research projects to support accountability reporting, communication of impacts and continual improvement of their path to impact planning. The main purposes and audiences are:

- **Flagship Review**: The ex-post research impact evaluation of AuScope is to inform an external review of the Flagship, which includes an assessment of the Flagship's objectives and the rate of progress. It is to identify and verify the impacts to date from the AuScope program in the context of how it is delivering on the Minerals Down Under Flagship goal.
- **CSIRO review:** The evaluation is to inform CSIRO's (and other external party) reviews of its programs and activities, in particular in relation to achieving its objectives and

representing value for money. Audiences may include Ministers, CSIRO at all levels and the general public.

4. Status of research and adoption

Nature of the impacts

The main impacts in the AuScope case study are associated with improved exploration success as a result of better information. The following impacts of the package of work undertaken under AuScope were identified:

i **Cost saving in exploration (economic impact):** The technologies provide better information and improve the efficiency of data collection, meaning that exploration effort can be more targeted. This decreases the risk in exploration projects and requires less resources to achieve exploration discoveries.

ii **New minerals discoveries brought forward (economic impact)**: Better information and exploration success encourages investment in exploration from both domestic and foreign firms (this could be further enhanced through State Incentive Schemes), which results in minerals discoveries being brought forward. Due to the limited data available at the time of preparation of this case study, the analysis of this impact focused on gold discoveries only. However, the same logic applies to other minerals and thus the estimated impact in this case study should be considered a subset of the full market potential.

iii **New mining activity (flow-on impact) (economic impact)**: More (targeted) exploration leading to more discoveries will then stimulate more mining activity to extract mineral resources. A 2012/13 survey of companies in the Australian Mining Equipment, Technology and Services (METS) sector identified the cost of operating a business in Australia as a significant challenge for most mining, exploration and services companies. According to this survey, 52% of the companies in the METS sector maintain competitive advantage by reinvestment back into the business.

iv **Reduced emissions (environmental impacts)**: The adoption of these technologies jointly will provide more targeted exploration effort, which reduces unnecessary use of drilling inputs, thus leading to reduced greenhouse gas (GHG) emissions and water and energy use. In addition, more targeted exploration will provide information to mining development or expansion projects early on, reducing any potential adverse impacts of natural habitats, soils and animals.

Of the impacts identified, (i), (ii) and (iv) were quantified, as discussed in Section 5. New mining activity was considered a flow-on impact of increased exploration activity and was not quantified as part of this analysis.

Note that Section 5 presents the assessment of the impacts resulting from the research outputs (in this case the package of work undertaken under AuScope to enhance mineral exploration success) more broadly. The impacts attributable to CSIRO research are discussed in the aggregation section (Section 6).

Counterfactual

Without CSIRO research, existing technologies could have led to the discovery and extraction of some additional resources at larger costs or over longer timeframes. In the AuScope partnership, CSIRO development of the SISS platform was critical to delivering the exploration information through the AuScope portal.

Attribution

90% of the research outputs required to enable the impacts assessed in this case study can be attributed to CSIRO, with SISS, HyLogger, Laterite and Calcrete Geochemistry and ASTER being led by CSIRO. However, it is important to acknowledge that the AuScope portal is a joint platform created and funded among 23 stakeholders, including Geoscience Australia, all state/territory governments and major universities across Australia.

Multiple stakeholders were involved in the adoption process. However, attribution in this case study was defined at 90% by taking into account the following information about CSIRO's role in key outputs:

AuScope Grid/Portal

Of the R&D for the SISS technology and AuScope portal, which provide the national spatial data infrastructure, 100% was developed by CSIRO. CSIRO also maintains the AuScope portal and associated registry services on behalf of AuScope and publishes CSIRO data to AuScope via SISS.

All State and Territory Geological Surveys and Geoscience Australia currently deploy and maintain the SISS technology against their datasets. They register the existence of those datasets with AuScope so it is published via the AuScope portal and access some of these services via their own organisations' portals. The University of Melbourne also deploys SISS and publishes AuScope data in the same way the surveys do.

National Virtual Core Library (NVCL)

CSIRO undertook 100% of the R&D of the HyLogger 3 technology, short-wave infrared (SWIR), visible to near-infrared (VNIR) and thermal infrared (TIR) mineral analysis algorithms and development of the Spectral Geologist (TSG™) software suite for hyperspectral mineralogical analysis.

State and Territory Geological Surveys currently deploy and operate the HyLogger 3 technology and TSG software. They maintain the core warehouses, which hold the drill core that is scanned by the HyLogger 3. All States and Territories (except for Victoria) own and operate a HyLogger 3.

It is likely that other inputs (such as implementation of the technologies, training and new equipment) would be required to unlock the full impacts. However, insufficient information was available to incorporate those into the analysis.

Adoption

According to information provided on the AuScope project, the market development and implementation stage is currently at 70-80% completion and a market penetration for mineral exploration (excluding petroleum, iron ore and coal) of 10-20% is anticipated over the next five years. Consolidated information on the current progress or adoption levels in terms of number and size of exploration projects is not readily available at this stage.

There are a number of results to consider associated with specific applications, e.g. the Laterite geochemical database launched in 2008 for the West Yilgarn Craton, Western Australia, was followed by an increase in exploration tenement uptake of over three times after each of the two data releases (covering 350,000 km^2) became available. The adoption of each application has been evidenced as follows:

SISS

All State and Territory Geological Surveys and Geoscience Australian have made some of their geosciences data holdings available via SISS as operational services. Geoscience Australia currently uses SISS to deliver remote sensing data and in projects involving geological and environmental information, while the Bureau of Meteorology has selected SISS as the reference implementation for the whole of Government National Environmental Information Infrastructure.

HyLogger

Six geological surveys currently use HyLogger for data acquisition and publication. In addition the HyLogger technology has been mandated for use in drill holes funded in part by the Western Australian governments Exploration Incentive Scheme. The Exploration Incentive Scheme is a WA State Government initiative that aims to encourage exploration in Western Australia for the long-term sustainability of the State's resources sector. It is an $80 million initiative, funded by Royalties for Regions over five years and has stimulated increased private sector resource exploration and ultimately will lead to new mineral and energy discoveries. All holes drilled with funding from this scheme are mandated to use the CSIRO HyLogger technology to appraise the core samples and make the information available in the public domain. Once in the public domain this bore hole information from across WA can be integrated together to provide a 3D geological model across the state.

Laterite Atlas

Laterite geochemistry and regolith-landform control have contributed and greatly assisted a number of discoveries including Johnstone Range, Callion, Bronzewing, Jundee-Nimary, Stellar, Jim's Find, Turett, Bottle Creek and Waroonga. For example, over 11 million ounces of gold have been discovered from Jundee-Nimary and Bronzewing deposits.

Data for the SW Yilgarn Craton was released in February 2006 as an interim report (Cornelius et al. 2006). There was strong interest by industry in the first release and within four weeks of the release, approximately 25 exploration licences, covering some 20,000 km^2, were applied for.

The 'Laterite geochemical database for the West Yilgarn Craton, Western Australia' was released in 2008. It demonstrated broad scale utility of laterite geochemistry for exploration across 350,000 km^2 in this moderately explored region. This multi-element geochemical atlas was successful in identifying major new geochemical trends and provinces, both in residual and in depositional terrains that could assist exploration and lead to the discovery of new mineral deposits. Exploration tenement uptake increased over three times after each of the two data releases.

Calcrete Geochemistry

Calcrete Geochemistry has led to numerous gold discoveries in South Australia, with an in-ground value of several billion. In particular it opened up the Gawler Craton to gold exploration which led to many discoveries (e.g. Challenger, Tunkillia and Golf Bore). The Challenger gold mine is currently producing over 60,000oz of gold per year and has produced approximately 950,000oz in total. Deposits have also been discovered in Western Australia in East Kundana, the Base Line, Golden Cities, Ghost Crab, Twin Peaks-Karari, Aphrodite and Plough Dam.

ASTER Geoscience Products

Based on this geological model of the mineral system and the selection of described mineral maps derived from ASTER data, the Chubko Prospect was discovered in 2012 by Kentor Gold Ltd. Mineralisation at Chubko is hosted by lensed quartz veins, showing up to 50-56 g/t Au associated with elevated Bi and As. This opens up the higher metamorphic schists to the south and east of the known mineralised trend for exploration for quartz-lode hosted Au deposits.

5. Assessment of the impacts

Quantified impacts

This section presents DAE's approach to quantify key impacts at maturity levels, based on the best data available to CSIRO for this analysis. Any assumptions and sources used in the analysis are outlined in the relevant tables with the impact calculation.

Cost saving in exploration

Given an annual expenditure on mineral exploration of $1.4 billion across Australia (not including petroleum, iron ore and coal), 15% target market penetration and assuming a cost reduction of 17.5%, total cost savings associated with AuScope as a result of the improved availability and accessibility of comprehensive geoscientific data and thus a more targeted exploration effort are estimated at $35.8 million per annum at maturity, as outlined in Table 5.1. These cost savings in exploration are significant to the industry in the context of increasing discovery costs, which according to MinEx Consulting (2012) have doubled in the last decade.

Table 5.1: Impact calculation of cost saving in exploration

	Measure	Value	Sources
	With CSIRO research		
A_R	Annual exploration expenditure (excluding petroleum, iron ore and coal) [$ per annum]	$1,363.1m	ABS (2013) Cat. 8412.0
B_R	Target market penetration at maturity [%]	15%	CSIRO estimate
C_R	Reduction in exploration costs at maturity [%]	17.5%	CSIRO estimate
D_R	Exploration expenditure [$ per annum]	$= A_R*B_R*(1-C_R)+ A_R*(1-B_R)$ = $1,327.3m	
	Counterfactual		
D_c	Annual exploration expenditure (excluding petroleum, iron ore and coal) [$ per annum]	$= A_R$ = $1,363.1m	
	Impact: world with CSIRO research - counterfactual		
D_i	Exploration savings [$ per annum]	$= D_c - D_R$ = $35.8m	

Note: Monetary values are presented in 2013 $AUD.

New minerals discoveries brought forward

To quantify this impact, the analysis focused on gold discoveries being brought forward by five years due to CSIRO research. Assuming that CSIRO research is used on approximately 20% of current gold discoveries across Australia and given a current market value of the gold industry of approximately $14 billion per year, out of which 57% is value added to the economy, the impact of new mineral resource discoveries brought forward as a result of CSIRO research is valued at $458.1 million per annum at maturity, as shown in Table 5.2.

Table 5.2: Impact calculation of new minerals discoveries brought forward

	Measure	Value	Sources
	With CSIRO research		
A_R	Market value of gold resources [$ per annum]	$14 billion	Geoscience Australia (2013)
B_R	Share of discoveries in which CSIRO research has been used	20%	CSIRO estimate
C_R	Gross value added share of output	57%	2009-10 ABS Input-Output tables
D_R	Valued added generated to the Australian economy [$ per annum]	$= A_R*B_R*C_R$ $1,596 m	
	Counterfactual		
D_c	Valued added generated to the Australian economy five years later [$ per annum]	$= D_R/(1+7\%)^5$ = $1,137.9m	
	Impact: world with CSIRO research – counterfactual		
A_i	Additional value added from earlier discoveries in the gold mining industry [$ per annum]	$= D_c - D_R$ = $458m	

Note: Monetary values are presented in 2013 $AUD.

Reduced emissions

The reduction in exploration costs calculated previously will decrease the emissions from exploration drilling activities. Given that 2.4% of the expenditure in the 'Exploration and

Mining Support Services' sector is used on petroleum products and assuming all of this represents consumption of fuel oil, a reduction of 1,888 tonnes of CO_2 can be achieved from avoided exploration activities. Similarly, 0.04% of the exploration expenditure is on electricity, which reduces indirect emissions of 62 tonnes of CO_2. If $24.15 per tonne is assumed to hold to internalise the cost of carbon emissions, this research would lead to savings to society of $45,597 per annum at maturity, as shown in Table 5.3.

Table 5.3: Impact calculation of reduced emissions

	Measure	Value	Sources
	With CSIRO research		
	Emissions from transport and energy used in exploration activity through AuScope [$ per annum]	No detail available	
	Counterfactual		
	Emissions from transport and energy used in other exploration activity [$ per annum]	No detail available	
	Impact: world with CSIRO research - counterfactual		
A_i	Exploration cost savings [$ per annum]	$35.8m	Derived in Section 6.4.1.1
B_i	Petroleum products expenditure share from total output for 'Exploration and Mining Support Services' [%]	2.4%	2009-10 ABS Input-Output tables
C_i	Wholesale diesel price [$ per litre]	$1.4	AIP (2013)
D_i	Emission factor for fuel oil [kg CO_2 per litre]	2.9	DIICCRSTE (2013)
E_i	Emissions savings from diesel [tonnes of CO_2]	$= (A_i*B_i*D_i*1000)/C_i$ = 1,888.1	
F_i	Electricity share from total output for 'Exploration and Mining Support Services' [%]	0.04%	2009-10 ABS Input-Output tables
G_i	Retail electricity price for exploration businesses [$ per kWh]	$0.2	DAE assumption
H_i	Emission factor for electricity [kg CO_2 per kWh]	0.78	DIICCRSTE (2013)
I_i	Emissions savings from electricity [tonnes of CO_2]	$= (A_i*F_i*H_i*(1000)/G_i$ = 61.9	
J_i	Carbon price or marginal abatement cost [$ per tonne of CO_2]	$24.15	DAE assumption
L_i	Value of emission reduced [$ per annum]	$=(E_i + I_i)*J_i$ = $0.05m	

Note: Monetary values are presented in 2013 $AUD.

Further impacts

This section provides an overview of the causal linkage from the adoption of AuScope to generate other impacts identified that could not be quantified, along with some examples evidencing the extent to which they have been realised to date. In this case study, the focus is on new mining activity generated from earlier discoveries.

New mining activity

Increased mining investment is likely to be generated if more targeted exploration, leading to higher discovery rates, is achieved (holding any other drivers for investment as constant).

This impact, however, is difficult to estimate as mining investment is largely driven by commodity prices and existing information on Economic Demonstrated Resources, rather than exploration effort. Operating expenditure of mining operation has a linkage to exploration services, but this is likely to be in relation to ongoing mining production, rather than exploration discoveries driving mining activities.

Distributional effects on users

The main beneficiaries from the research outcomes are exploration companies, mining companies (as flow-on effect on the economic sector), and regional communities if increased exploration activity and employment in specific regional areas.

Externalities or other flow-on/spillover effects on non-users

The main economic flow-on effect is the increase in economic activity generated in the mining sector due to new resource discovery, although this would greatly depend on the specific location of the deposit and any extraction costs required.

The AuScope project will also provide positive externalities, as the information can be used in other fields (e.g. to analyse desertification, dust storms, soil quality) by organisations in other industries, such as the Bureau of Meteorology and the National Environmental Information Infrastructure.

6. Aggregation of research impacts

Aggregation of impacts and attribution to CSIRO research

The impact estimates obtained in this case study address different economic aspects of exploration costs and the value of resources discovered. These impacts can be aggregated directly along with any other environmental or social impacts generated as a by-product of achieving efficiencies in exploration activities.

The existing project data did not allow breakdown of the cost saving or improvement in discovery rate in each stage of the exploration value chain. Thus, a core assumption across impacts is that ASTER, Laterite and Calcrete atlas, HyLogger and the AuScope portal will need to work jointly to achieve any expected outcomes.

Assuming 90% attribution to CSIRO, the ex-post impact evaluation indicated that the value of the impacts generated by the package of work undertaken under AuScope that are attributable to CSIRO research is $444.5 million per annum at maturity, as shown in Table 6.1.

Table 6.1: Summary of impacts from the AuScope project at full maturity ($ per annum)

	Impact	Quantified in monetary terms?	Type	Annual value
i	Cost saving (reduced time/reduced risk) in exploration	Yes	Economic	$35.8m
ii	New minerals discovery (due to new data)	Yes	Economic	$458m
iii	New mining activity (flow-on impact)	No	Economic	-
iv	Reduced emissions	Yes	Environmental	$0.05m
v	Externalities on other sectors (e.g. meteorology, environmental sector, fisheries, etc.)	No	Economic/Social /Environmental	-
	TOTAL			**$493.9m**
	TOTAL ATTRIBUTABLE TO CSIRO (90%)			**$444.5m**

Note: Monetary values are presented in 2013 $AUD.

Risks and uncertainties

Estimates are surrounded by a significant degree of uncertainty. Some of the most significant risks and issues affecting the impact estimates are outlined below. They include variations to the assumptions around:

- Market penetration and reduction in exploration costs at maturity (both estimates were provided by CSIRO based on long-term targets);
- Share of gold discoveries in which CSIRO research has been used (the current estimate is based on CSIRO assumptions);
- Benefits being brought forward by five years (the current estimate is based on CSIRO assumptions); and
- Attribution (the current estimate does not take into account all other inputs required to realise the impacts).

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Appendix A: Evaluation framework

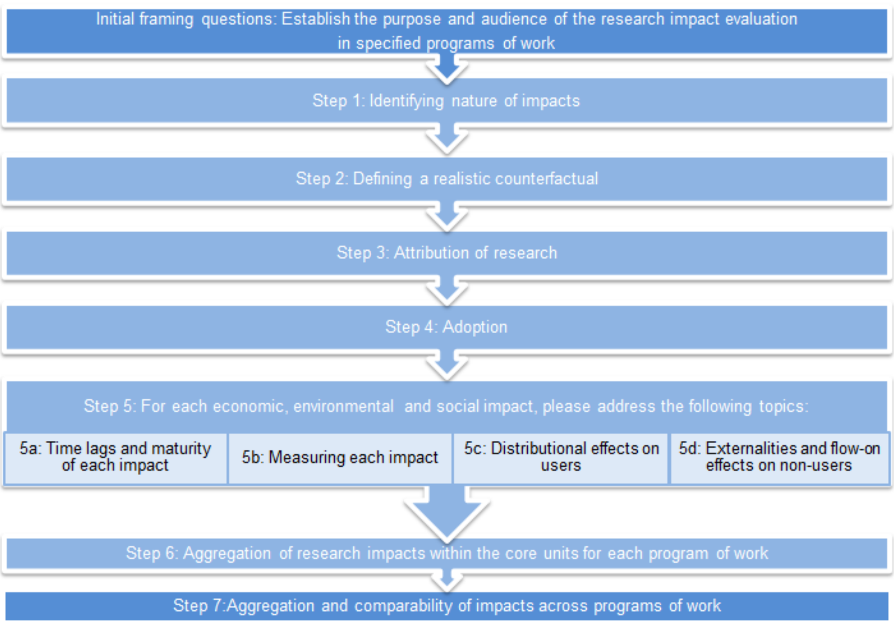
Ex-post impact evaluation framework

In order to comprehensively and consistently evaluate research impacts, and taking into account CSIRO's methodological challenges, DAE developed a framework that consists of the following four groups of steps:

- **Initial framing – Purpose and audience of the impact evaluation**: The starting point is to identify the primary purpose and audience of the ex-post impact evaluation. This needs to be clarified early on as it will determine the most appropriate methodologies and the types of impacts to focus on.
- **Steps 1-4 – Status of research and adoption**: These steps are used to identify the nature of the main impacts from the research being evaluated and the status of adoption.
- **Step 5 – Assessment of the impacts**: This step quantifies and estimates impacts in monetary terms, where possible.
- **Steps 6-7 – Aggregation of research impacts and comparability**: These steps aggregate diverse impacts from individual programs of works to a single evaluation measure or indicator when appropriate.

The four parts, which consist of the seven more detailed evaluation steps as outlined in Figure A.1, comprise the framework structure [and are explained in more detail in Deloitte Access Economics *Decision making framework for ex-post impact evaluation of CSIRO's research impact – Stage 1* (DAE, 2013).

Figure A.1: Steps in the ex-post research impact evaluation framework



To ensure a consistent understanding of the framework and its application, this section outlines a number of key considerations underpinning the evaluation framework.

What does 'ex-post' mean in the context of the framework?

An ***ex-post*** evaluation refers to the assessment of a program of research, such as of an individual flagship, theme, or a group of individual projects, after it has occurred. As such, an '***ex-post research impact evaluation'*** refers to the evaluation of the impact attributable to a program of research after the research has been completed and outputs have occurred. In order to be ex-post, while research has to be complete, adoption may be incomplete and some impacts may be still be in the future. Ex-post impact evaluation contrasts with 'ex-ante impact evaluation', which refers to the evaluation of prospective impacts and is undertaken before the research has produced outputs.

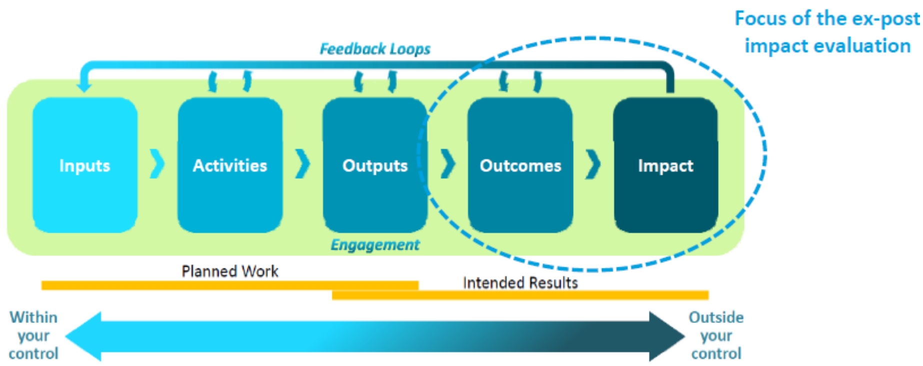
What are 'impacts' in the context of this framework?

In an ex-post impact evaluation of research, CSIRO (2013) has defined **impact** as:

> *An effect on, change or benefit to the economy, society or environment, beyond those contributions to academic knowledge. Impact includes, but is not limited to an effect on, change or benefit to the activity, attitude, awareness, behaviour, capacity, opportunity, performance, policy, practice, process or understanding of an audience, beneficiary, community, constituency, organisation or individuals in any geographic location whether locally, regionally, nationally or internationally. Impact also includes the reduction, avoidance or prevention of harm, risk, cost or other negative effects.*

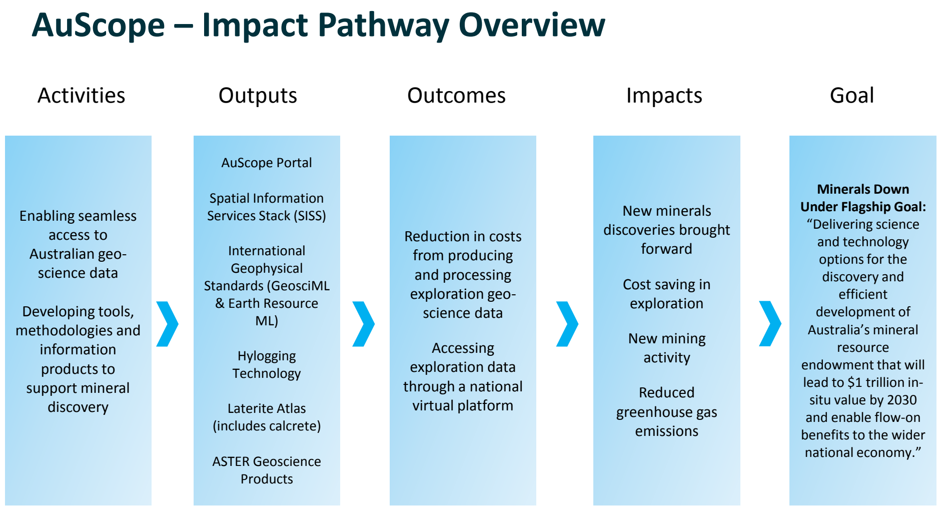
An impact is typically an external effect or change beyond the organisation that produced it. It is the culmination of the CSIRO's impact pathway, as illustrated in Figure A.2.

Figure A.2: CSIRO's Impact Pathway



An Impact Pathway diagrams for the AuScope impact case study is provided below. It illustrates the process by which planned research work translate into tangible outcomes and impacts to society.

Figure A.3: CSIRO's Impact Pathway for the AuScope case study



What types of impacts are being evaluated under the framework?

The ex-post impact evaluation framework guides the evaluation of the effects, changes or benefits generated by completed research to the economy, society and the environment. It includes the **valuation of realised and projected economic, social and environmental impacts**. It excludes the valuation of potential impacts that cannot yet be expected or realistically projected, as well as the valuation of other research aspects such as research quality.

Stage 1 of the project presented the following definitions for economic, social and environmental impacts in line with latest GRI Performance Indicators (2011):

- **Economic impacts**: Economic impacts are impacts on an economic system at a local, national or global level such as changes in revenue, operating costs, profitability, gross domestic product (GDP), employment or investment returns.
- **Social impacts**: Social impact refers to how an activity affects the surrounding community. This includes impacts on health, community engagement, skills and labour practices.
- **Environmental impacts**: Environmental impacts are impacts on living and non-living natural systems, including ecosystems, land, air and water.

What is being evaluated?

Research at CSIRO is organised in a matrix in which groups, programs or divisions provide research capabilities to address research priorities defined in national flagships. Research projects are the smallest component within research portfolios, however most single projects are unlikely to lead to an impact in their own right. For this reason, the core unit of research evaluation for CSIRO is a **'program of works'**, which refers to related activities in a portfolio of research activity leading to the one outcome. A program of works encompass entire themes or flagships, group of projects, or those programs of work whose planned impact is summarised in Impact Statements (DAE, 2013; CSIRO, 2013).

Limitation of our work

General use restriction

The report has been prepared at the request of CSIRO for the purpose of demonstrating the value of CSIRO’s research through ex-post impact evaluation. This report may be released into the public domain, but we accept no duty of care to any other person or entity who chooses to rely on this report other than CSIRO.

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