Chapters only for

Assessment of CSIRO Impact & Value

Report prepared as input to
CSIRO's Lapsing Program Review

Prepared for CSIRO

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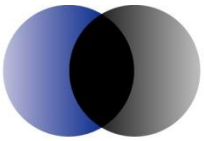

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Purpose & approach

Review focused on whole-of-CSIRO impact & value

This report is designed to provide an overview of the processes through which CSIRO has impact and creates value for the Australian community, along with some credible indicators of the scale of its impact and value. It seeks to build an understanding of the value supported by the organisation as a whole – as a technical input to the Lapsing Program Review process. This has been done through a combination of

Case studies & vignettes

- Probing of a range of CSIRO initiatives to demonstrate forms of value and the various ways that CSIRO complements Australia's overall innovation capability. This probing has led to a number of specific indicators of value and impact, and a better understanding of how these values are likely to evolve over time.

Update of past studies

- Briefly reviewing a number of the assessments and case studies done as part of our earlier assessment of CSIRO impact and value (ACIL Tasman, 2006), providing a longitudinal dimension to the current assessment.

Collective value in capability, systems etc

- Taking a higher level, whole of CSIRO, view of the ways in which CSIRO brings value to the whole system, including consideration of culture and incentives, breadth and depth of capability, including responsiveness and leadership, track record and forward prospects.
- Drawing from these elements, some conclusions about overall value and impact have been inferred – especially about overall CSIRO impact and value relative to overall CSIRO costs.

We used and extended the approach utilised in our 2006 review, but with a stronger emphasis on the factors driving the value of CSIRO as a whole. This approach has included emphasis on CSIRO as an integrated entity offering a flow of R&D services while building and maintaining a high quality, broad and deep capability to respond to emerging questions. There was also more scope than in 2006 to consider actual 'runs on the board' ranging from proof of concept out to active implementation and commercialisation.

Basis for CSIRO's contribution to value

Value added to national innovation capability

CSIRO's value has been approached as an addition to national innovation capability that fills gaps, adds critical mass and leadership, and in particular that brings a capacity for highly responsive, mission-oriented research and policy and strategy advice in relation to national priorities. Economic, environmental and social values, including societal risk management, are all relevant targets for CSIRO work – and examples of all have emerged from the case studies.

CSIRO's value is viewed as lying in:

- the *flow of delivered research outcomes and research based advisory services*
- the *building and maintenance of potentially valuable research capabilities* (skills, research infrastructure, networks, databases and other collections)
- the *systems and internal cultures* that allow these capabilities to be managed to add value to Australia's innovation efforts

Case studies

Impact and value relative to aggressive counterfactual

A collection of case studies and vignettes was selected on the basis of their power to illustrate the range of value creation mechanisms in use across CSIRO and to provide some indicators of actual value. The activities probed range from modest stand-alone activities up to Flagships and prospects for growing cross-Flagship collaboration. Where dollar values were estimated, these were assessed relative to an aggressive counterfactual (the no CSIRO case) and in general excluded a range of plausible high value impacts. In this sense, the valuations were conservative – usually highly conservative.

Conservative case study value of $6 billion

That said, across the collection of case studies, we inferred a credibly conservative – that we believe to be highly conservative – valuation, in terms of realised benefits and serious forward options, of $6 billion. The figure should be viewed as a *lower bound on the present value* of the extra options delivered by CSIRO involvement across this subset of CSIRO activities – net of forward costs in implementing the options but not net of CSIRO's costs. This figure could be viewed as an underestimate of the value of the case studies, to be compared to the costs incurred.

The period over which that value is delivered varies depending upon the nature of the example and the counterfactual (the case where there is no CSIRO) considered as appropriate for each example. ACIL Tasman notes that some of this value is beginning to be realised now, other amounts have strong prospects for being realised in the near term, while others are necessarily longer term and in some cases relate as much to insurance against future risks as they do to guaranteed revenue streams.

Specific case study and vignette impacts and inferred values that underpin this $6 billion underestimate include:

- Climate Adaptation Flagship:
  - Top down assessment suggested contribution to reduction in Australia's costs of adapting to climate change, only across the period to 2030, of the order of $2 billion – plus other benefits and insurance;
  - As examples, 'bottom up' assessments suggested potential value of the order of $1 billion from climate-ready crops, of the order of $200

million for coastal communities through better planning and zoning and substantial value in relation to planning for increased bushfire risks.

- Prawn breeding and novel feed supplementation:
  - Value of delivered prawn yield increases by $430 million plus additional benefits from extending and diversifying the applications of the technology;
  - Novel feeds add further production value and could support useful royalty streams, export potential and displacement of some stress on wild harvest fisheries.
- Cement substitutes and novel products:
  - Plausibly conservative royalty streams of tens to hundreds of millions of dollars on niche products that can compete based on functional characteristics – underwriting research risks and offering substantial upside, even before accounting for GHG mitigation effects.
    - … Early position in potentially large overseas markets.
  - Strong options to support lower cost GHG mitigation strategies:
    - … With an indicative $50 million in value through advancing Australian access to the technology under a moderate carbon pricing regime, though plausibly much more;
    - … Plus potential to accelerate global mitigation through practical expansion and demonstration of low cost mitigation options that are relevant to a substantial proportion of current global emissions.
- Murray-Darling Basin Sustainable Yields Project:
  - Conservative $2.8 billion value linked to more efficient deployment and better risk management of the investment funds already committed to buyback and water infrastructure efficiencies.
- Resistant starch grains:
  - Present value, primarily via improved health outcomes for Australians, *very* conservatively assessed at about $100 million, and plausibly several times greater as capability is transferred to grains and crops other than barley and wheat;
  - + additional returns to agriculture and CSIRO royalty streams from new non-commodity cereal crops capable of commanding premiums in export markets.
- Titanium within Light Metals:
  - With commercial partnerships in place, revision of 2006 assessment of the opportunities for TiRO and product fabrication suggests significant strengthening above the earlier assessment of value of $275 million+

- The UltraBattery
  - Commercialisation in place for both automotive and stationary applications will support returns to CSIRO, though structure is commercially confidential.
    … Plausible revenue streams valued at tens of millions of dollars.
  - Substantial opportunities, within a small field of possibilities, to alter the early nature of moves into more fuel efficient hybrid vehicle fleets and to support more effective early use of renewables within the energy mix.
    … Plausibly large impacts via the social cost of carbon saved and improved incentives for global mitigation – further enhanced by implications for non-GHG pollutants and oil dependency.
- Mapping undersea mineral deposits
  - No quantified value developed within the vignette, but immediate cultural and policy value, and longer term potentially high value in supporting commercial exploration.
- Biochar
  - Not explicitly valued, but potentially very high value if the work leads to acceptance of certain applications of biochar for purposes of carbon accounting under international protocols.
    … Plausible role for biochar as a substantial contributor to lower cost abatement, given its complementarity with several aspects of farm production – with potential value of many billions of dollars under a carbon target policy.
- Radio astronomy and the SKA
  - High value for Australia if wanting to participant in big science projects, probing important science questions, in a cost effective way that plays to Australia's competitive advantages.
  - Indicative estimate of a conservative expected *tangible* value over the life of the project, well over $100 million – driven by the high prospects for the SKA being located in Australia and funded internationally.
- Cross-CSIRO climate work
  - Currently the subject of an active proposal for a major coordinated program of activities that could deliver very high value, but this value has not been explicitly quantified.

Extension to whole of CSIRO

In looking at wider CSIRO activities, we identified a substantial number of areas broadly analogous to some of the case studies – with high prospects for these activities adding very substantially to the value supported by the case studies and vignettes. We also noted high likely value in the forward planning

for the evolution of CSIRO – including increased collaboration across larger programs and the Transformational Capability Platform investments, which appear to align well with future capability demands.

This probing of where the case studies and vignettes fit relative to the whole of CSIRO supported a conclusion that the value of CSIRO's impact across the entire research portfolio is almost certainly some significant multiple of the value captured just by the case studies and vignettes – for which $6 billion was developed as a highly conservative estimate. The value created by recent CSIRO activities is likely therefore to be at least several tens of billions of dollars.

This value, relative to the counterfactual, needs to be compared to the costs incurred in deriving the value. CSIRO has drawn on decades of legacy and capability accumulation in creating this impact. There is a level of subjectivity in determining which costs are relevant for purposes of comparison. We have proceeded on the assumption that the purpose of the analysis is to contribute, alongside other commissioned work, to guiding decisions on forward funding – with a natural interest in whether recent outlays on extracting impact and value from the legacy and skills of CSIRO have been big enough to justify these recent costs.

Viewed in these terms, we concluded that the assessment of impact and value would most sensibly be compared to CSIRO costs over the past 3 to 5 years – with a broadly comparable present value of costs of the order of $5 billion. CSIRO costs are covered from a range of sources, with about half being appropriation funding, but all funding sources entail opportunity cost.

On this basis, we concluded that the value 'purchased' in recent years through CSIRO's research and advisory activities has almost certainly been several times the relevant costs – plausibly much more – and that the investment has robustly performed well.

Recommendations

Our assessment provides strong support for the mission-oriented, multidisciplinary and responsive model now being used across CSIRO. This model has strong synergies with the real options framework used in our assessment of CSIRO's value and impact. At an organisational level it appears that CSIRO plans very much with an eye to flexibility and responsiveness. However, we believe, based on our interactions with specific areas of CSIRO in the course of this project, that there is scope for carrying through this approach, and the type of options-based planning tools used in probing value, more deeply in program planning. This could deliver some significant improvements in flexibility and value for money.

Integrate options planning at an early stage "pre-project" to maximise flexibility

We have observed that in some areas CSIRO's flexibility in redirecting resources is more apparent as reactive than as proactive strategy. It is one thing to periodically assess new information and redirect resources in response. It is another to integrate options planning from the start. In other words when considering investing in a new research project we recommend that CSIRO look at ways of building and maintaining greater flexibility to respond, at low cost, to plausible new information.

We consider there is scope for more *proactive* planning, within Research Groups and Flagships

- There should be planning from the start for flexibility in R&D processes as well as outcomes. This approach will tend to favour choices of technology, capability and commitment to capital investment that are different from the natural strategies if the emphasis is only on reactive use of existing flexibility.
  - For example, in choosing between approaches that rely heavily on physical engineering or ICT, there might be a preference for the latter if it is seen as offering greater flexibility for change, and greater scope for serendipitous application, even if not nominally more prospective or lower cost.
- The various research areas appear good at creating flexibility in R&D outcomes, and at exercising available flexibility in R&D resource management.
  - But they are not necessarily ensuring that new projects and programs are designed to provide maximum flexibility in the first place; i.e. it is not clear that they are creating the optimal level of strategy flexibility.
- The case for a flexible strategy was made in our last review, but it is not clear that substantial progress, below the broader organisational level, has occurred.

Create a stronger emphasis on public good outcomes from research - even research that involves private funds

We believe that there is considerable scope at the "pre-project" stage to provide greater clarity and guidance on the nature of the "problem" to be solved. There is a role for Governments to invest in R&D because they:

- are direct users of the information delivered; and
- recognise limitations on an efficient level and mix of R&D being undertaken without this involvement (i.e market failure, and sometimes regulatory failure, exists).

The case for intervention when markets fail (or regulatory impediments limit market incentives and capacity to respond to opportunities) is well based, provided that the intervention does not do more harm than good. However, sometimes it is better to intervene by attacking the impediments rather than throwing R&D funds at the resultant gaps.

One of the problems with just directing money at market failures is that the very forces that have impeded the markets from making the investment in R&D can act to inhibit effective adoption and use of the R&D funded by governments to address the failure. This is not automatic, but it is a risk, and indeed a generic risk, to be managed when symptoms not causes are attacked. It is also a risk that has not been uncommon in the recent history of R&D support in CSIRO.

It should be recognised that sometimes there are conflicting and even confusing signals regarding the function of Government funded R&D activity. And questions arise on how to balance public against private good emphasis in work and funding. We recognise that the confusion entails perceptions of external as well as internal expectations, and links in part to the statutory functions of CSIRO.

We recommend that CSIRO place stronger emphasis on public good outcomes as the focus of planning. This can often involve engagement with private interest but as a means to that end – as a way to make the delivery of public good outcomes more cost effective.

Current perceptions within the organisation probably favour an excessive emphasis on commercial relative to public good outcomes. It should be clearly recognised that efforts by CSIRO to maximise commercial returns from its work can sometimes conflict with the success of the work in delivering greater public good outcomes – the primary rationale for CSIRO.

1 Purpose

Technical report for the LPR process, covering recent impact and value of CSIRO

This report has been prepared for CSIRO as an input to its current Lapsing Program Review and the forthcoming discussions leading up to a fresh round of quadrennial funding. These processes will be taking place in a tight Australian Government budgetary context. This report is one of several pieces of work that will be drawn on during this process, with a specific focus on impact and value – delivered and in prospect.

The report is designed to provide an overview of the processes through which CSIRO has had impact and continues to create value for the Australian community. The report also aims to provide some credible indicators of the scale of its impact and value. It must be stressed that our consideration of value did not involve a comprehensive trawling through all CSIRO's work. Instead our analysis seeks to build an understanding of the value supported by the organisation as a whole. This has been done through a combination of:

Case studies

- Probing of a range of CSIRO initiatives to demonstrate forms of value and the various ways that CSIRO complements Australia's overall innovation capability. This probing has led to a number of specific indicators of value and impact, and a better understanding of how these values are likely to evolve over time.

Earlier reviews

- Briefly reviewing a number of the assessments and case studies done as part of our earlier assessment of CSIRO impact and value (ACIL Tasman, 2006), providing a longitudinal dimension to the current assessment.

Mapping case studies to all CSIRO

- Taking a higher level, whole of CSIRO, view of the ways in which CSIRO brings value to the whole system, including consideration of culture and incentives, breadth and depth of capability, including responsiveness and leadership, track record and forward prospects.

Inferences about impact and value

- Drawing from these elements, some conclusions about overall value and impact have been inferred.

2 Introductory comments

CSIRO impact and value is complex and balanced cannot easily be achieved

Developing an assessment of the impact and value of CSIRO that is balanced and insightful is not easy. CSIRO is a large complex organisation, undertaking leading edge research in a range of areas that are inherently 'exciting' and where the research objectives in many cases are patently of high value. That is not the same as saying that CSIRO's research is of high value – though in many cases we concluded that it is. Risk is inherent in research. We recognise that research impact and value can be diminished by the research of others. Equally, the research of others can create opportunities to add value, through effective packaging and delivery and to create new value by exploiting scope as well as scale economies in collaboration.

This review builds on our earlier review

…and allows reassessment of CSIRO's actual research management

This is our second review of CSIRO's impact and value. This second chance to investigate CSIRO's contribution has afforded the opportunity to trace the development of what was, at the time of the last review, largely the promise of a new operating model with relatively little tangible value that could be tied to the new model. We have observed scaling back of once promising areas in at least one Flagship – very much in line with the options management processes we assumed and modeled at the time. This contraction by CSIRO was made in order to limit risks and waste, while seeing other areas within the same Flagship exceed expectations.

We have also seen new missions and strategies emerging – as external circumstances have changed or as the collection of capabilities available to attack issues more broadly have evolved to the point where this change in emphasis has made sense.

Care is needed to prevent case-by-case assessments leading to big opportunities being missed

Care is needed to ensure that Australia and the world does not argue its way into a series of 'social traps', in which each individual research organisation concludes that the risks are too great or that the rewards that could realistically be captured are too small to justify commitment to high value propositions. These issues are discussed further in Section 3 below.

Size & scope economies to limit risks

CSIRO's ability to bring size and scope economies to bear on priority issues clearly has potential to lessen some, but not all such risks of bias against high value opportunities. However, it may well be necessary for the external funding environment to also take heed of these risks in determining how to strike the right balance between support for research that, case by case makes investment sense, and support for research that plays to Australia's strengths in contributing to better global outcomes – with reliance on give and take across nations.

Global challenges

Many of the areas where CSIRO is operating are of global interest – though in most cases a national perspective has been emphasised. Furthermore, in some cases, such as GHG mitigation where there are global issues, Australia has a declared prominent position in relation to contribution and global influence.

Section 6.1 clearly shows that CSIRO has a role in these global innovation spaces – with a special emphasis on support for coordination in relation to research and research utilisation.

Implications for the assessment framework

The next section addresses several of these issues in more detail to provide a basis for taking these matters into account in our assessment. We note at the outset that a number of issues recur as themes throughout our assessment. We are aware, especially in the context of a less than deep and comprehensive review of all of CSIRO's activities, that assessing the balance of CSIRO's effort against impact and value needs to be approached with great caution. In our assessment we have tended to take a conservative approach, erring on the side of under estimating rather than over estimating impact and value. This approach has applied to the assessment of individual case studies and to the fact that the case studies considered barely scratch the surface of the wide portfolio of research activities currently being managed by CSIRO.

Review not focused on optimising the investment

Provided that CSIRO impact and value is large in relation to costs, this assessment of impact and value can be effective in reaching a robust conclusion about whether benefits exceed costs. However, we recognise that this approach can create risks of under assessment of value with the potential outcome resulting in under investment. Determining optimal investment levels for organisations such as CSIRO should not be based solely on treating conservative value estimates as actual values.

In pulling the story together, we have sought to provide additional balance as an offset to these risks of bias from a conservative analysis.

At the same time, of course, we do not want to suggest that an organisation delivering benefits in excess of costs is operating efficiently with every dollar spent. Marginal investment could well not be cost effective. On the other hand, funding limitations could be preventing very high value from being achieved from the next investment increment. This aspect of the efficiency of the investment through CSIRO has not been a focus of the present study.

Primary focus on *external* impact & value

It is also important to note that we have only undertaken a review of impact and value. This project is not a management consultancy review of performance against strategic objectives. We have certainly been interested in the alignment of CSIRO's work with national research priorities and innovation objectives, as external pointers to value potential and alignment with government objectives (which in turn links into CSIRO's statutory

function to support government processes). CSIRO's internally expressed objectives, that will continue to evolve over time, have not been central to our consideration. We have focused on what has been delivered and what is in prospect in terms of external impact and value.

Single value figures are potentially highly misleading

Finally, it is important to stress that value is not necessarily something that can be reduced to a single number, whether a dollar value or other quantified measure. CSIRO – and indeed the National Research and National Innovation priorities – are dealing with complex, multidimensional contributors to the things that communities value. Individuals, societies and political processes are perfectly capable of making judgments about value without quantification. We all see the costs of maintaining Australia's Defence capability – but it is not common to see the matching dollar value of benefit. There appears to be at least bipartisan support (though clearly not universal support) for the view that it is cost justifiable for Australia to maintain a substantial regional Defence capability – presumably delivering some mix of deterrence, response capability, capacity to support international peacekeeping initiatives, and general insurance for the community.

Similarly, attempts are made periodically to value education services, but these attempts are necessarily highly limited and most people develop a strong position on education expenditure without ever focusing on a single value estimate.

In this context, many Government departments spend years managing 'policy' without ever developing measures of the value of these policy services. This does not mean they do not have to account for what they deliver – but it recognises that a level of judgment is needed based on a range of indicators that relate to things of value to society.

It would not do justice to the range of services offered by CSIRO, in its contribution to overall R&D and innovation capacity, if the focus were on a single number. We have sought here to give a feel for the range of impacts and associated values involved, along with selective pointers to credible (and generally conservative) estimates of the dollar value of *some* of these elements.

Again, we stress that a sound investment strategy cannot be based on these value indicators alone – this would imply substantial downwards bias in the level of resources committed plus there could be bias in the way in which those resources are deployed. What these dollar valuations can do is indicate a lower bound on the level of 'financial underwriting' implicit in the CSIRO investment portfolio, via the subset of value propositions that can be discussed in relation to the costs of financing CSIRO.

3 Balanced assessing of R&D

3.1 Conservatism vs optimism

Developing a balanced assessment of the impact and value, even of a relatively straightforward and focused research program, is difficult. Even research that has already appeared to 'hit a brick wall' often retains latent insights and capabilities that add to the store of future opportunities[1]. In other cases, delivered benefits can take years and even decades to emerge.

Any approach to assessing appropriate levels and forms of future investment that focuses *only* on impacts and associated value that has already been delivered and 'banked' will necessarily be seriously biased downwards. . That said, if the R&D environment had been stable for many years, past performance – with more scope for identifying later impact and value – could have been relied on more heavily to reduce this bias.

Cannot safely rely on extended past performance to represent recent value and impact

In CSIRO's case, there is certainly a long and proud history of impact and value. However, this impact and value was largely delivered under operating models that differ in substantial ways from the current model, which focuses on Flagships, Transformational Capability Platforms and a large portfolio, mission-focused operating model. This changing focus in CSIRO's approach and management limits the scope for relying heavily on past experience and 'banked' value to demonstrate the likely value for future investments. Importantly CSIRO's major change in direction could certainly introduce bias in assessing the value of the current operating model from only understanding the value of 'banked' impact.

R&D commonly offers 'insurance'

In is important to understand that research and innovation capability can also have high value as insurance against changing circumstances. New risks and opportunities can emerge, where the capacity for rapid response can have high value. This capacity can radically affect the flexibility of a society to respond rapidly to a major problem by ensuring there is access to:

- Capability
- Technologies, models and information 'on the shelf', waiting for the demand to emerge,

[1] We have encountered examples of this within this study – such as in the withdrawal of CSIRO from much of its aluminium-focused work within the Light Metals Flagship (because of a shift in industry commitment) only to find new opportunities, in collaboration with a range of Australian SMEs, for the technical capabilities in cathode technologies that had been assembled. At the same time, elements of the aluminium-linked IP have been secured for possible future dusting off.

- Access to 'built' scientific infrastructure and collections.

In the course of this assessment, we have looked at CSIRO contributions to each of these elements of societal capability to deal with uncertainty.

Tempting to overstate value

Conversely, it is relatively easy to get quite bullish about 'exciting' R&D, addressing big problems and opportunities. However, we recognise that history does strongly suggest substantial caution. We acknowledge that while innovation has driven 'progress' across most areas of human activity for millennia, the 'successful' innovations have often come from unexpected, even serendipitous, sources.

A high proportion of R&D fails to deliver on its science objectives, while an even higher proportion fails to make it through to market and to the realisation of the value that drove the R&D in the first place. However, this is in the nature of R&D. If all R&D investment delivered the outcomes as planned, we could confidently conclude that there is nowhere near enough investment occurring in R&D. Indeed, the R&D being done might sensibly be reassessed as not really being R&D.

Risk and serendipitous value are inherent in R&D

In fact risk and uncertainty is inherent in R&D – as are the possibilities for reward and, arguably, the prospects for spotting unexpected opportunities. R&D and innovation are no more 'sausage factories' than is oil exploration. Efficient levels of investment in oil exploration – given demand – involves a high proportion of preliminary geological assessments that proceed no further and of high cost exploration wells that do not result in commercial discoveries. Efficient levels of investment in R&D must have a level of 'failure' or high value opportunities will be missed where it would have been cost justifiable to go after them.

Valuable research can fail to meet objectives…

Of course, failure relative to original objectives does not mean the investment is wasted – it will generally have built knowledge and skills and may well have led to new insights. Serendipity is a key element in research value and impact – and many high value innovations have emerged as serendipitous by-products of research directed at other questions and indeed research that had not dreamt of these serendipitous opportunities[2].

…and good R&D can be under-used

Good R&D, and even the best technologies, often fail to get commercial traction or 'efficient' levels of take-up. This is often for reasons that have more

[2] Attachment O includes a brief discussion of one such serendipitous outcome – the development of an integrated chip to help a CSIRO radio astronomy search (unsuccessfully) for black holes, but that proved an ideal solution to the emerging task of developing fast wireless networking. Both problems had a similar need – capacity for very fast separation of a small signal from a lot of noise.

to do with the commercialisation processes or the control of IP than with the inherent merits of the research and technologies.

As discussed previously, where the problems are big, there is a good chance that there will be multiple players looking for solutions. This can and commonly does limit the likely value added by any one contributor, irrespective of the science merits of the work being done. They may be 'beaten to the prize' but, even if first to market, the additional social value of the work can be greatly reduced by the counterfactual – by a world that would plausibly have had substitute technologies not much later.

Of course, care is needed here. If every innovator concludes their chances are too small to make a big difference even though the potential prize is big, this could instead lead to the prize never being attained. If the benefits are all private and capable of being captured by the successful innovator, this need not be a big problem. As we discuss later, if there is market failure and/or the benefits are substantially public – in relation to global GHG mitigation, to protection of ecosystems, to technologies where control of IP is difficult, etc – there are risks of underinvestment that may justify an intervention.

This type of reasoning could be seen to involve a potential 'social trap' in which there is systematic underinvestment – narrowly based assessment of value by multiple players allows a big opportunity to be missed. These circumstances are, of course, the very conditions in which government support for R&D is seen as least controversial. We discuss later the extension of this reasoning to attacks on global problems where there are global spillovers – and here there is the added risk of governments individually looking at innovation from a national perspective and collectively under-investing in R&D and innovation of very high global value.

Range of global spillovers

Risks of climate change have, of course, brought a special focus on global spillovers (and the Australian Government has taken a high profile in addressing these concerns). However, analogous global as well as national spillovers have been around a lot longer – in relation to water management, wild fishery management, acid rain risks etc.

It is appropriate to bring a level of skepticism to any probing of R&D value. Equally though, it is dangerous if this leads to a level of pessimism about prospects that is excessive and that would tend to support underinvestment. One of the key problems does lie with attribution – it can be difficult or even impossible to fairly attribute success.

This difficulty flows from several interacting factors:

- The way that each generation of scientists 'stands on the shoulders of giants';

- The high levels of collaboration involved across research organisations;
- The often crucial role of local adaptation of innovations whose fundamentals were developed elsewhere; and
- Because the value of innovation often depends, almost perversely, on having a range of substitutable technologies emerge fast enough to allow the cost or productivity advantages to be passed through to society as a whole, rather than being captured as monopoly rents that limit take-up.
  - A high value technology without substitutes is likely to be priced well above costs and to limit demand and take-up as part of a rationale strategy to capture as much value as possible, but in doing so limiting the total value delivered.

3.2 Value of sustained Australian innovation

Against this background, and before plunging into a detailed consideration of CSIRO's recent activities, it may be helpful to look at some of the impact of *sustained Australian innovation in agriculture* to address a background trend that would be seriously damaging in the absence of innovative responses. In this Section we look at trends in agricultural costs and prices. We stress that this discussion is only to illustrate a wider proposition – that *sustained R&D can make a big difference to the costs and benefits associated with forward trends in threats and opportunities*. This includes a range of trends that are the focus of current CSIRO work, as is discussed below.

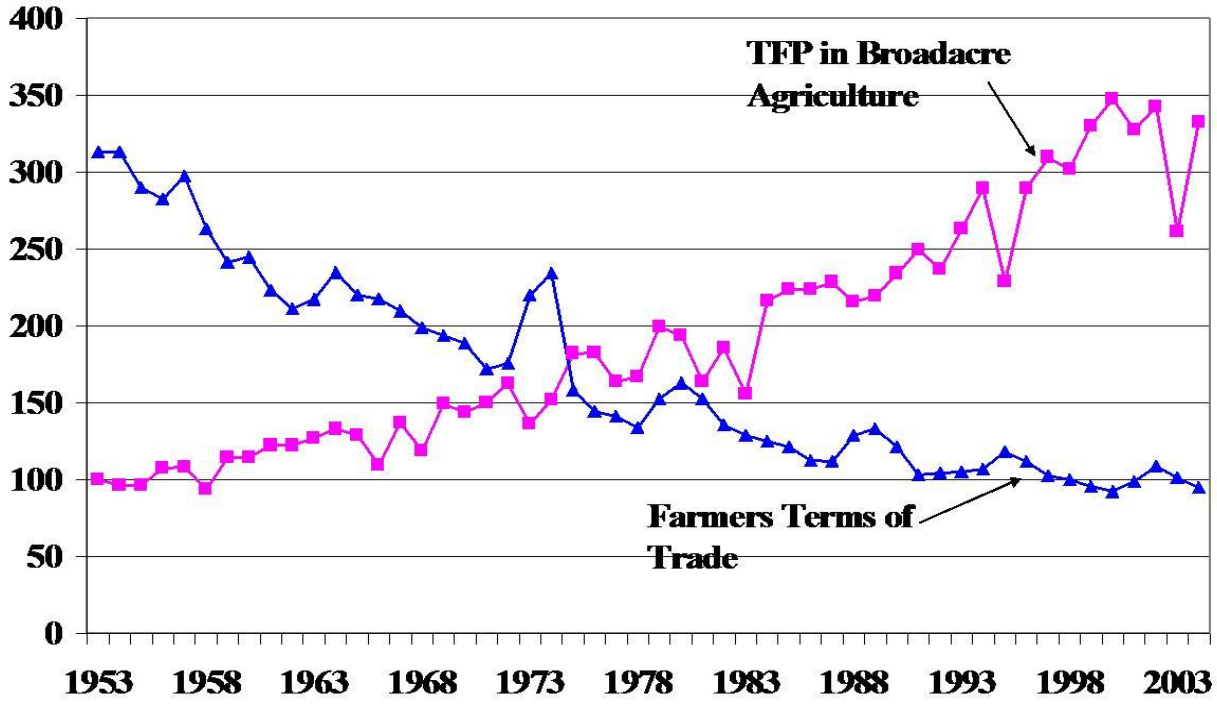
Agriculture has faced sustained threats

Australian agriculture is strongly export focused, supplying into world markets that are highly competitive, if also substantially distorted in the way these markets operate. Australian and international suppliers into these markets have, for many decades, been highly innovative in developing lower cost and more productive farm systems and in adapting product mixes to evolving demands and regulations (including the development of new products to meet emerging demands). CSIRO research over many years has been a contributor to this innovation. The beneficiaries of these processes have been consumers of food and fibre, as the innovation has supported largely price-based competition that has lowered the effective cost of many products.

Localised innovation has been crucial

However, agriculture relies very heavily on country- and region-specific innovation that recognises the character of soils and rainfall, the nature of transport and processing infrastructure and the nature of labour markets, and that can respond to evolving local regulation to address concerns from food safety, through waste management to sustainability. Local innovation can also allow the evolution of regulations to occur in ways that entail less conflict between demands for food, fibre and the environment.

Chart 1 **Australian agriculture: trends in terms of trade and total factor productivity**

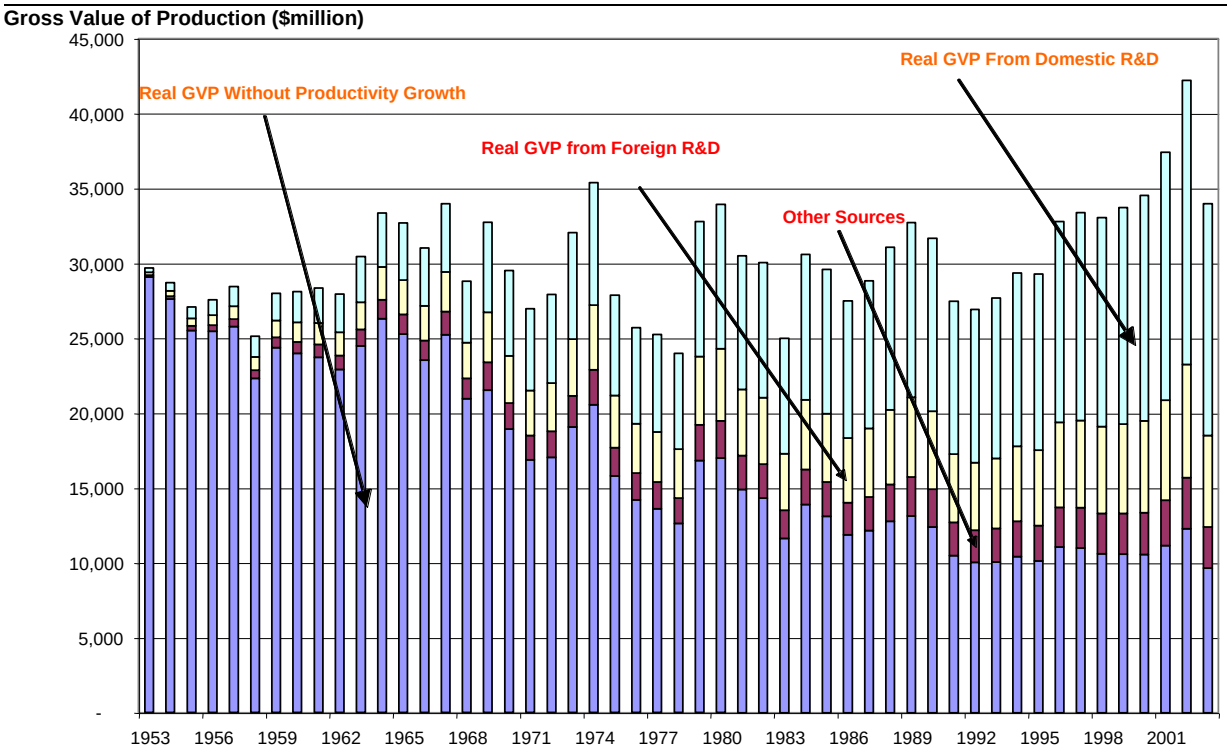


Source: Mullen (2007), based on ABARE analysis

Chart 1 plots the history of Australian agricultural terms of trade since 1953. The terms of trade effectively measure the ratio of agricultural output prices relative to the price (not the cost) of inputs. If farm commodity prices fall, or if the price per unit paid for inputs rises, then the terms of trade falls. If an Australian farmer had maintained a stable production system – same input and output mix) – since 1953, the farm sector's ratio of returns to costs would have fallen by more than two thirds over the 50 year period. Of course, long before this happened, the farm would have ceased to be viable and agricultural production would have shrunk dramatically.

In fact, the opposite has occurred. Chart 1 also shows the trend in total factor productivity (TFP). This is a complex economic measure of success in adapting the production patterns to limit the damage from any such trends and to exploit opportunities for increasing technical as well as economic efficiency. It is not a simple partial measure of productivity – tonnes per hectare etc. It is essentially a measure of the delivered capacity to offset the decline in terms of trade, or otherwise to deliver financial performance greater than would otherwise have occurred.

Chart 2 **Impact of TFP on offsetting damage: attributed to source of innovation**



Source: Mullen (##Mark to provide)

The productivity trend is striking. As the terms of trade were falling by two thirds, TFP was trebling. Of course the events were not entirely independent, but the terms of trade effect is tied very strongly to overseas commodity markets and the need to compete with increasingly productive agriculture (or subsidised production) from other countries. The terms of trade pattern largely reflected a sustained threat to the competitiveness of Australian agriculture, while the TFP patterns shows a sustained innovation response.

The combined effect is shown in Chart 2.

The real gross value of farm production actually rose, as the terms of trade pressures were more than offset by improved productivity which allowed Australian agriculture to compete effectively (the chart also shows the encroaching effects of the drought in 2003 – which is relevant to our later consideration of current CSIRO work in developing crops more capable of dealing with climate change or, of course, climate cycles).

Australian innovation provided most of the offset…

Importantly the chart also provides an indication of the sources of the innovation that allowed this response to occur. Not surprisingly, there was a mix of taking up overseas innovations (better tractors etc) and local Australian

R&D, including of course, the adaptation of some overseas innovations to Australian conditions.

...with CSIRO being a key contributor

Our 2006 assessment included the example of CSIRO playing a major role in localising an overseas developed cotton seed innovation to deliver a cotton crop that requires dramatically lower levels of chemicals and substantially lower water. However, there have been numerous other individual initiatives that have added to this picture. It is no doubt correct to argue that given its history, CSIRO has been an important contributor to the mix of adaptations that lead to the picture in Chart 2. Some other notable examples that do little more than skim the surface of the work done across the period include:

- CSIRO's leadership role in the trialing and release of myxomatosis as a stunningly successful biological control for rabbits in the 1950s;
- Analogous work leading up to the use of calicivirus for renewed rabbit control from the 1980s – and a wide range of successes in addressing other environmental pests, such as control of salvinia weed in waterways;
- Development of an aphid-resistant lucerne in the 1980s, when Australian lucerne crops were seriously threatened;
- Substantial contributions to the systematic improvements in livestock and grain productivity through plant and animal breeding, farm system development and pest management;
- Major contributions leading to the use of dung beetles to control fly populations.
- Ongoing involvement from the earliest trials of low tillage agricultural methods in the trend into conservation agriculture that has supported substantial productivity trends in crops and soil retention and where the added value in greater retention of soil carbon has more recently been recognised.

The case study of APSIM also discusses a range of agricultural innovations where CSIRO has contributed over the past couple of decades.

Of course, the need for farm sector innovation continues – all the more so given threats of possibly rapidly changing climate conditions in some regions. CSIRO continues to play an active role in this area, as flagged above, and wider sustainability concerns that have recently been crystallized in the creation of the Sustainable Agriculture Flagship. While agriculture has shrunk in terms of its share of the Australian economy, this has been because of growth in other sectors, not because of shrinkage in agriculture. Agriculture's real value has risen across this period and of course it continues to sustain important regional economies and to supply much of Australia's demand for fresh foods.

However, we have included this discussion, not for what it says about agriculture, but for what it says about the potential of a sustained, evolving

program of R&D and other innovation activities to address sustained threats and, by analogy, a sustained flow of opportunities.

Analogous trends now relevant

Trend curves strikingly similar to the above terms of trade trend can be projected running forward in relation to such matters as:

Health & aging

- the health and productivity implications of lifestyle diseases and diseases of the aging, including diabetes and colorectal cancers – and increasingly of vector-based illnesses of humans and animals, such as exotic influenzas, hendra virus etc;

Climate change

- the trend impact, in the absence of effective mitigation and adaptation, of climate change on national income (something modeled in detail as part of the Garnaut Climate Change Review), health and lifestyle options;

Ecosystem threats

- prospects for a range of species and ecosystems, including wild harvest fisheries, lower Murray-Darling ecosystems.

None of these trends is likely to be suited to an easily derived one-off fix. Expectations are that systematic R&D and innovation, plus smarter regulation and policy (nationally and internationally) and altered community behaviour will all be contributors to offsetting the otherwise implied risks and damage. In each of these cases, there will be a need for localised options, reflecting the particular regional climates, demographics, soils, coastal threats, infrastructure and ecosystems. There is also likely to be a strong case for Australia continuing to play an active role in influencing international responses – playing to its areas of competitive advantage, including in R&D. Such a role has clearly been recognised by the Federal Government and is discussed further below.

What the above two charts do is show that it is credible for a sustained R&D approach to make a difference in these circumstances. What we seek to do in the following discussion is to build an understanding of the role CSIRO can and does play in making this difference even stronger.

4 Approach

2006 review was necessarily forward looking

As noted above, our last CSIRO impact review (ACIL Tasman, 2006) took place relatively early in the life of a major new business model, with a strong mission orientation', captured most prominently by the new Flagships. The last review was, as a result, substantially oriented to looking at the potential for value being created by the new business model, with only limited scope for citing 'runs on the board' that had emerged from the new model[3].

Different emphasis now

With substantially more time passed, and with the emergence of new Flagships, the Transformational Capability Platforms and with growing interest in the mechanisms for effective coordination across Flagships, portfolios and emerging research areas, we have shifted emphasis somewhat in the present review:

Value across CSIRO & through time

- We have focused more on the proposition that CSIRO's value lies heavily in the cross-organisational coordination arrangements, and the mechanisms through which its research activities and capability evolve over time.

More than the sum of its parts

  - In effect, we have probed the proposition that CSIRO is worth more than the sum of its parts, and that a balanced assessment of the value and impact of CSIRO must take into account these linkages, cross-sectionally and through time.
    - … In undertaking this analysis, care has been taken to ensure we have avoided double counting

Case studies as windows on all of CSIRO

  - While we have examined a range of case studies, they have been viewed as much as windows into the range of ways that CSIRO operates as a whole to create value, as they are examples of stand-alone research work.

More probing of realised value

- We have had more opportunity to probe hard examples of applied outcomes from CSIRO work under the current business model – including commercialisation and policy advice to Government.

CSIRO is a complex organisation charged with responsibility for delivering research and research services, and tapping research available from elsewhere, to deliver, through innovative approaches to threats and opportunities, value to

[3] That said, our assessment led to the conclusion that CSIRO was undertaking high value work in relation to a range of matters of real interest to the community, to industry and to Australia. Much of that value lay in expanding options to deal better with major external pressures – include concerns with climate change and policy responses, with developing public health threats, with natural resource management etc. The analysis developed the theme that CSIRO has a valuable role to play in helping the community to better manage the risks posed by these developments and concerns – prominently through support of government processes – alongside the roll out of commercially valuable IP.

Australian industry and the Australian community and to advance national objectives and government processes.

Multiple elements to the approach

Reflecting this situation, our assessment has involved a mix of:

- Examination of the structure of CSIRO and its operating model and the relationship of this to its functions.
- Careful probing of the mechanisms by which these operations could seek to deliver value, consistent with its functions.
- Assembling an understanding of the interplay between capability building and sustainment on the one hand, and on-going delivery of valuable outcomes on the other.
- Looking in some detail at a range of recent CSIRO activities, chosen as examples of broader CSIRO value propositions:
  - This has included a spread from individual projects through to Flagships and cross-Flagship collaboration.
  - It has involved research driven mainly by commercial opportunity through to research directed primarily at supporting better advice to government processes.
  - It has included probing the pathways by which the capabilities now being used have arrived at these current applications to show the mechanisms for value creation over time and to provide some basis for attaching value to the new capabilities emerging from current research activities.
- Revisiting and updating some of the assessments undertaken in our 2006 review.
- Looking, with *greater spread but less depth*, at the range of on-going activities.
  - This approach has provided a basis for making an assessment of the relevance of the insights gained from the probing of a subset of activities to inferences about the value and impact of CSIRO activity as a whole.
  - It has also provided a platform for assessing the wider range of opportunities for CSIRO as a whole to deliver value greater than the sum of its individual research activities:
    - … Diversity that allows for better management of organisational risks.
    - … Breadth of adaptable capability suited to addressing challenges in a rapidly changing global context.
    - … A culture strongly focused on practical solutions, and naturally oriented to the use of multidisciplinary teams and drawing on other research to deliver practical solutions.
- Looking at some of the challenges that arise in ensuring that the global and Australian responses to key threats involve appropriate investment in

technologies – and what this might imply for the value attached to some CSIRO work and capability.

- Looking for insights into ways things might be done better while focusing on providing a credible assessment of recent impact and value.

Options framework central to value concept…

As with the earlier assessment, we have taken the view that research and innovation investments are *appropriately and usefully viewed as investments in building a richer set of options for dealing with credible risks and opportunities*. This investment can involve creation of value and options more in the form of 'insurance' against major risks than firm delivery of tangible value. Some of this value is linked strongly into the structure of the total CSIRO investment portfolio.

…including insurance value

We argue strongly that a balanced assessment of impact and value would fail without adequately recognising the value of the options created in:

- new technologies;
- commercial partnerships;
- skills creation;
- insights into ways to take technologies further; and
- opportunities to attack new challenges.

Equally we recognise that, over time, these identified valuable options need to be able support a flow of 'realised' value sufficient to justify the ongoing costs associated with supporting CSIRO – though this value should include the value of reduced societal risks even where the risks have not played out.

A balance is needed, and we explore the thesis that CSIRO is capable of striking such a balance, with:

'Normal benefits 'underwriting' strategic research and capability

- an adequate flow of normal benefits to underwrite the costs of the research;
- the associated building and maintaining of capability;
- while the resultant options can include more transformational possibilities – in reducing major risks and/or opening new opportunities with major implications for Australia.

Extrapolation of lessons beyond the case studies

Using the case study findings and the understanding of CSIRO's wider activity we then seek to extract a coherent view of CSIRO's overall value and impact. We have not focused in detail on the comparison of case study costs to case study benefits. That is not the purpose of the case studies. It so happens that most of the case studies where we have probed lower bounds on plausible value have strongly suggested benefits that are well in excess of project direct costs. However, we have been more concerned with whether whole of CSIRO benefits exceed whole of CSIRO costs – and the primary function of the case studies has been to feed into an understanding of whole of CSIRO impact and value that can be related to whole of CSIRO costs.

Primary focus on the net forward value of the options delivered

Of course, CSIRO's costs are not the only costs involved. Taking innovations to market can be very costly. In looking at value, we have focused principally on value net of commercialisation and implementation costs – but not net of CSIRO costs. These values can then be compared to CSIRO costs to inform judgments about costs relative to benefit. They can also be viewed as indicators of the current net value of the options now in place as a result of CSIRO's work – as indicators of how much an informed community might reasonably be willing to pay to buy the realized value and the forward possibilities as is. This figure will be net of future implementation costs, but does not and should not include the past costs incurred by CSIRO. This is because we later account for CSIRO's costs in getting to this point – and essentially ask whether these forward values exceed the costs incurred in getting here.

It is important to recognise that royalty streams paid by commercial partners are net of such commercialisation/implementation costs – commercial agents agree to royalty payments on the basis of expecting to cover them out of surplus. The same can generally be said of improved policy advice, assuming the translation into different policy settings will need to weigh the higher costs associated with bringing CSIRO insights into the policy response. A number of the innovations considered appear to offer functional advantages sufficient to justify commercialisation, before counting public good effects, such as GHG mitigation in the absence of a carbon price. In these circumstances, the gross value of these public good benefits may be appropriate.

We could, with more time and budget, have carried out finer dissection, but given the purposes of the study and the inevitable uncertainties, and given the orders of magnitude of the numbers that have emerged, we believe this extension would have been over-engineering the analysis.

4.1 Value framework

Options approach, relative to counterfactual

As with our 2006 analysis for the previous review, we have approached this assessment using a framework that views the primary rationale for innovation investments as lying in the *options* they create – options to deliver valuable outcomes, to better manage serious risks and to build a pool of capability suited to the next generation of opportunities and threats. This framework requires that the conceptual possibilities be tempered by a sound appreciation of both the risks of failure and the nature of the competition that may both reduce the prospects for success and limit the value of success. This need is reflected in a strong emphasis on the nature of the counterfactual.

Need to recognise the value of flexibility

At the same time, this approach recognises that options carry rights (and often costs) to use new information without compelling their use. The valuation

approach that has been used supports attaching high value to flexibility to better manage risks of failure and the waste of resources. We find that CSIRO's structure and operating model is well-suited to:

- the exercise of flexibility, in testing possibilities but limiting commitment;
- making such commitment to invest conditional on the results of testing and
- diverting resources into more prospective areas and away from areas where prospects after testing are diminishing or costs are rising.

In practice, we are unaware of any other organisation with comparable strengths across these areas while sustaining the breadth and depth of capability that CSIRO has.

Flexibility is a feature of the operating model

This scope for active portfolio management, to allow opportunities to be pursued while limiting risks of excessive investments, is a feature of CSIRO's operating model that appears, both in principle and in terms of some of the empirical examples considered, to offer high value.

Value of risk reduction and insurance

Another feature of the options valuation approach, and an extension of the above points, is the emphasis it gives to the value of risk management and insurance. Classical investment paradigms tend to require that expected benefits exceed expected costs. Expressed in terms of societal utility, that requirement is reasonable. Expressed in terms of flows of benefits and costs under various scenarios that are risk weighted, it can entail some strange consequences. That principle would suggest that individuals insuring their cars and houses are being irrational – they are paying premiums calculated to exceed expected claims. People buy insurance because of attitudes to risk – and are willing to pay premiums for additional protection against extreme risks.

A lot of CSIRO's work can sensibly be viewed as entailing substantial insurance. It invests (along with others) in options that can limit downside risks. For example, and reflecting several of our case studies, CSIRO invests in:

- climate adaptation strategies to limit the risks of damage from major climate change that does occur, while also investing in options to more cheaply lower the risk of extreme climate change occurring in the first place;
- better understanding of the hydrology of the Murray-Darling Basin, to protect society against the risks of unintended damage in Basin planning and management, from the risks of failing to gain maximum value from the associated resources and communities, and in particular to ensure the large commitments of funds to the system over the next several years are not wasted;
- manufacturing technologies that could protect Australian industry against threats to competitiveness and/or that underpin threats to the value of

Australia's resources – while opening up opportunities in technology exports;

- public health strategies, especially linked to 'lifestyle' conditions that pose a growing threat for society in terms of both individual health and the costs of financing health care – such as diabetes and colorectal cancers.

Again, extra irons in the fire can be cost effective

Notably, CSIRO adds capacity into some of these areas even though, given the global attention these matters are receiving, the chances of CSIRO making a large difference are probably small – but by CSIRO contributing to the knowledge and understanding of the problem increases the prospects for some earlier successes, and the value associated with this is also potentially very large. As we argued in our last review, when dealing with large challenges, well-targeted additional 'irons in the fire' research, can have both low probability and high value.

We are confident, following our current assessment, that these processes are happening in CSIRO – and that, given the nature of CSIRO, Australian society is acquiring an increasingly valuable portfolio of options that align reasonably well with needs. This alone does not prove that the resources consumed by CSIRO are being used efficiently and that does require probing the nature, and where feasible, the scale, of the value being delivered.

For this, we have mainly looked to a subset of activities – ranging from Flagships and emerging coalitions of Flagships down to modest 'let's turn this rock over and see what is underneath' investigations to broaden future opportunities for innovation. Each area has been probed for the direct value propositions that it supports, but even more importantly for the insights offered into activity in CSIRO more generally. We have looked at how each area draws from options and value created in the past as well as how research draws across CSIRO in assembling capability applying it to priority research areas. We have also considered the opportunities it may be creating and supporting for future work by CSIRO. We have considered the external linkages, the pathways to implementation and, where appropriate, the commercialisation arrangements.

Assessment has not relied on a single value number

We have not attempted to collapse all valuations into a single number. For example, in a case study on geopolymers as low-emission cement substitutes we distinguish between:

- the commercial opportunities offered; and
- the value to national objectives in relation to climate change of delivering, earlier or more rapidly, a mitigation technology that could have wide application internationally;

- that might contribute, alongside Australia's substantial investments in areas such as carbon capture and storage, to improved international influence in negotiating global climate policy settings.

Both forms of value align clearly with CSIRO functions – but are very different in their nature. In this case at least they appear not to be competitive, with one exception.

Potential trade-off between commercial returns and public good value

Efforts by CSIRO to maximise commercial returns from its work can conflict with the success of the work in delivering greater public good outcomes. Pricing a geopolymer product to maximise royalty revenues – where the product has a level of 'monopoly position' in the market because of its functional characteristics, might limit the rate at which the GHG mitigation benefits of the technologies are realised, particularly global mitigation benefits. Similarly, high pricing might lower the prospects for these technologies contributing to a shift in global perceptions of the cost of mitigation and willingness to commit to stronger mitigation policies.

Publicly funded organisations commonly face this sort of trade off and it needs to be managed. That said, the Case studies below give good evidence of CSIRO being able to manage strategies in which commercial returns are actively pursued to hedge investment risks and especially to derive returns from overseas markets – while CSIRIO maintains a strong emphasis on the public drivers for the research.

5 Rationale for CSIRO funding

CSIRO's role and functions are specified under its Act, as set out in Attachment A, and the key provisions of which are summarised in Section 6.1. However, any assessment of the value of impact still needs to be aware of the broader reasons why government funds might be directed at R&D – recognising that the allocation funds to CSIRO, of the order of $700m per annum, are substantial.

Governments will sensibly spend on R&D, both:

- because they are direct users of the information delivered; and
- because they recognise limitations on an efficient level and mix of R&D being undertaken without this involvement.

The former rationale is fairly straightforward and uncontroversial. The case study of CSIRO support for the Murray-Darling Basin planning process (Attachment I) is a clear case in point. Australian Governments, through COAG, sought better information on which to base fundamental change to Basin planning and to support the more efficient deployment of the billions of dollars committed to address the economic, social and environmental challenges in the Basin.

Similar comments apply to a wide range of CSIRO work, including much of the Climate Adaptation Flagship's activity (Attachment E**Error! Reference source not found.**) and indeed to CSIRO's much wider Climate Strategy considered in the vignette covering all of CSIRO's climate-linked work (Attachment P). Governments have a need for better information and options in relation to GHG mitigation and costs, infrastructure readiness for plausible climate outcomes etc.

The latter rationale is always the difficult one. The case for intervention when markets fail (or regulatory impediments limit market incentives and capacity to respond to opportunities) is well based, provided that the intervention does not do more harm than good. However, this need not always be the case, and sometimes it is better to intervene by attacking the impediments rather than throwing money at their resultant gaps. In many cases, this argument will at best support government funding sufficient to span the gap, relying still on significant private sector incentive and willingness to take risk.

One of the problems with just directing money at market failures is that the very forces that have impeded the markets from making the investment in R&D can act to inhibit adoption and use of the R&D funded by governments to address the failure. This is not automatic, but it is a risk, and indeed a

generic risk, to be managed when symptoms not causes are attacked. It is also a risk that has not been uncommon in the recent history of R&D support.

Certainly a lot of CSIRO activity is being directed at problems where there are substantial spillover and public good elements.

6 What is CSIRO?

Our assessment of the impact and value of CSIRO is integrally tied into our understanding of the nature of CSIRO and how it complements national innovation capability. This is particularly true given our concern with additionality of CSIRO's impact and value – we have focused less on the value of the services being performed by CSIRO than on the extra value of innovation and policy advisory services that exist because of the operation of CSIRO. It is this contribution to overall value – principally value delivered to the Australian community – that must ultimately justify Government investment in CSIRO.

6.1 Formal nature & functions

Attachment A sets out details of the functions specified for CSIRO under its Act.

Notable in all this is that CSIRO is a statutory research organisation with some very specific features:

- It is charged with much more than doing research – while clearly set up as a research organisation, its own research activities are viewed as instruments, and not the only instruments available to CSIRO, for assisting industry and benefiting the community.
- Its own research is to be purpose driven – assisting industry, advancing the interests of the Australian community and supporting national objectives and Government processes.
- It has, as a primary purpose, the requirement to focus on the utilization of its research, and any other relevant research:
  - It has an explicit responsibility to network and integrate innovation solutions to real problems and challenges that are applicable to industry and national concerns and objectives – and to engage in processes that will assist with better utilization of the resultant capabilities.
  - Practically, this could be interpreted as *requiring* that it operate with the level of multidisciplinary research coordination, and engagement with industry and government strategy and policy processes, to ensure the delivery of impact and value.
  - Furthermore, it could reasonably be inferred that CSIRO is to have a particular focus on what might be viewed as national priorities – which more recently could be interpreted as close alignment with the National Research Priorities.
- There is no constraint on the fields of research in which it engages – only on its purpose and utilization.

6.2 Characterisation and operating model

With over 6,000 staff, spread across 16 research Divisions and 10 National Research Flagships, in 55 locations, and with an annual budget that exceeds $1.3 billion, CSIRO is a large research organisation even by international standards.

CSIRO differs from (and complements) the universities in ways that have proven of great significance to our review. However, CSIRO does perform very substantial and wide-ranging educational functions – from public education in science through to providing an environment in which almost 800 postgraduate students can engage in serious and largely impact-oriented research. This ties naturally into its function as discussed in Section 6.1 above (and especially functions d and e of Attachment A).

Box 1 sets out an indicative break-up of R&D funding sources against nature of organisation undertaking research – with CSIRO being included as a part of the "Australian Government" organisations in the bottom left.

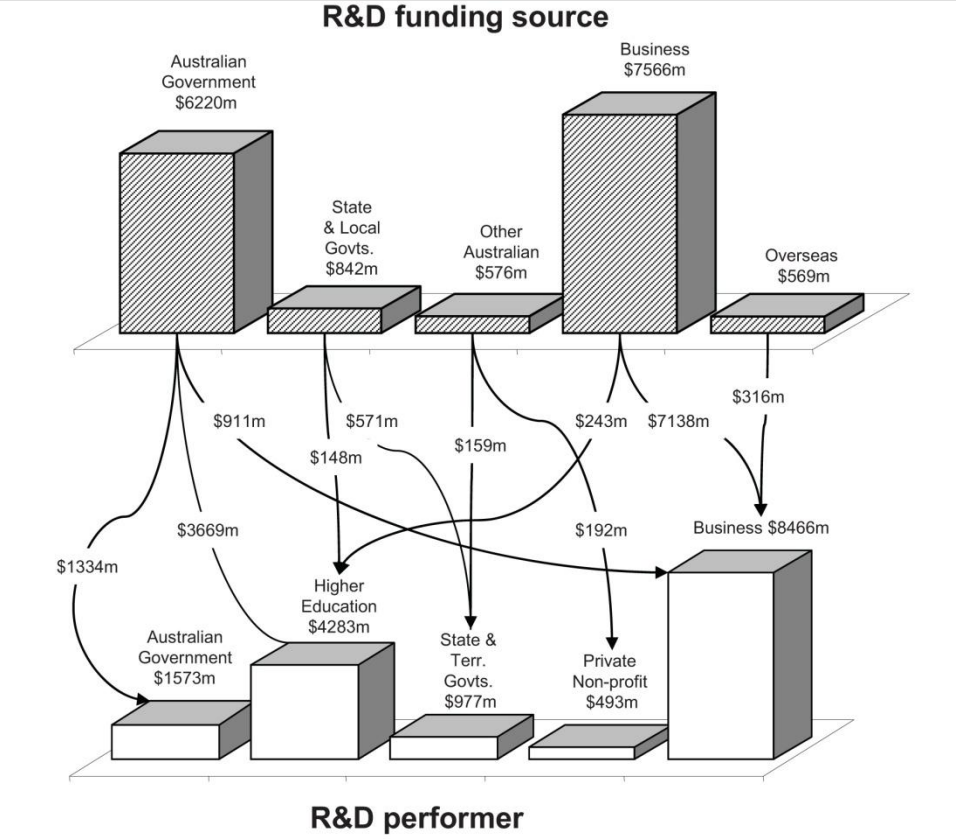
Within this context, it is important to recognise that CSIRO, while big relative to other R&D organisations, accounts for only a fraction of the funds and is small relative to collective Government expenditure on other research organisations.

While CSIRO is extremely diverse in the research it undertakes, it is a lot more focused than most higher education institutes and, as is discussed below, aligns very closely with National Research Priorities. This does suggest CSIRO is well placed to bring scale economies to some research efforts: through its own inherent scale (and capacity to focus) in particular priority areas, through its ability to coordinate research across multiple agencies and through its function requiring it to look to opportunities to support the effective utilization of all research. It also strongly suggests that CSIRO could add value by helping to plug strategic gaps that may exist in the R&D being done elsewhere and by bringing resources and skills to bear explicitly on packaging and delivering 'solutions' – through commercialisation, policy advisory services etc.

In broad terms, our review of CSIRO activities has strongly supported the view that CSIRO is committed to operating in this space – complementing the rest of the innovation system with particular emphasis on the focus on national research priorities and the delivery of practical innovation contributions to overall solutions.

The nature of the organisation has evolved very substantially since its formation – as has the nature of national concerns and priorities, and the character of Australian industry.

Box 1 **Indicative funding flows into Australian R&D, 2004-05**



[a] Only the major flows are shown and the sectoral descriptions are those of the ABS. 'Other Australian' includes non-profit agencies, individuals, and others. The data are as shown by the ABS, but with one major exception. The original ABS data were in line with the OECD Frascati manual, which is applied by the ABS. However, this excludes some important funding measures, in particular, funding provided through the R&D Tax Concession to the business sector. Accordingly data on government spending on the tax concession in 2004-05 (of $580 million) have been added to Commonwealth funding and removed from business sector funding. It is also important to note the large anomaly (about one billion dollars) between Australian Government funding of higher education shown above and in the budget papers (cf. table 12.1).

Data sources: ABS 2006c, *All Sector Summary Research And Experimental Development, Australia*, Cat. no. 8112.0, 11 October; Australian Government (2006d).

CSIRO, and indeed Federal research agencies collectively, attract only a small proportion of the dollars directed into R&D in Australia, where funding is dominated by business and where the bulk of Government funding is directed into higher education institutes. CSIRO is a large research organisation operating in an innovation system where there are very large numbers of other organisations (firms, universities etc) collectively accounting for most of the dollars but most of which are substantially smaller than CSIRO. Even amongst the Federal Government research agencies, CSIRO still accounts for a minority of the funding.

While the data underpinning the chart are a little dated, the picture remains broadly correct. Trends at the time the chart was prepared suggested a growing share of funds from business.

Source: Productivity Commission (2007), *Public Support for Science and Innovation*

Recent developments in CSIRO's operational model have increased the emphasis – in a manner that seems entirely consistent with the above formal functions and interpretation of its natural role in the innovation system – in several important ways:

- Very close alignment with the National Research Priorities, with CSIRO reporting that about 90 per cent of its total expenditure is directed at these priorities;
- A strong focus on large-scale, multidisciplinary, mission-oriented teams – most notably with the National Research Flagships, but extending into a substantially wider range of purpose-oriented collaborations across CSIRO as well as between CSIRO and outside organisations. This has involved:
  - More extensive, and increasingly hard-wired into the organisational structure, collaboration across Divisions and specialties, encouraging a culture in which such collaboration to support the creation of solutions to complex real problems is viewed as necessary, the norm and important.
  - The development of new skills within CSIRO where this adds to the flexibility to compose multidisciplinary teams with the right mix of skills and where this is seen as justified given current and plausible future demands for these services, and likely scope for external sourcing consistent with CSIRO's approach to 'king-hitting' major threats and opportunities.
  - A pervasive emphasis on *transformational capabilities*.
- A strong emphasis on implementation and utilization, through substantial investments in industry partnering, through commercialisation strategies and through deep engagement on support for policy processes, especially in relation to large-scale challenges for the nation.
  - CSIRO now holds over 3700 granted or pending patents and has 155 revenue-producing licenses over its IP.
- Strong emphasis on the balanced development of both directly applicable innovation solutions and the stewarding of capability to underpin future work of this kind – noting that these can commonly be complementary, especially in relation to the research infrastructure and complex skill sets emerging naturally from the operation of Flagships.
- Heavy engagement with the CRC Program, with its analogous, and largely complementary, emphasis on multidisciplinary approaches to the creation of (mainly) industry-relevant innovation.
  - CSIRO is a participant in well over half of all CRCs.
- A strong emphasis on stewarding research infrastructure – including hosting of three National research Facilities and managing eight National Biological Collections.

  - These are all legitimately seen as integral parts of Australia's innovation capability – and in all cases this infrastructure is accessible by researchers outside of CSIRO.
- While risk management has always been a central feature of investment strategy – and more generally of life – it is probably true that CSIRO has been, in part as a result of its alignment with National Research Priorities, increasingly focused on delivery to the community of a richer set of tools and options for better managing major risks.
  - In relation to climate projections, mitigation and adaptation, to river and groundwater management, to sustainable agriculture and fisheries, to management of growing public health risks linked to increased life expectancy and changing lifestyles, to strategies to maintain natural resource and industry competitiveness etc – CSIRO is focusing on delivering a better understanding of risks and opportunities, and a more diverse range of options for responding more effectively to these risks and opportunities.
  - In recent years community concerns and values have moved strongly into areas where there is massive uncertainty, including climate trends and ecosystems.

Of course, CSIRO has not been alone in moving in these broad directions. The research funding system in Australia strongly supports research organisations, CRC proponents etc to look at the alignment of their research activities with national priorities. The growth of Centres within universities as well as the evolution of the CRCs has encouraged more active multidisciplinary team creation and a strengthened focus on impact beyond the quality of the research.

However, we believe that CSIRO stands out for the scale and scope at which this has been done and shifted to the core of the organisation's operational model and culture – and for the diversity of capabilities that have been organised within the operational model, along with incentives and culture. The proposed Australian Integrated Carbon Assessment Service, as discussed in Attachment Q, provides a clear example of the scale and scope of related skills and experience that CSIRO is able to focus on an issue of national priority – scale and scope internally, as well as the extensive external links.

CSIRO has a more explicit function to extract value from the research of others than do other research organisations. It would be a mistake to underestimate the incentives that can exist to do this, even without an explicit function, but this function probably supports a culture more naturally oriented towards research coordination as part of mission focus than would be common elsewhere. Realistically though, this is a question of degree rather than sharp demarcation. However, CSIRO Flagship Collaboration Fund – an explicit mechanism spanning the portfolio, rather than individual incentives

within program areas – is an example of systemic commitment to collaboration in its research. The Collaboration Fund has recently been the subject of a broadly supportive effectiveness review (Review of CSIRO Flagship Collaboration Fund, CSIRO 2010).

CSIRO has long had a strong reputation for the quality of its science. One of the challenges in focusing more strongly on multidisciplinary approaches to attacking large problems and opportunities is that it might encourage a lowering of the standards of the science in favour of running down the discipline-specific science capital while drawing on the legacy of good science to support conversion to applicable innovations. It is even conceivable that some shift in this direction might be appropriate.

However, CSIRO has taken a position of guarding its quality standards while undertaking a substantial rebalancing of its culture and the emphasis in its work:

- CSIRO is ranked in the top 1 per cent of world scientific institutions in 14 of 22 research fields, based on Institute for Scientific Information data on citations as at July 2009.
- Across the 10-year period to May 2009, the average citation rate for CSIRO's research publications was well above the national and world averages and 33 per cent above the world averages.
  - In 2009, its citation rate was more than 24 per cent and 38 per cent higher than the Australian and world averages respectively. This pattern has been rising significantly in recent years.

We would expect this position, and the resultant reputational effects, to have assisted with the attraction and retention of high calibre professional staff, while also underpinning higher credibility in the work being done that pushes the boundaries of science.

Against this background, we believe that CSIRO can be usefully characterised as:

1. Building, maintaining and deploying multidisciplinary innovation capabilities within a mission-oriented culture.
   - This capability maintenance must strike a balance between current exploitation of existing capabilities and investment in future capabilities because of the value this can offer through expanded societal options.
2. Vertically coordinating its activities across several sections of the innovation cycle from early stage applied research through to commercialisation
3. Investing across multiple jurisdictions including industries, states and territories and national boundaries – involving strong networking with complementary organisations in Australia and internationally.

4. Investing, in research, research coordination, research capability and the application of research to strategy, funds drawn from a range of sources, including:
   - Commercial returns on past innovation work (royalties, dividends and sale of equity), and
   - Money sourced from industry and government agencies via a range of arrangements from consultancy fees through to commercial partnerships, but with approximately half of its total funds currently coming through Federal Government appropriation.

These appropriation funds provide the financial resourcing to attack innovation prospects that are otherwise constrained by various forms of market and regulatory failure. They also appropriately entail stringent accountability requirements.

None of this is intended to argue that CSIRO is 'better' than other elements in the innovation system but it does support the view that it is different. It implies that the overall 'portfolio' of national innovation capability is likely to be *different in shape as well as size* for the presence of CSIRO. This portfolio spans private and public sectors, universities, other research institutions etc.

Diversity and complementarity can bring great strength to a portfolio – adding robustness, better managing risks and allowing for cost effective pursuit of more (individually) high risk but high potential reward opportunities. We believe, based on our assessment, that CSIRO has brought strength to the national innovation portfolio.

In any case, a key purpose of CSIRO is, we assume, to add value to this national 'portfolio' of innovation capability – and presumably on the basis that it adds more value than it costs.

This is logically quite different from showing that the things CSIRO does are of high value – if there is the prospect that those things would be done anyway, even without CSIRO. We have tried to focus on the question of whether Australia is better off for CSIRO's presence – as opposed to whether Australia is better off for the work being done by CSIRO. As in our 2006 review, this has required careful consideration of the counterfactual – of what would have happened had CSIRO not been doing these things. The answer to this question rests strongly in the aspects of CSIRO that change the shape of Australia's innovation capability and the extent to which CSIRO has brought scale to the process that has substantially altered forward prospects. Our conclusion has been strongly that CSIRO's presence has had impact and value overall.

CSIRO's contribution of value to the national portfolio could come in one or more of several forms:

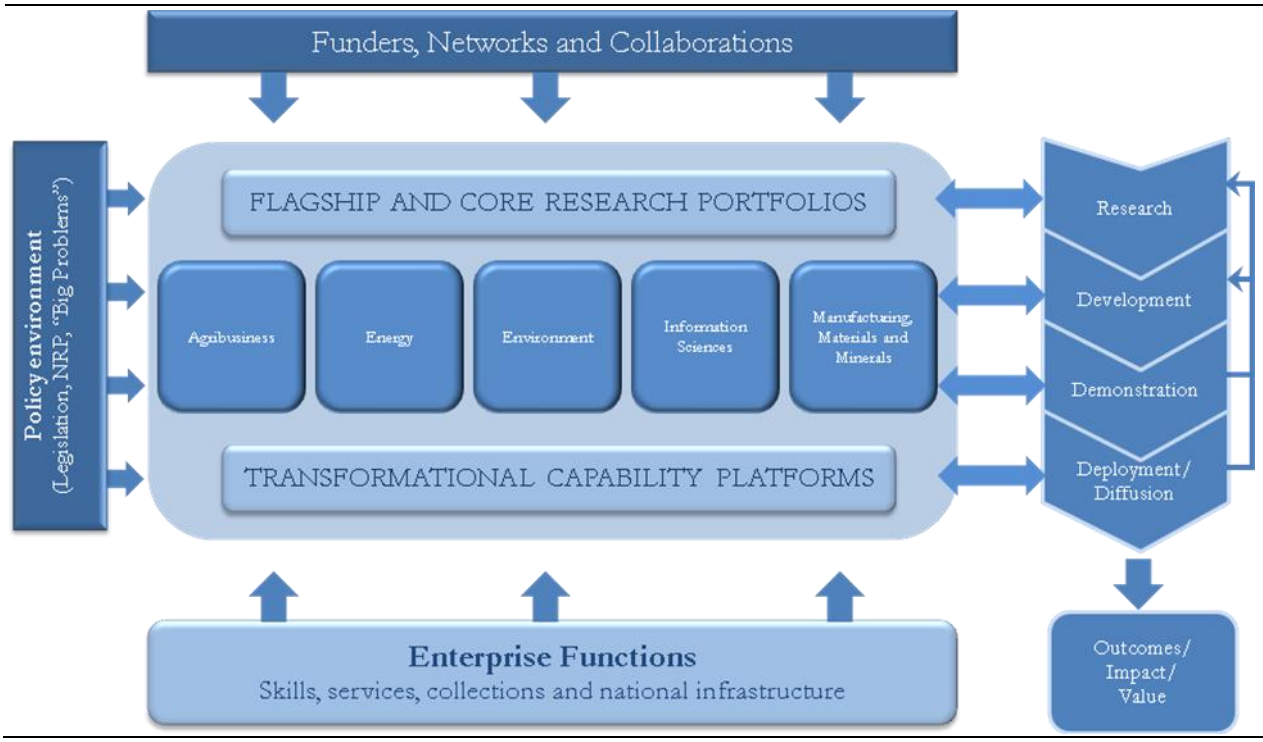
- CSIRO might offer fundamentally different capability to that which would otherwise be available – opening innovation possibilities that would otherwise be much weaker.
- CSIRO might offer capabilities analogous to those held elsewhere in the system, but by adding scale to the harnessing of those capabilities, improve the prospects for earlier and or better progress on potentially high value research and innovation prospects.
  - For large challenges and opportunities, it can be highly cost effective to add 'extra irons to the fire' if this substantially improves the prospects for a breakthrough.
- CSIRO might provide a cost effective platform for building and maintaining a range of capabilities of likely future value provided that they can be accessed and applied rapidly to emerging risks or opportunities.
  - The character of CSIRO may, in some areas, support better size and scope economies in relation to maintaining these capabilities, coupled with opportunities to offset capability maintenance costs through on-going useful purpose-oriented research work, along with the machinery for rapid redirection to emerging prospects.
- CSIRO might be able to provide research and innovation coordination functions, and mechanisms for feeding innovation occurring elsewhere more rapidly or appropriately into industry and government strategy.
  - This might stem from its multidisciplinary culture and mission-orientation – and its statutory role in supporting industry and government.

We have, in the course of this assessment, considered examples of all these forms of value adding.

These functions and the above characterisation provide, at a strategic level, a rationale for CSIRO's organisational structure and operating model – spanning dimensions of scale, scope, culture, incentives, linkages to wider capability and evolving strategy.

Figure 1 provides one overview of the operating model in a form that emphasises some of these key attributes.

Figure 1 **CSIRO's Operational model**



Source: ACIL Tasman

CSIRO operates in groups. Within these groups are divisions which are substantially delineated on the basis of their specific skills – though, even at this level, multidisciplinary approaches are common. Outcome driven multi-disciplinary research is undertaken across these groups through the core research portfolios and Flagships.

However, CSIRO is far from being a collection of research groups. CSIRO is strongly integrated vertically, horizontally *and through time*. The integration comes from:

1. Collecting capacity (human resources and services) from a range of specialist providers, and organising this capacity into research groups
2. This capacity is then coordinated through portfolios and Flagships.
3. The portfolios and Flagships coordinate CSIRO capacity in response to research priorities set by Government and other funders which also provides a 'path to market' either in the form of policy development and/or commercialisation.
4. Crucially though, CSIRO is also strongly integrated through time.
   - At any point in time, CSIRO is drawing on past research to attack current issues, while building capabilities to feed into future innovation activities.

- Both these activities have value and any attempt to weight CSIRO's impact and value by focusing only on one of these elements is prone to serious bias – that could in turn lead to poor investment decisions.

With the maturation of some of the Flagships, scope for coordination across Flagships is increasingly viable, is receiving increasing attention and offers a range of attractive value propositions.

Importantly, collaboration across Flagships is also becoming a normal feature of the operating model. For example, there are increasingly strong linkages across the Energy Transformed, Climate Adaptation, Food Futures and Sustainable Agriculture Flagships – both because of linkages across the science disciplines and linkages across key drivers of demand. At the same time each of these Flagships brings a specific focus on aspects of planning for change.

Underpinning this portfolio and Flagship activity is CSIRO's capability which includes its human capital, its collections and national infrastructure. The maintenance and management of this capacity is largely undertaken within the divisions of each research group.

6.2.1 Transformational capability platforms

To ensure that CSIRO's capabilities continue to be at the cutting edge, CSIRO implemented a multidisciplinary initiative known as **Transformational Capability Platforms** (TCPs). The ultimate aim of TCPs is to strengthen key cross-organisational groups of capabilities.

Currently there are four TCPs, namely:

- Transformational Biology – the aim of this platform is to be a catalyst for a step-change in CSIRO's biological capabilities by combining human, plant, and animal biology with genomics, phenomics and whole-of-system approaches.
  - The TCP is supporting the analysis of DNA, RNA, proteins and/or metabolites, with high performance computational facilities and expertise in bioinformatics, mathematics and (bio)statistics.
- Advanced Materials– the aim of this platform is to create programs that at a large scale combine physics, engineering, chemistry and biology in order to develop the materials of the future. The TCP is establishing improved capabilities in:
  - bio-mimetic materials and the intersection of nanotechnology and biotechnology
  - materials by design – computational and simulation science for design of materials
  - high throughput materials research to increase the rate of materials discovery and exploration of new compositional space. This includes

materials informatics and modelling as well as high throughput synthesis, screening and characterisation.

- Computational and Simulation Sciences – the aim of this platform is to enable a step-change growth in CSIRO's computation capabilities to accelerate delivery of next generation applications for industry and community. The TCP combines four distinct elements in computational science:
  - Scientific, engineering and humanities problems.
  - Algorithms (numerical and non-numerical) and modelling and simulation software developed to solve the problems.
  - Computer and information science that develops and optimises the advanced system hardware, software, networking, collaboration and data management components needed by teams to solve computationally demanding problems.
  - Infrastructure (computation, communication and data storage) that supports both the science and engineering problem solving and developmental computer and information science

- Sensors and Sensor Network Technologies – the aim of this platform is to stimulate multidisciplinary collaboration on a large scale to allow CSIRO to realise sensors and sensor applications vast potential. The TCP has an emphasis on sensor networks for environmental science and natural resource management. However, it is establishing links across all potentially relevant parts of CSIRO's activities. The TCP uses all five layers of sensor networks:
  - Components, especially sensors.
  - Devices
  - Networking (i.e. communicating systems of devices).
  - Data management and data fusion.
  - Information extraction and use (data mining, analysis and modelling).

It is intended that by directly investing in each TCP there will be a step change in CSIRO's research capabilities on a scale and scope that is beyond what is possible for any single Business Unit. With this in mind TCPs engage widely with multidisciplinary capabilities, with internal and external linkages, and with projects being undertaking across CSIRO to ensure capability development is guided by an understanding of scientific trends and their application to the current and emerging challenging problems and opportunities.

7 How does CSIRO add value?

CSIRO has a unique position within the Australian innovation system, involving elements of scale, breadth and depth – but also important aspects of organisational structure, infrastructure and personnel capability and incentives. These can be traced in part to its function – especially the strong emphasis on effective application of outcomes and the diversity of its brief – and to the operating model and research and communication culture that has since evolved.

CSIRO is now characterised by its mission orientation, its professed capacity to mobilise large-scale research attacks quickly, as demands arise, and its multidisciplinary organisation of teams, while maintaining excellence and international standing in relation to its science. It needs to be seen as far more than a collection of current projects and programs – with its key value drivers lying in the linkages across programs, skill areas and through time.

CSIRO's value lies in:

- the *flow of delivered research outcomes and research based advisory services*
- the *building and maintenance of potentially valuable research capabilities* (skills, research infrastructure, networks, databases and other collections)
- the *systems and internal cultures* that allow these capabilities to be managed to add value to Australia's innovation efforts;
  - This includes value added directly through R&D delivered by CSIRO, but also the impact and value flowing from CSIRO's leadership and catalytic roles in encouraging focused collaboration and the extraction of value and use from research being undertaken elsewhere.

These three dimensions interact strongly, and mean that a balanced assessment of CSIRO's value cannot be done simply through a case-by-case exploration of the impact of individual initiatives.

The first two are almost self-evident and requirements of CSIRO's functions. The third is more empirical in nature, and might reasonably be viewed as a key focus of our review. To what extent has CSIRO developed and now maintains the systems and internal cultures that allow these capabilities to be managed to add value to Australia's innovation efforts?

The next section sets out the rationale used in selecting the case studies – and stresses the key role seen for the case studies in illustrating these systems and cultures in action.

8 Selection of case studies

Our original brief called for a relatively small number of cases studies to be done in depth. Following discussions with the client, it was agreed that it would be preferable to introduce greater breadth to the case studies even though, within time and budget constraints, this would mean somewhat less depth, at least on average. We felt that more case studies were needed to credibly establish the main elements of the impact and value propositions.

This was in part because of our view that the case studies needed to do much more than demonstrate the value and impact of the specific areas of focus of the case studies themselves. Case studies were selected to illustrate ways in which CSIRO was seeking to have impact and in general we sought case studies that could illustrate multiple mechanisms, building to a firmer understanding of CSIRO as a whole and as more than the sum of its individual programs.

Case studies ranged from full Flagships, and indeed a consideration of cross-Flagship work and trends in relation to climate change, down to quite specific programs. Probing ranged from reasonably deep analysis back to vignettes to illustrate particular points (Table 1). Each case study and vignette selected was intended to provide evidence of value created in one or more of the areas of proposed value. In selecting the case studies we worked to ensure as even a spread as possible across CSIRO's Groups.

Table 1 **Case studies demonstrate CSIRO's multi-dimensional value**

	Flow of delivered research outcomes and research based advisory services	Build and maintain potentially valuable research capabilities	Systems and internal cultures	CSIRO Group
"Deep" analysis				
• Aquaculture Prawn breeding and novel feed	√√		√	Agribusiness
• Climate Adaptation Flagship as a whole	√√	√√√	√√√	Environment
• Geopolymers as cement substitute and HySSIL spin out	√√	√	√√	Manufacturing Materials and Minerals Group
"More shallow" analysis				
• APSIM (using past BCAs)	√√√		√	Agribusiness
• BARLEYmax	√√√		√	Agribusiness
• OpticCool	√√√		√	Energy Transformed Flagship (ETF)
• MDB strategy	√√√	√√√	√√√	Water for a Healthy Country Flagship(WFHC)
• Ultra Battery	√√√	√√√	√	ETF
Vignettes				
• Biochar	√√	√√	√√	Agribusiness & ETF
• First map of Australia's undersea mineral deposits	√	√√√		Wealth from Oceans Flagship
• SKA	√	√√√	√√√	Astronomy and Space Sciences
• Cross CSIRO Climate strategy		√√√	√√√	Energy/Agribusiness/ETF/Climate Adaptation Flagship/WFHC

The scope and depth of some of the assessments evolved as the probing proceeded, but the broad reasoning is as reflected in the table.

We did not seek to identify the highest value areas of CSIRO work, though clearly we did need to be dealing with a substantial block of impact and value across the set of case studies – if this was to afford a base for drawing conclusions about CSIRO's overall impact and value. Had we selected what were considered the highest value opportunities, this would have seriously constrained the scope for extrapolation beyond the case studies.

Selection of the case studies followed a much wider assembly of potential candidates, within a format that has been progressively developed to the large table included in Attachment B. That attachment now affords coverage of most areas of significant CSIRO involvement, along with indicators of investment and outcomes and outputs. We draw heavily on this table in Section 12 below, in discussing extrapolation from the case studies to all of CSIRO.

Table 2 provides a broad overview of where the case studies are located relative to the Flagships. The boundaries here are not absolute – reflecting the complex array of ways in which CSIRO resources are organised. However, the figure provides a reasonable overview.

Table 2 **Indicative relationship between case studies and CSIRO Flagships**

Flagship	Case Studies and vignettes
Climate Adaptation Flagship	Considered as a whole
Future Manufacturing Flagship	Cement substitutes & novel products
Sustainable Agriculture Flagship (& Plant Industries division)	APSIM Biochar in soils
Water for a Healthy Country Flagship	Murray Darling Strategy: Policy & support
Food Futures Flagship	Aquaculture prawns & novel feeds Resistant starch grains
Light Metals Flagship	Titanium (with some discussion of other metals)
Energy Transformed Flagship	UltraBattery OptiCOOL Biochar in steel
Wealth from Oceans	Undersea mineral map
CAF, FMF, WfHCF, ETF, SAF	Cross CSIRO Climate strategy
Other CSIRO Research Portfolios	Radio astronomy & SKA

The first thing to be said about the case studies organised this way is that we have only done case studies on a tiny fraction of CSIRO activities. We have only looked at one Flagship as a whole. Within the other Flagships, we have not necessarily homed in on the most prospective activities. Within Light Metals, the titanium work is probably the most prospective. On the other hand, the undersea mineral map, while possibly having strong long-term value potential, was chosen as an example of a broader investment in knowledge, relevant to understanding Australia, but not the main exemplar of the value propositions underpinning the Wealth from Oceans Flagship. The three examples in the Energy Transformed Flagship are very specific technologies – with substantial potential and challenges – but again hardly representative of the balance of the Flagship as a whole.

Again the case studies should be viewed as a small subset of CSIRO activities that serve two main purposes:

- They do, following our probing, demonstrate high value in their own right – value that is significant in relation to overall CSIRO costs.
  - In this sense they are seen as providing robust support for the inference that CSIRO does offer value that is high relative to costs even before considering the areas not covered.
- They also illustrate the types of mechanisms – especially collaborative, intense, application-focused multidisciplinary mechanisms – that line up

with our conclusions as to the space within Australia's innovation system where CSIRO appears best suited to adding value.

Their primary value to the present study lies not in their 'stand alone' value but in the way they illustrate wider value opportunities, for which their stand alone value is a credible starting point for making an informed judgment. The coverage of activities set out in Attachment B and the relationship between the case studies and the range of additional prospects set out there, is of central importance to any extrapolation.

It would also be dangerous to view the set of case studies and vignettes as representative of the 'shape' of CSIRO's research objectives and outcomes. Again, Attachment B and also C are more informative about this. However, in Section 12 below, we do seek to assemble a better understanding of how the case studies line up against other high credibility activities and associated value propositions from across CSIRO.

In terms of representativeness, we note that several of the case studies and vignettes have significant elements of climate adaptation and mitigation. This is of course naturally the case for the Climate Adaptation Flagship and the vignette covering the cross-CSIRO climate work. However, it emerged also in relation to the work on geopolymers and the UltraBattery, with biochar and even (unexpectedly) with the SKA. It is certainly possible that this mix overstates the overall CSIRO emphasis – while it is also true to note that support for climate policy objectives has emerged as a major element across CSIRO and Government objectives.

9 Overview of case studies

Each of the case studies has been the subject of an attachment. We provide here a brief summary of each assessment – covering rationale as well as conclusions as to value and impact. We have not attempted to quantify all sources of value and impact – and for some vignettes we have not inferred a quantified value at all. However, Section 0 does try to draw together a view of what could be inferred about the collective value of the case studies, as a precursor to the discussion of the wider value and impact of CSIRO.

9.1 The Climate Adaptation Flagship

This case study is discussed in Attachment E.

Australia is facing significant challenges due to the impacts of climate change including reduced rainfall, more frequent and severe heatwaves and coastal inundation. The science suggests that these impacts are essentially "locked in" and will continue to increase in severity for some time irrespective of any efforts to mitigate greenhouse emissions.

There will be an economic cost associated with the impacts of climate change. In Australia's case estimates point to a potential reduction in annual GDP of up to 7% a year by 2100. Clearly, the amount of money "at risk" is very large and even a small contribution from CSIRO could make a big difference. Early access to better information on which to base investments with better adaptation prospects can bring high value because of the propensity for poor design features being 'locked in' for many years in long-lived investments, such as infrastructure and commercial and residential developments etc.

There is good evidence that well designed adaptation measures can help reduce the costs of climate change (perhaps by as much as half). However, ill informed, uncoordinated or poorly targeted measures can have severe costs due to inefficiencies, missed opportunities and downside risks.

These risks will tend to be exacerbated in situations where there is uncertainty as to the exact timing and nature of the impact. In such situations, deferring an irreversible commitment to incur an adaptation cost can be a very rational course of action.

The Climate Adaptation Flagship (CAF) brings together a wide range of skills and capabilities from within CSIRO to help provide information and solutions that will help Australia to adapt to a changing climate. The range of activities being undertaken by the Flagship is considerable. In this report we have chosen to focus on three areas, each of which is briefly discussed below, as

well as developing a 'top down' estimate of option value across the whole of the Flagship. This 'top down' assessment of the option value of the Flagship's work programs pointed to a present value (7%) out to 2030 in excess of $2 billion, with the likelihood of significant further benefits being 'locked into' already built and zoned infrastructure assets beyond that point.

9.1.1 Bushfire research

Current climate projections point to conditions that will exacerbate the severity and damage of bushfires in many parts of the country. CSIRO is developing the tools we need to better understanding the behaviour of bushfires, their likely impact and how people and infrastructure can be better protected. The indications are that CSIRO research will have significant impacts on survivability of a bushfire.

While it is impossible to test the counterfactual, some relatively conservative assumptions suggest that the work on fire truck safety on its own created value (in terms of lives saved) of around five times the total cost of the program in 2009 alone. Benefits from other aspects of the research look to be at least an order of magnitude greater.

9.1.2 Coastal communities

With our large and growing coastal population the risk of coastal inundation due to sea level rise coupled with greater storm intensity is an area of increasing risk. CSIRO's research is supporting the adaptive capacity of coastal councils in South East Queensland (SEQ), Westernport in Victoria and coastal areas around Sydney. CSIRO analysis of the benefits of better managing development in SEQ suggest that it could reduce the cost of a 2.5m inundation event in 2030 by up to $700m (for housing alone).

If we take the average annual cost of past inundations in SEQ, ($130m), as the possible future cost and assumed the same ratio of savings as suggested in a US study on the value of foresight then the saving due CSIRO's research in one year would be $26m – with a conservative present value, if sustained, of the order of $200m. The potential saving from this single stream of research thus compares very favourably with the total $9 million cost of the coastal communities program.

9.1.3 Climate ready crops

CSIRO's work on climate ready crops aims to develop the options for crop varieties for planting beyond 2025. Importantly, CSIRO's research aims to not only identify and breed crop varieties better able to cope with extreme

temperature events, but also to have increased yield from being better equipped to benefit from the higher CO_2 concentrations in the atmosphere.

Even with some rather conservative estimates the difference in the NPV of wheat exports between 2010 and 2050 with and without the new wheat varieties is almost $1.1 billion. The head start that CSIRO has reportedly got in this field of research means that waiting for a solution to be developed overseas would reduce the benefit by about half compared to the business as usual case.

9.2 Cement substitutes and novel products

This case study is discussed in Attachment G.

Geopolymers have strong potential as a substitute binder in concrete and in a range of cement-based products. With cement production accounting for over 5 per cent of Australia's GHG emissions, 8 per cent of global emissions and an even higher percentage of emissions from rapidly developing economies, such as China, a key attraction lies in the scope for a dramatic reduction in the emissions intensity of concrete and related products. At the same time, these geopolymers should support a range of improved functionality in products.

The development is almost inevitable, but rapid progress requires a coordinated attack from the chemistry, including locally available input sources, through to compliance standards and testing to enable application of the new products to mainstream uses. CSIRO offers capability across the range, with special strength at the testing and standards end – with these involving both valuable checks on risks and potential regulatory impediments to faster reductions in GHGs.

CSIRO is a key player in coordinated innovation activities across Australia, and its capability clearly influence prospects and timing. In addition, it has established commercial vehicles for marketing novel concrete products, has specific IP in relation to a significant geopolymer product with special application in the US (a lightweight roofing tile) and has advanced research relevant to a global opportunity in replacement railway sleeper. The early strength of these niche products lies in their improved functionality – which can now substantially underwrite CSIRO's exposure, while the main game – of potential for earlier substantial and cost competitive GHG reduction, with possibilities globally – is pursued.

We have explored the nature of the commercial and GHG reduction opportunities. They are not independent – and moves to price carbon in Australia and elsewhere would translate to stronger commercial opportunities.

Modelling of the commercial opportunities from the roof tile opportunity alone (where an MOU is in place with a major US firm) suggests a conservative risk-weighted assessment of value of the order of $30 million, with upside potential in excess of $130 million. Other products, including sleepers, show significant promise (with commercialisation being explored) in potentially much larger markets. These assessments suggests that the risks in the CSIRO work are now more than covered by the value of commercial options – while CSIRO focuses on what might be seen as the main game: earlier, competitive penetration of the large pre-mix concrete market that accounts for the bulk of relevant Australian and global emissions. There are substantial public good elements to this area.

The technologies could allow Australia to reduce significantly its costs of complying with a carbon pricing regime – such as the ETS. The reasoning set out earlier suggests potentially high value here for CSIRO if there is relatively early implementation of an ETS with rising marginal abatement costs. As an indicator, 5 per cent substitution for cement from around 2020 could have an ETS value of the order of $50 million over a period of 5 years. The value of global abatement, were there any acceleration in substitution flowing from CSIRO's work, would be many times greater – especially if this were to encourage a stronger global response to climate risks.

9.3 Aquaculture prawn breeding & novel feeds

This case study is discussed in Attachment F.

This case study analyses the impact of CSIRO's new prawn breeding and genetic selection techniques, and the development of novel aquaculture feeds. However, as with many CSIRO outputs identified in this study, the principle subject is an example of one specific output (with direct commercial application) of a significant body of research in this case into animal breeding management and protein for human consumption.

Key immediate impacts identified in the work include:

- A demonstrated threefold increase in farmed prawn production on one commercial prawn farm, with two other farms at advanced stages of breeding
- High prospects of extending the performance of elite stock up to 10 times current industry averages
- Significant reduction in cost of production of farmed prawns which will lead to a change in the relative price of farmed verses wild catch prawns
- A potential increase in net value of prawn production, based on growth rates alone, in Australia of approximately $430m dollars (present value)

- The development of a novel bioactive feed ingredient that increases prawn growth rates by 50 per cent compared to current feeds
  - As the novel bioactive feed ingredient is based on agricultural waste streams, future prawn feeds are likely to reduce the need for raw materials to be sourced from wild catch 'industrial' fish resources
- The establishment of a novel bioactive feed ingredient industry in Australian with a gross value of up to $21m (present value).
- Increased value of prawn production estimated at $84m (present value)
- Domestic royalties of approximately $1.0m (present value)
- Substantial international royalties

Longer term opportunities, with potentially high value, include:

- If both the innovative breeding process and novel feeds are applied to a range of other species the potential benefits (economic, social and environmental) are substantial.
  - If the technology is successfully applied to other farmed species it is likely to reduce the cost of production significantly, increase quality, and reduce reliance on wild stocks.
  - At this stage CSIRO believes that this technology can be applied to other species. Trials of the breeding program are already under way with salmonid species
- Over time, and if widely adopted in Australia and overseas, the innovations combined are likely to alter the relative prices between farmed and wild catch as farmed prawns become cheaper to produce domestically and internationally.
  - This change in relative prices will reduce the incentives to continue to fish depleted fisheries, reducing the economic losses of inefficient fishing effort
- The increase in production and the development of novel feeds will significantly increase the policy levers that governments will have to manage fisheries
- Creates an option to continue to provide animal protein for human consumption should climate change detrimentally affect wild caught fish stocks and terrestrial livestock production
  - The area that could be developed for prawn farming in Australian is extensive and able to be chosen to exploit saline water resources and sited to reduce climate change risks

9.4 APSIM

This case study is discussed in Attachment H.

APSIM is one example of the extensive agricultural production systems modeling where complex interactions of physical factors of production are modeled.

APSIM, and agricultural and forestry production system modelling and decision support systems (DSS), have a long history within CSIRO and constitute an excellent example of the 'systems' approach to complex research problems employed by CSIRO.

APSIM, and other DSSs, has struggled to achieve widespread adoption by farmers and their advisors. To overcome this, CSIRO has engaged in extensive research on farmer decision making, which according to CSIRO has generated considerable benefits. A significant investment made by CSIRO in exploring the application of simulation modelling to farm decision making was in the FARMSCAPE program. Benefits reported by CSIRO stemming from FARMSCAPE include:

- Increasing farmer adoption nationally of soil moisture and nutrient monitoring to depth
- Increasing industry acceptance of crop modelling as an diagnostic and decision aid
- Promotion of the use of seasonal climate forecasts as important inputs into crop production decisions combined with stored soil moisture measurements
- Diagnosis of important production constraints and elucidation of practices to increase yield and lower risks

Yield Prophet®, an on-line risk management service based on APSIM, has been commercialized in conjunction with the Birchip Cropping Group (BCG). Subscriptions to this service have been increasing since its introduction in 2002

The majority of the value of APSIM and other simulation models is generated when they are used by researchers to identify key risks, and ways of managing them and communicating these results to farmers. Specific examples of the value created by APSIM include:

- Demonstrating that mungbean production is profitable in northern Australian cropping areas when sown in spring with good soil moisture
- Canola can be a valuable and profitable crop in northern cropping rotations.

The development of simulation modeling has been extensively used by researcher to better prioritise research investments by allowing the testing of

hypotheses by simulation modeling rather than in relying solely on field research.

9.5 Murray-Darling: Policy & strategy support

This case study is discussed in Attachment I.

CSIRO was able to draw on expertise from a wide range of CSIRO areas, including significant components of the Water for a Healthy Country Flagship (and nits strong legacy from the Land and Water areas of CSIRO), to provide to COAG comprehensive whole-of-system modelling capabilities in respect of Basin hydrology and sustainable yields. CSIRO also coordinated the massive multi-agency, multi-jurisdictional work needed to deliver the sustainable yields project – making this CSIRO's largest single project.

The values at stake were (and remain) very large. The Basin supports agriculture production of the order of $15 billion annually – that is increasingly threatened by water reliability issues; massive sunk infrastructure investment linked to historical irrigation patterns; is the primary water supply to urban centres, including Adelaide, where the opportunity cost of alternative supplies is very high; and supports extensive very high value non-extractive uses, linked to numerous ecosystems and environments that are under intense pressure from water supply.

This work was done to support the Murray Darling Basin Plan, and in the context of Federal Government commitment of more than $12 billion over 10 years, expectations of analogous funds coming from other sources and establishment of the Commonwealth Environmental Water Holder to manage the growing water entitlements of the Commonwealth for maximum environmental value. Better understanding of the system is a key to getting good value out of these huge investments.

Analogous work would have proceeded without CSIRO's capabilities, but it would have been different. CSIRO brought the depth of systems understanding, plus large scale computing clout, that allowed earlier development of more comprehensive models with much greater scope for exploring patterns of sharing of impacts across the system. The modelling revealed substantial departures from the simplifying assumptions previously used. In the consideration of the counterfactual it appears likely these assumptions would have been required. Discussions with the client in the Basin planning processes confirmed a view that the product was substantially more powerful than could otherwise have been achieved in the time frame.

The Planning process and the massive rollout of investment in Basin entails large infrastructure costs, and substantial withdrawal of water from a range of uses, with social and economic consequences that will be largely irreversible. Delay in acting involves high risks – and so does and early action given the uncertainties. Earlier and better understanding of the system, and especially the cross-system variations, offers the potential to reduce potentially large risks of costly errors. This very insurance has high value, given the level of investment being made – with real prospects for the better information making a substantial difference to the process. Delay in getting to this level of sophistication could therefore entail high costs.

Against this background, we explored conservative assessments of the value of the superior information to the planning and investment processes – including investments in water savings and investments in a growing portfolio of environmental water, needing management.

We developed an indicator assessment of value, across risk mitigation and improved investment efficiency, of $2.8 billion. This is considered conservative – and plausibly highly conservative.

The project itself was revenue positive for CSIRO – the work was done as a consultancy – but it drew heavily on the substantial investment in the WfHC Flagship. This work alone raises very substantially the conservative estimate of whole of Flagship value we developed in 2006 of over $700m.

9.6 Resistant starch grains

This case study is discussed in Attachment J.

In the 1990s CSIRO became interested in researching the nutritional properties of grains. This work, which involved a multi-disciplinary team, originated in CSIRO's Plant Industry Division and is now within the Food Futures Flagship. At the time this research commenced most other grains researchers were only focusing on productivity benefits. As a consequence CSIRO appears to be well ahead of other researchers in the area of nutritional grains research.

CSIRO's research which has produced BARLEYmax™ and a high amylose wheat variety. The research for this grains shows there is significant potential for improving Australians cardiovascular health, reducing the incidence of colorectal cancer and Type II diabetes. All of these diseases fall within the Government's National Health Priority Areas for research.

- Grains with high levels of resistant starch have been shown to have preventative health benefits when eaten in sufficient quantities.

- CSIRO has patented a form of Barley, known as BARLEYmax™, which contains a gene which has high level of resistant starch. This grain is now in commercial production.
- CSIRO has used the technology and lessons learned with BARLEYmax™ to develop the high amylose wheat variety, high amylose is another form of resistant starch. This wheat variety is expected to be commercialised by 2013.
- The present value created by investing in these two grain varieties and delivering them to the Australian market has been conservatively estimated to be as high as $554 million (using 7 per cent discount rate).
  - However, if **even more conservative** assumptions for take up, and the value of a statistical life year, are used, the measured benefits fall to just under $100 million.
- These estimates do not factor in a range of values and options created by the research and commercialisation including:
  - Any premium on the processed food produced using the two grains.
  - The option value created by opening up the potential for introducing the capability and knowledge CSIRO has developed to produce preventative health benefits in other grains and crops, with the likely next contender being rice.
  - The option which has been created to develop a new export market for BARLEYmax™ and HA wheat.
  - The stream of royalties and license fees associated with exports and/or the sale of the patent to overseas grain growers and food producers.

9.7 Titanium within the Light Metals Flagship

This case study is discussed in Attachment K.

When we reviewed the Light Metals Flagship in 2006 we noted both high potential value and some areas where there was a likelihood of needing to pull back in the medium term. Revisiting the Flagship has provided good evidence of both proposition – including CSIRO's willingness to pull back and divert resources based on the emerging evidence.

Australia is rich in titanium ores, but undertakes no local processing of ores – Australia cannot be competitive with current technologies. CSIRO has focused on novel technologies that play to Australia's competitive strengths and that offer potential for substantial cost reduction.

The titanium work has largely been tracking the more optimistic branches of the options tree developed then, when we inferred a risk-weighted value of the order of $275 million across the work on TiRO and product fabrication. The main negative element has been some slippage in timing which, while still

consistent with Flagship targets, does entail some heightened opportunity costs. This has been offset in large part by the likely avoidance of one of the then proposed high cost demonstration stages.

The Flagship has made substantial progress with both areas of titanium work, passing through the proof of concept stages, where this was a serious risk factor (detracting from value) earlier, and advancing in the development of commercial arrangements and funding that aligns well with the nature of the emerging opportunities. These arrangements recognise the value of CSIRO's work to date, while securing access to the type of investment needed to move to commercialisation.

Against this background, we concluded that the value of the work on titanium has increased significantly.

9.8 The UltraBattery

The task of reducing carbon emissions to long term sustainable levels is not a simple one. Achieving the necessary reductions in carbon emissions will require major technological shifts and innovations. Indeed the IEA in 2008 argued that a massive increase of energy technology research, development and demonstration is needed to achieve the necessary carbon constrained outcomes. The IEA also suggested that the transport sector poses a significant challenge to achieving meaningful emissions reductions in the energy sector.

CSIRO has been working on energy storage technologies for over 20 years. And its work on the UltraBattery draws amongst other things on its work with supercapacitors and hybrid motor vehicles. The UltraBattery is a hybrid energy storage device which integrates a supercapacitor with a lead-acid battery in a one unit cell. The UltraBattery has a number of characteristics which make it stand apart from other batteries including the facts that it is less expensive than batteries used in most hybrid vehicles

CSIRO's research on the UltraBattery commenced in the Energy Technology Group but was eventually moved into the Energy Transformed Flagship. The multidisciplinary Flagship team identified that the UltraBattery technology also offered opportunities as an energy storage source for renewable energy such as wind and solar.

CSIRO has invested approximately $4 million in the automotive and stationary aspects of the research. Another $3.7 million of the research undertaken was funded by Federal and State Government grants.

Over the period from 2005 to May 2010 CSIRO has entered into commercialisation and distribution agreements for automotive and stationary uses of the UltraBattery. Details of any upfront payments and/or royalties to

be paid to CSIRO under these commercialisation agreements are not publicly available.

The prospects for the take up of the UltraBattery into the next generation of hybrid motor vehicles have been enhanced by the US Government awarding a $32.5 million grant to the US licensee that will allow the company to expand its production capacities to test and manufacture the UltraBattery for hybrid automotive applications.

New motor vehicle fuel efficiency regulations announced by the European Parliament in 2009 and by the United States Government in 2010 have placed increased pressure on car manufacturers to find fuel efficient technologies. Batteries, such as the UltraBattery, will be needed to achieve these new mandated fuel efficiencies. Analogous regulatory change in other countries seems probable and a range of Asian countries could be attracted to the potential not just to limit GHG emissions, but to limit the wider range of emissions from internal combustion engines and to reduce reliance on imported oil.

A key here will be to see lower battery costs translate rapidly through to lower vehicle prices – and for this early competition in the battery market is likely to be important. There are few advanced contenders to the UltraBattery. This opens the possibility of the UltraBattery having influence over rates of take-up of new vehicle technologies out of proportion to achieved sales – with flow through to global GHG outcomes.

In addition to any upfront commercialisation payments, CSIRO is now well placed to access significant royalty revenue from the commercial agreements. The level of penetration the UltraBattery achieves in the new fuel efficient vehicles will be an important factor in the stream of revenue generated. Scenarios around alternative penetration rates for advanced battery fuel efficient vehicles and the UltraBattery's share of this market suggest the if the UltraBattery is in the market by 2015 the stream of royalty revenue alone could be worth;

- $9 million – assuming penetration of advanced battery vehicles achieves 10 million new vehicles in 2020, with an UltraBattery market share of 20 per cent and a 7 per cent discount rate
- $17.7 million – assuming penetration of advanced battery vehicles achieves 20 million new vehicles in 2020, with an UltraBattery market share of 20 per cent and a 7 per cent discount rate
- $35.1 million – assuming penetration of advanced battery vehicles achieves 40 million new vehicles in 2020, with an UltraBattery market share of 20 per cent and a 7 per cent discount rate

- $52.7million – assuming penetration of advanced battery vehicles achieves 40 million new vehicles in 2020, with an UltraBattery market share of 30 per cent and a 7 per cent discount rate.

In addition to these private (commercial) benefits there are a range of other advantages of the automotive use of the technology that may benefit society at large, but which may prove difficult to capture commercially including:

- Reducing greenhouse gas emissions
- Reducing non-greenhouse gas emissions
- Synergies with 'smart grid' applications.

In addition the stationary storage use of the UltraBattery technology could help to address issues associated with the supply-side volatility of some forms of renewable electricity generation.

If the stationary use of the technology is successfully commercialised CSIRO should also receive revenue streams from its licensing agreements. Depending on the assumptions regarding market take up, the NPV of the stream of royalty revenue discounted at a rate of 7 per cent could range from $5.5 million to $36.6 million.

9.9 Mapping of undersea mineral deposits

The Wealth from Oceans Flagship and partners have assembled *The Australian Offshore Mineral Locations Map*. This map has been developed to be viewed on the Australian Marine Spatial Information System developed by Geoscience Australia in consultation with CSIRO and marine research institutions

This project meets two information policy objectives of the Australian Government. The first relates to, as far as possible, making public sector information available to the community. The second policy objective, that has been a long term goal of the Australian Government, is the development of national spatial data infrastructure (SDI). A component of a national SDI is accessible public data both onshore and offshore.

The value associated with the Offshore Minerals Resources map lies in the information it provides for improved decision making and consultation between government, NGOs and industry.

Bringing this undersea minerals data together data creates options for the Government to use this data for both decision making and policy formation. For industry it provides information that will help them assess and plan offshore minerals projects at some future time.

The value of this data to industry will be enhanced if:

- The locator map for the Offshore Mineral Locations map is machine readable so that output can be exported into a Geographic Information System (GIS) by other users.
- The AMIS data was integrated with other programs that are key parts of wider processes developing components of what might ultimately become a national SDI. These include:
  - AuScope and the Integrated Marine Observing System as both programs are developing interactive portals to provide access to geoscience and marine data respectively.

9.10 Biochar

CSIRO has been investing in biochar technologies in two distinct areas – biochar as an input to steel production as part of the Minerals Down Under Flagship and biochar as a soil additive, now being done within the Sustainable Agriculture Flagship. CSIRO's investment in biochar demonstrates the risk management role that CSIRO fulfils for Australia.

Both areas of research are driven by the potential of biochar to store carbon. The demonstration of use in steel manufacture is at an advanced stage and appears to be an applicable technology with high reliability carbon storage. For soils, there remains both science uncertainty, principally in relation to durability of storage in particular circumstances and specific impediments to application linked to international accounting for soil carbon and Australia's approach to the accounting requirements. That said, in both applications, indications are that biochar could offer substantial low (and even negative) cost abatement.

The soils work on biochar was elected in part to illustrate CSIRO approaching a prospect with small, targeted investment to provide a basis for deciding on future strategy if any – and to then develop a research area, in collaboration with the States, in what emerged as a prospective area.

The immediate origins of the current biochar research stem from a successful application for $50,000 to the Land and Water Division Opportunity Development Fund. The project was to undertake an international literature review of biochar production and application to Australian agricultural soils.

This was very much a low cost strategy to acquire some options over a possible area of innovation.

As a result of this investment, CSIRO was able to influenced the policy debate on the contribution agriculture could make to national GHG abatement strategies.

Dependent on both further development of the science and developments in relation to the treatment of soil carbon under international GHG accounting –

with Australia pushing strongly for change – biochar could become an important element in the mix of measures to limit atmospheric greenhouse gases, with the potential in some applications for it to be highly cost competitive.

As a technology, it should be widely applicable in many countries beyond Australia – including a range of developing countries.

9.11 Radioastronomy & the SKA

The trend in modern science in several areas has been to move to 'big science' projects, internationally funded in order to share large costs and anticipated science benefits, and located where in the world the science could best be done. When dealing with relatively pure science, these tend to be high cost ventures with poor prospects for cost being justified by tangible economic and social impacts. They typically require recognition of large value in the cultural and pure science objectives of the work.

CSIRO has a well-established leadership position in radioastronomy in Australia. The SKA radio telescope is a proposed 'big science' project, now at an advanced stage of planning, where Australia happens to have high competitiveness as to where the facility will be located. It offers large areas of 'radio quiet' land in which to locate sensitive receivers, advanced technologies (largely driven by several capability areas across CSIRO as well as with other agencies) with particular application to the technical needs of the SKA, a high international profile in radioastronomy and strong capabilities to support the type of investment long term in a politically stable location. Radio astronomy also has a strong track record in spinning off high value technologies – including a major role, from within CSIRO, in the development and commercialisation, of high speed wireless networking.

Were the SKA to be located in Australia, and especially if Australian technologies were to play a central role, there is the distinct possibility that tangible benefits to Australia could actually exceed Australia's share of tangible costs – while continuing to allow Australia to share in the science benefits.

CSIRO's leadership role, facilities and reputation are critical parts of the process that has Australia now competing only with South Africa to be the location – with the major risks now being dominated by the attitude taken to the choice between optimising the science and offering a major project to South Africa, with an element of support for a developing country.

Even factoring in these risks, indicative options modelling we have done, updating earlier modelling prepared as part of the original business case we prepared for the Federal Government, suggests that expected costs to Australia

are more than covered by expected tangible benefits – conservatively by more than $80 million, with only modest risk of falling short and with substantial upside. This modelled figure is net of all investment costs incurred along the way. If expressed on the same basis as the other value estimates developed in this study, then CSIRO's substantial investment costs would be added back in. This suggests a conservative figure well over $100 million.

This assessment of modest risk and substantial tangible upside stands, but in itself understates the value implied for Australia if implied the type of active Australian participation in the project is valued highly. The science questions being addressed are wide-ranging.

The project offers an opportunity for Australia to participate in big science in a way that plays to Australia's competitive advantage in reducing costs and tapping into opportunities.

CSIRO's role across a wide range of areas has been crucial to reaching the current position where Australia appears well placed as the site for the facility.

9.12 Cross-CSIRO climate strategy support

CSIRO has a range of research under way across the organisation that is relevant to climate modelling and prediction, mitigation and adaptation – including links into a range of Flagships whose research is not explicitly focused on climate change. This work, and CSIRO's external collaboration arrangements in these areas, have progressed to the point where it sees substantial value in a more systematic coordination of research – including a proposal for a new large-scale collaboration – the Australian Integrated Carbon Assessment System.

We certainly recognise substantial opportunities in a more balanced, broader and progressively optimised approach to managing climate threats. Better risk management, and better balancing of measures, between adaptation and mitigation and between early and later action could deliver substantial benefits through reduced risks of serious error and early identification of new prospects.

We have not attempted to value the work, but if done well we would anticipate high value.

10 Summary of direct case study value inferences

Noting that we stopped well short of developing explicit dollar valuations of all the outcomes and options in the case studies and vignettes, and that we sought to be conservative even in the bits we did value, it is useful to assemble some of the inferences to allow a more collective view to be taken. Except where stated to the contrary, dollar valuation figures below relate to conservative estimates expressed in present value terms. They are not net of CSIRO costs but are intended to be net of implementation costs – being calculated typically via cost and benefit differences relative to the counterfactual.

- Climate Adaptation Flagship:
  - Top down assessment suggested contribution to reduction in Australia's costs of adapting to climate change, only across the period to 2030, of the order of $2b;
    - … + benefits locked into infrastructure extending further;
    - … + insurance against plausible limited success or delay in global mitigation strategy
  - As examples, 'bottom up' assessments suggested potential value of the order of $1b from climate-ready crops, of the order of $200 million for coastal communities through better planning and zoning and substantial value potential in relation to planning for increased bushfire risks.
- Prawn breeding and novel feed supplementation:
  - Value of delivered prawn yield increases, $430 million+
    - … + potential for substantial further increases
    - … + potential to transfer technology to other species
  - Novel feeds could support useful royalty streams, export potential and displacement of some stress on wild harvest fisheries.
- Cement substitutes and novel products
  - Plausibly conservative royalty streams of several tens of millions of dollars on niche products that can compete based on functional characteristics – underwriting research risks.
    - … Early position in potentially large overseas markets.
  - Strong options to support lower cost mitigation strategies:
    - … Indicative benefits of $50 million from advancing Australian access to the technology under a moderate carbon pricing regime;

  - … Potential savings in the global social cost of carbon of several hundred billion dollars and modest early acceleration of access, with potential to influence global mitigation strategy.
- Murray-Darling Basin Yields Project:
  - Conservative $2.8 billion value linked to more efficient deployment and better risk management of the investment funds already committed to buyback and water infrastructure efficiencies
    - … + potentially high value from better management of the environmental water portfolio;
    - … + options, some being exercised already, to extend the capability to other water systems
- Resistant starch grains:
  - Present value, primarily via improved health outcomes for Australians, very conservatively assessed at about $100 million, and plausibly several times greater as capability is transferred to grains and crops other than barley and wheat
    - … Value under less conservative , but still probably conservative, assumptions could be in the order of $550 million
  - + additional returns to agriculture and CSIRO royalty streams from new non-commodity cereal crops capable of commanding premiums.
- Titanium within Light Metals
  - With commercial partnerships in place, revision of 2006 assessment of the opportunities for TiRO and product fabrication suggests significant strengthening above the earlier assessment of value of $275 million+
- The UltraBattery
  - Commercialisation in place for both automotive and stationary applications will support returns to CSIRO, though structure is commercially confidential.
    - … Plausible revenue streams valued at tens of millions of dollars.
  - Opportunities, within a small field of possibilities, to alter the early nature of moves into more electrified vehicle fleets and to support more effective early use of renewables within the energy mix.
    - … Plausibly large impacts via the social cost of carbon saved and improved incentives for global mitigation – further enhanced by implications for non-GHG pollutants and oil dependency.
- Mapping undersea mineral deposits
  - No quantified value developed within the vignette, but immediate cultural and policy value, and longer term potentially high value in supporting commercial exploration.

- Biochar
  - Not explicitly valued, but potentially very high value if the work leads to acceptance of certain applications of biochar for purposes of carbon accounting under international protocols.
    - … Plausible role for biochar as a substantial contributor to lower cost abatement, given its complementarity with several aspects of farm production – with potential value of many billions of dollars under a carbon target policy.
- Radio astronomy and the SKA
  - High value for Australia if wanting to participant in big science projects, probing important science questions, in a cost effective way that plays to Australia's competitive advantages.
  - Indicative estimate of a conservative expected mean tangible net benefit (risk-weighted for the chance that the SKA will be located in South Africa), over the life of the project, of the order of $80 million – driven by the high prospects for the SKA being located in Australia.
    - … This figure, based on earlier business case modelling, is net of the costs of the project itself. Placed on the same basis as the other estimates, the figure would be two to three times this size.
- Cross-CSIRO climate work
  - Currently the subject of an active proposal that could deliver very high value, but not quantified.

The values considered here span commercial returns back to CSIRO, development of commercial opportunities for Australian firms, insurance against major risks in relation to such matters as public health, climate change, river systems and wild fisheries management and conservation. As a general proposition, and especially since our last review, CSIRO has made solid progress in advancing well past the proof of concept stage and into active commercialisation processes. These developments have allowed significant reduction in the investment risks from a CSIRO perspective and have established what we consider to be some high value options from an Australian perspective.

The 'big ticket' opportunities remain speculative but large. Because CSIRO is addressing major issues, it is not surprising that it is operating in spaces where there are often several competitors and this had to be reflected in the counterfactual. Sometimes the competition can be complementary in delivering on public good objectives, but it can also mean that commercial prospects still span a wide range.

These considerations have been factored into our assessments, in that we have sought to develop conservative estimates of expected value. Taking the above case study-level assessments suggests an aggregate conservative valuation,

across the collection of case studies, of the order of $6 billion plus very substantial upside. Again, the figure is expressed as a present value (7 per cent discount rate) of the options that have been created, without netting the CSIRO costs incurred – comparison with CSIRO costs comes later. The upside includes:

- Real prospects for the benefits actually quantified to prove much greater;
- A range of potential values and impacts that we have not sought to quantify;
- Other values where some quantification has been done – but not of the value to Australia.
  - Across all the work on mitigation options, the value expressed in terms of the scope for reduction in global damage, as reflected in the marginal cost of carbon as opposed to potential value to Australia in lowering the costs of complying with a target, is huge.
  - Attachment D sets out the reasoning in relation to these outside impacts that happen to align closely with Australian Government objectives and that could, by contributing alongside a range of innovations to a tipping point being reached in global negotiations, make a large change to global climate policy with large value for Australia.
- Additional value linked into the overall maintenance of capability suited to other applications.

Of course it is relatively easy to chip away at individual assumptions made in looking at future value – assumptions are needed. The discussion in Section 3.2 does lend credence to the argument that these processes of sustained attack on big challenges can deliver very large gains. It is also important to recognise that, where conservative assessments have been made of a number of values, then simply adding these values together tends to become 'super conservative'. This is just a statement of how statistics works. The sum of several variables, each with large variance, will generally display a lot less relative variance. While the downside risks assumed in reaching a conclusion about one conservative valuation may be quite plausible, to hit these worst case assessments in respect of a range of largely independent investments becomes much less plausible.

Against this background, we believe a present value estimate of the order of $6 billion dollars for the valuation of the collection of case studies and vignettes should be viewed as highly conservative.

Of course, this value has come out of decades of capability accumulation and in most cases several years of Flagship operations. In this context it is reasonable to ask whether these case studies alone would seem to have enough value to cover CSIRO's costs. This is not an entirely clear cut question. Of course, if all of CSIRO's costs since its formation were counted and expressed

in current value terms, this $6 billion would fall well short. However, this would be an unfair comparison for several reasons:

- It would not do justice to the above conservatism arguments
- It would ignore the stream of outcomes delivered by CSIRO over this period – including a substantial contribution to the agricultural value set out in Section 3.2, but extending much more widely.
- It would fail to account for the fact that these past costs were sunk, but that investment that extracted additional value from this work and capability could be highly cost effective even if it failed to cover the sunk costs.
  - From a strategy perspective for CSIRO's future funding, it would seem far more important to focus on the evidence in the case studies that the recent investment by CSIRO has been able to realise value large enough to justify the investment – treating the legacy of capability that has been tapped as sunk.
  - Given the evolving nature of CSIRO, this would seem far more appropriate as a pointer to whether further investment in the order of magnitude that CSIRO has received in recent years is likely to be cost effective, again taking the legacy as sunk.
- It would fail to factor in the contribution to the future legacy value, to be tapped by CSIRO and other researchers in the future.

Section 12 below considers the extent to which we can reasonably infer that the case studies that have been considered represent only a part of the overall value of CSIRO – this is clearly the case, but the discussion there suggests that whole of CSIRO value is likely to be at least several times the value represented by the case studies.

However, in comparing these value estimates to CSIRO costs, it would seem dangerous to look at trying to relate these value estimates (whether the conservative $6 billion represented by the case studies or the likely several times higher figure represented by all of CSIRO's work) to more than a few years of CSIRO costs. This is because the main purpose is to derive a feel for the rate at which value is being created by CSIRO relative to outlays.

This reasoning would suggest that the relevant cost comparator would be of the order of 2-3 billion dollars of appropriation money. There is necessarily some arbitrariness here – there is no clean 'year zero' that affords a useful starting point in assessing innovation. However, we believe that the types of value we have outlined in working through the case studies have largely been enabled by the investments over a relatively brief period of time – with this offering a useful basis for assessing the likely fertility of further investment.

On this basis, we would tend to conclude that the case studies alone appear likely to have more than covered the relevant CSIRO costs. Of course, a substantially stronger conclusion then follows in the discussion in Section 12.

11 Impact through collaboration

Of course a lot of the case study material cited above involves work where CSIRO has been one of a range of collaborating research and/or industry participants. Collaboration is a powerful way of drawing heightened value out of disparate specialist skills. This can include elements of either or both of:

- Composing teams with the relevant skills and motivation to attack an agreed opportunity; and
- Bringing together multiple sources of funding that may be driven by different – but mutually compatible – objectives underpinning willingness to invest.
  - The collaboration arrangements could be viewed as a joint venture, to share costs and risks, as a cost effective way of the different participants to pursue their own objectives.

In recent years, CSIRO has greatly increased its emphasis on collaboration:

The move to Flagships was itself a collaboration arrangement, initially substantially entailing collaboration across CSIRO to deliver focus, leadership, critical mass and appropriate skills across the range of disciplines relevant to the focus. As a research model, it enhanced CSIRO's flexibility and capacity for rapid response to major issues. The very existence of such a model could be viewed as adding substantially to the value of the capabilities held within CSIRO – by making them more accessible and suited to delivering 'big project' effort directed at big opportunities and threats.

The various case studies and vignettes emphasise these cross-CSIRO linkages, and they are further developed in Attachment C.

Similarly CSIRO has a long history of external collaborations, especially via the CRCs.

However, we have also observed a substantial strengthening in the commitment to collaboration since our 2006 review. The Flagships are focusing more tightly and are actively pursuing large project collaborations with outside organisations. It appears that these sorts of arrangements are seen increasingly as the direction in which maturing Flagships should evolve, especially as they are able to focus more tightly on fewer, high prospectivity opportunities.

Purely as an example, we note that the Water for Healthy Country Flagship has:

- Since 2007 moved from having over 600 active external research contracts in 2007, with an average value under $30,000 and contributing $22 million

in revenues, to 197 contracts in 2010, with an average value of almost $650,000, contributing about $40 million in revenues.

- As part of this, entering into a range of large, and in several cases, long term research relationships and contracts:
  - $27 million of fully-funded research establishing the future water resource availabilities of key regions (the "sustainable yields" projects; 2007-2009)
  - The establishment of the Urban Water Security Research Alliance, a $50 million, five year program with 50 percent CSIRO co-investment (2008-2013)
  - The establishment of the Water Information Research and Development Alliance, a $50 million, five year program with 40 percent CSIRO co-investment (2008-2013)
  - The establishment of the Southeast Australian Climate Initiative (II), a $9 million, three year program with 30 percent CSIRO co-investment (2009-2012).
  - The establishment of the Goyder Institute in partnership with South Australian (SA) and Commonwealth governments and collaboration SA universities, a $50 million to $100 million, five year program with 25% CSIRO co-investment (2010-2015).

Analogous trends are emerging across the maturing Flagships. This current study is not to review the CSIRO strategy, but it does seem relevant to observe that these types of relationships appear well suited to attacking challenges of the type and scale that motivated the formation of the Flagships, while providing powerful mechanisms for both undertaking more appropriate research with a better mix of skills and for boosting the 'pathways' to market – especially where this involve influencing government policy settings.

12 Value in the wider CSIRO portfolio

Section 0 assembles a strong weight of evidence to suggest that just the case studies and vignettes that have been explored support strong enough value to cover the recent relevant investments costs across CSIRO. This relates to recent value enabled, under the current business model, as a result of recent investment that has been able to tap into CSIRO's legacy and breadth of current capability and its capacity to play a role in coordinating work across multiple agencies. The assessment was based on only partial coverage of the value drivers underpinning the case studies and on the use of conservative valuations even of those outcomes and options explicitly valued.

However, the case for CSIRO more than covering its costs is substantially deeper than this. The case studies barely scratch the surface of CSIRO's range of activities and the value inherent in the set of capabilities it manages within a system suited to rapid deployment, focused on key challenges and opportunities. The case studies considered account for substantially less than 20 per cent of CSIRO's costs in recent years.

As was argued in Section 8, the case studies were not chosen on the grounds of being the pinnacle of value from CSIRO – they were chosen to illustrate the range of mechanisms for delivering value in use and to develop a credible lower bound assessment of impact and value across the set of case studies (as assembled in Section 0).

Equally, they were not chosen as necessarily truly representative of average level of benefit/cost across all of CSIRO. It would be inappropriate to assume that total CSIRO impact and value could be inferred on a pro rata basis from the case studies.

Nonetheless, the basis on which the case studies were chosen does strongly suggest that there is likely to be additional value across the remainder of CSIRO's activities, including:

- Further individual activities, from projects up to Flagships and beyond, that are broadly analogous to those examined in the case studies, and that appear to support analogous value proposition.
- Broader capability options, tied into the collection of capabilities being fostered by the research work and by the Transformational Capabilities Platforms process (Section 6.2.1) and into the operating model and culture.

12.1 Mapping other activities against the case studies

Attachment B provides a large table of CSIRO activities, across themes within portfolios, that encompasses the case studies but extends much more broadly and including indicators of investment, the multidisciplinary nature of much of CSIRO's research, some indicators of key outputs, outcomes and options. The table is large – perhaps useful in showing the scale of the activities and the possibilities beyond the case studies, but also making serious digestion of the content against the backdrop of the case study results difficult.

Table 3 provides a greatly truncated form of the table, which aligns a number of representative and broadly 'analogous activities' against each case study. This is designed to provide some feel for the scope for extrapolation from the case studies, based on further probing of other areas of CSIRO. The table shows a rich set of analogous activities that, *prima facie* at least, should support additional value.

Note that it is not even necessary to form judgments as to the cost effectiveness of the investments in these areas for them to be relevant to the overall assessment of CSIRO value. Already in Section 0 we have aligned all of CSIRO costs against the value of the case studies – the costs have been 'acquitted' in this process. Additional value from other activities simply adds to the implied benefits without altering these associated all of CSIRO costs. To the extent that there is additional value, the conservatism of the assessment is strengthened.

Of course this does not mean that investments by CSIRO should not be assessed in terms of their own cost effectiveness – of course they should, but that assessment is relative to forward strategy planning, not to the demonstration of whether past impact and value has been large relative to past costs. We would expect a number of the activities – though not necessarily all – set out in the following table to prove up well if subjected to deeper probing but we have not done the assessment and we do not rely on this inference to support our analysis.

Our reading of the two mappings, in Table 3 and Attachment B, is of a rich set of activities likely to add very substantial value on top of that implied directly by the case studies.

Attachment C (and the 108-capability mapping exercise behind the development of the table) is also relevant for the way it recognises the value of the broad multidisciplinary capability in CSIRO, along with the scale and culture, in composing its focused and mission-oriented teams.

Table 3 **Indicative mapping of other CSIRO activities against the case studies**

Case Studies	Identified Value	Estimated Current value of the acquired options (PV)	Examples of Other CSIRO work with potential for similar value propositions
Climate Adaptation Flagship	• Options to reduce net cost of dealing with locked in climate change • Insurance value • Improved information • Lives and infrastructure protected	PV to 2030 >$2b (no accounting for the value of human life protected)	Livestock industries Portfolio's biosecurity work – including AAHL (see Box 2) Creates Insurance value, through capabilities and diagnostic emergency response facilities. AAHL has recently improved the efficacy of human influenza vaccines and provided a pathway for delivery of the first H1N1 pandemic influenza vaccine to the global market place. The costs of a biosecurity outbreak can be very high. Eg. the cost of a major avian influenza pandemic in a developed economy could be as high as 3 per cent of Gross Domestic Product. ACIL Tasman 2006 assessment estimate the value of AAHL's Foot and mouth Disease risk management alone could be in the order of $350-700m (NPV) Clean Coal research being undertaken in the Coal Technology Portfolio is an important transitional technology for Australia and internationally in a carbon constrained world.
Future Mfg Flagship's Cement substitute and novel products	• GHG mitigation • Commercialisation potential • Support for national objectives for international climate policy • *Lower cost compliance for a carbon price*	Commercial value $30m , with upside potential >$130m.	CSIRO has commercialised a technology, known as Windlabs, which provides a more precise method of locating wind farms. CSIRO research on robotic mining has been commercialised and is now the industry standard. In addition to providing productivity improvements for mining this technology has created a safer working environment by reducing workers exposure to environmental hazards. The Future Manufacturing Flagship is currently advancing its research on printable solar cells, which should have potentially wide applications and hence good commercialisation prospects.
Food Future Flagship's Aquaculture Prawns and novel feed ingredient	• Transform the productivity, profitability and sustainability of Australia's prawn farming industry	$400m increase value of prawn production	The FFF is undertaking similar work in fields such as Atlantic salmon, abalone and oyster farming. The Flagship is also working on a range of research using biosensors. One biosensor research stream is paving the way for instruments that will eventually replace detector dogs.

Case Studies	Identified Value	Estimated Current value of the acquired options (PV)	Examples of Other CSIRO work with potential for similar value propositions
	• Reduce the pressure on wild catch		
Food Future Flagship's Resistant Starch Grains	• Preventative health benefits • Commercialisation benefits • Export potential	PV $110m to as high as PV $823	The FFF is also undertaking research into producing Omega 3 plants. Omega 3 in the human diet has been shown to have considerable preventive health benefits particularly for CHD. However, there is also some evidence it is useful in addressing depression and arthritic pain. etc. The Flagship is also developing high value wheat crops for the domestic and export markets. The Preventative Health Flagship's work with the National Bowel cancer screening program has seen five year bowel cancer survival rates likely doubled.
UltraBattery	GHG mitigation from vehicles and stationary energy Commercialisation has created royalty stream potential	PV of CSIRO royalty stream value alone could be in the order of ~$15m to ~$89m	The ET Flagship is undertaking a range of other research to reduce GHG including Smart grids. The Flagship has recently commenced a $100m trial with Energy Australia to test out the technology.
MDB strategy - Policy & support	Provide Government with modelling support Improved efficiency of the strategy	5%/10% efficiency improvement = $1b/$2b	CSIRO has undertaken a wealth of fisheries research including into total allowable catch. For example, CSIRO developed a scientifically based assessment and harvest strategy framework (to be applied in Australia's Southern and Eastern Scalefish and Shark Fishery. This concept has been applied in other fisheries
SKA	Pure science benefits Activity creates benefits for Aust'n industry funded by overseas science institutions Options for testing GHG friendly electricity solutions	Net tangible benefits +$80 m	Australian Telescope National Facility and the Canberra Deep Space Communication Complex provide pure science outcomes. With some finance being provided from outside of Australia. There is a wide range of other facilities, research collections and other facilities maintained or strongly supported by CSIRO.
APSIM	Multiple value paths from multidisciplinary capability Better farm and business decision making		The Wealth from Oceans Flagship has developed models to help reduce oil and gas exploration risk and optimise well placement. The Flagship also undertakes modelling and analysis to enable production of accurate forecasts of ocean conditions in the Australian region's oceans for the first time. The Computational simulation Science Transformation Capability Platform provides access to advanced visualisation tool and imaging and image analysis service
Biochar	low cost (selectively negative		The Livestock industries portfolio has develop new sheep breeding technologies to enable

Case Studies	Identified Value	Estimated Current value of the acquired options (PV)	Examples of Other CSIRO work with potential for similar value propositions
	cost) CCS options Example of strategic seed funding opening doors		resistance to fly strike. Creating the potential to improve animal welfare and reducing the risk that Australia's wool industry will lose market share due to animal welfare concerns.
Light metals Flagship- in particular Titanium	Options to add value to a key Australian resource (Ti)	2006 evaluation of $270m, with upside of $1.5b+ has strength-ened substantially	Australian Future Fibres Research and Innovation Centre - CSIRO is collaborating with Deakin University to undertake carbon fibre research, which creates options for the creation of for the development of a new Carbon fibre industry in Australia. Scientists previously working in the LNF have been assigned to work in this new research centre
Undersea Mineral map	Support for government policies to limit unnecessary costs & risks Longer term support offshore mining		CSIRO has numerous collections, such as the National Algae culture collection and the national fish collection, which provide options for research to halt biodiversity decline.
Opticcool	Potential GHG mitigation Commercialisation returns	TBD	The PH Flagship has licensed a colonoscopy simulator technology. The Plant Industry Portfolio has created a cotton fibre measurement instrument which has been commercialised.
Cross CSIRO Climate Change	Demonstration of self-hedging character of multiple CSIRO strains in mitigation and adaptation		CSIRO has implemented a multidisciplinary initiative known as **Transformational Capability Platforms** (TCPs). The ultimate aim of the TCP is to strengthen key cross-organisational groups of capabilities to produce impact. Australia is experiencing growing urbanisation coupled with aging of infrastructure. CSIRO's Sustainable Cities research theme aims to revitalise Australia's cities through new planning and design technologies and integrated urban infrastructure and management solutions. The research brings together capability/knowledge and specialist methods, tools and technologies from CSIRO Flagships and Divisions

Data source: ACIL Tasman and CSIRO

Box 2 **Australian Animal Health Laboratory (AAHL) – provides insurance against biosecurity risks**

AAHL is a major national animal disease facility managed by CSIRO Livestock Industries. It was established in 1985 at a cost of $150 million (1985 dollars) as a centre for the diagnosis of and research into new and emerging animal diseases, in order to protect Australia's disease-free status and trade in animal products and live animals.

AAHL is co-funded by CSIRO and the Commonwealth Department of Agriculture, Fisheries and Forestry. It is also receives research funding from industry organisations and commercial companies.

AAHL's primary role is emergency disease response in the event of an exotic disease outbreak in Australia. It provides diagnostic testing and surveillance and research to develop new diagnostic tests, vaccines and treatments for emerging animal (livestock, aquaculture and wildlife) diseases of national importance.

A critical component of AAHL's emergency disease response capacity is its ability to provide 'surge' capacity in the event of a major disease outbreak.

AAHL is a party to a number of international partnerships and collaborative arrangements. For example, it is a regional reference laboratory for the World Organisation for Animal Health.

ACIL Tasman's 2006 analysis of the value created by AAHL aimed to build up to both a lower bound estimate of 'quantifiable' value delivered by AAHL and a characterisation of any remaining components of value that are relevant to the overall assessment of AAHL. The analysis focused on two diseases: foot and mouth disease and Avian Influenza. Both diseases have the potential to cause very significant economic damage to the Australian economy should an outbreak occur. The results showed that the value that AAHL delivers in FMD detection and control alone is in the order of $25 million to $52 million per annum. This estimate represented a lower bound of quantifiable value delivered by AAHL. The estimated were based on expected financial costs to the economy and did not include the likely substantial additional insurance premium, over and above expected 'claims', the community might be prepared to pay to reduce the likely impact of a potentially very high cost of an outbreak of these or other diseases.

To provide an indication of the insurance value associated with Avian Influenza, we draw attention to an 2006 report by the World Bank, which estimated that the cost of **a major avian influenza pandemic** in a developed economy could be as high as **3 per cent of Gross Domestic Product**.

The value of AAHL has been demonstrated since the 2006 evaluation by ACIL Tasman through AAHL's response to outbreaks of other diseases including:

- Hendra virus, which not only poses a risk to horses but also human life; and
- Equine Influenza, which resulted in the lock down of the horse racing industry in a number of Australian states
- Swine flu- providing a pathway for delivery of the first H1N1 pandemic influenza vaccine to the global market place.

In the case of Equine Influenza AAHL played a major biosecurity role in containing the disease. The value associated with minimising the extent of the outbreak to NSW, Queensland and the ACT, rather than the whole of Australia is significant. Further, it is arguable that through AAHL's diagnosis and testing the time of the lockdown in NSW, Queensland and the ACT was lower than might otherwise have been the case. Reducing the lockdown period by even week would entail considerable value. For example, ABARE estimated that NSW, Queensland and the ACT horse industry (equine businesses, farming and recreational enterprises) lost $**3.35 million** in income **each day** as a result of the 2007 outbreak.

AAHL continues to provide Biosecurity insurance against these and other diseases and it can be expected that the value of this insurance has increased in real terms since ACIL Tasman's 2006 assessment.

Source: ACIL Tasman, 2006 Assessment of the Australian Animal Health Laboratory and Report of the Equine Influenza Inquiry by the Hon. Ian Callinan AC, dated 23 April 2008 and DAFF INQ.016.0001 submission to the inquiry containing ABARE briefing,

12.2 Lessons for all of CSIRO value

Against this background, we have reached the view that the indicative value figure of $6 billion should be viewed as quite conservative in relation to the case studies and substantially more conservative again if viewed as a lower bound on CSIRO value. Realistically, we would expect the valuation to come out of a systematic trawling of all CSIRO activities, in a similar manner to that done in the case studies, to lead to a value figure that is some significant multiple of the conservative case study figure.

There seems little to be gained by trying to pin this down to a single number. The error bands would necessarily be huge (though starting well above the $6 billion figure).

As outlined earlier, we would see it as reasonable to compare this value figure to CSIRO costs over a 3 to 5 year period – something of the order of $5 billion. This is where the purpose of the comparison is to judge the recent 'fertility' of investment in CSIRO off the back of the sunk investment in the past – which we see as the more policy-relevant interpretation of the purpose of our study.

We strongly suspect that a 'whole of life' assessment of the value of CSIRO would again point to value well in excess of costs, but that is not the question we address in comparing recent costs to recent delivery, off the back of this recent investment, of high value options for Australia.

Our analysis strongly supports the view that recent CSIRO operations have been creating value, both for Australia and globally, that is substantially in excess of recent costs. Even heavily conservative estimates of value look to be at least several times costs. Both the conservatism and the focus of appropriate research, policy engagement and commercialisation on big issues concerned with high risks for society suggests the potential for a lot more value. The same assessment provides strong support for the mission-oriented, multidisciplinary and responsive model now being used across CSIRO.

It does not follow from this that CSIRO is delivering a high return on every dollar invested, though our general impression is that the CSIRO operating model is less likely, than those of many research organisations, to persist with research as evidence of falling prospects emerges. Nonetheless, deeper probing of the management of the 'marginal dollars' – within and across research areas – would be needed to underpin a strong conclusion about overall efficiency as opposed to the cost: benefit considered here.

Equally, a conclusion that recent investment has returned well does not logically imply that the same will be true of future investment. Nonetheless, our assessment did display an impressive range of opportunities for continuing

to create value – at least as prospective as the forward options observed at the time of our 2006 review. We expect strong performance to continue across a wide base of activities.

In some areas, CSIRO's flexibility in redirecting resources is perhaps stronger as a reactive strategy than a proactive one. It is one thing to periodically assess new information and redirect resources in response. It is another to integrate options planning from the start, looking at ways of building and maintaining greater flexibility to respond, at low cost, to plausible new information. Such proactive planning for flexibility can drive significantly different strategy – favouring different approaches to key problems in terms of technical approaches, capabilities, capital intensity and flexibility of capital investment. At an organisational level CSIRO plans very much with an eye to flexibility and responsiveness. Based on our interactions with specific areas in developing the case studies, we believe there is scope for carrying this approach, and the type of options-based planning tools used in probing value, more deeply in program planning. This could deliver some significant improvements in flexibility and value for money.

We did encounter some evidence of confusion and even conflict in dealing with the competing pressures to deliver commercial returns to CSIRO, to assist industry and to generate public good outcomes by addressing market failures and gaps in outside capability. Such confusion can be traced in part to CSIRO's formal functions (including the explicit function to assist industry), in part to the organisational history and in part to funding pressures. Some confusion of this type is probably inevitable for an organisation operating in CSIRO's space and having an impact there. Strong alignment with National Research Priorities helps in limiting these concerns

Nonetheless, we believe there could be scope for limiting these concerns through clearer external as well as internal emphasis on public good outcomes as lying at the heart of the rationale for CSIRO activity. Under this approach, commercial revenues would be viewed as a means to an end – and primarily as a way of using what are effectively 'joint venture' relationships with private interests to deliver efficient responses to problems involving both private and public good elements. *Cost effective delivery of public good outcomes* (including corrections for both market and regulatory failures, including in innovation markets) would be the primary objective, affording greater consistency.

13 Recommendations: CSIRO strategy

The Terms of Reference for this project required ACIL Tasman to briefly identify any areas where CSIRO could improve (a) the level of impact delivered from CSIRO activities and (b) its capacity to demonstrate impact, as well as the implications of this study for CSIRO's strategic planning. This has not been a strategic planning exercise – and we are aware that such an exercise is under way. However, our assessment has pointed to some lessons that appear highly relevant to that planning – and perhaps even more so to the more detailed planning and justification of individual elements in the overall CSIRO portfolio.

Our assessment provides strong support for the mission-oriented, multidisciplinary and responsive model now being used across CSIRO. This model has strong synergies with the real options framework used in our assessment of CSIRO's value and impact. At an organisational level it appears that CSIRO plans very much with an eye to flexibility and responsiveness. However, we believe, based on our interactions with specific areas of CSIRO in the course of this project, that there is scope for carrying through this approach, and the type of options-based planning tools used in probing value, more deeply in program planning. This could deliver some significant improvements in flexibility and value for money.

Integrate options planning at an early stage "pre-project" to maximise flexibility

We have observed that in some areas CSIRO's flexibility in redirecting resources is more apparent as reactive than as proactive strategy. It is one thing to periodically assess new information and redirect resources in response. It is another to integrate options planning from the start. In other words when considering investing in a new research project we recommend that CSIRO look at ways of building and maintaining greater flexibility to respond, at low cost, to plausible new information.

Anticipation of need for flexibility

We consider there is scope for more *proactive* options planning, within Research Groups and Flagships

- There should be planning from the start for flexibility in R&D processes as well as outcomes. This approach will tend to favour choices of technology, capability and commitment to capital investment that are different from the natural strategies if the emphasis is only on reactive use of existing flexibility.
  - For example, in choosing between approaches that rely heavily on physical engineering or ICT, there might be a preference for the latter if it is seen as offering greater flexibility for change, and greater scope for serendipitous application, even if not nominally more prospective or lower cost.

- The various research areas appear good at creating flexibility in R&D outcomes, and at exercising available flexibility in R&D resource management.
  - But they are not necessarily ensuring that new projects and programs are designed to provide maximum flexibility in the first place; i.e. it is not clear that they are creating the optimal level of strategy flexibility.
- The case for a flexible strategy was made in our last review, but it is not clear that substantial progress, below the broader organisational level, has occurred.

Create a stronger emphasis on public good outcomes from research - even research that involves private funds

We believe that there is considerable scope at the "pre-project" stage to provide greater clarity and guidance on the nature of the "problem" to be solved. There is a role for Governments to invest in R&D because they:

- are direct users of the information delivered; and
- recognise limitations on an efficient level and mix of R&D being undertaken without this involvement (i.e. market failure, and sometimes regulatory failure, exists).

The case for intervention when markets fail (or regulatory impediments limit market incentives and capacity to respond to opportunities) is well based, provided that the intervention does not do more harm than good. However, sometimes it is better to intervene by attacking the impediments rather than throwing R&D funds at the resultant gaps.

Market failures can also stop interventions from working

One of the problems with just directing money at market failures is that the very forces that have impeded the markets from making the investment in R&D can act to inhibit effective adoption and use of the R&D funded by governments to address the failure. This is not automatic, but it is a risk, and indeed a generic risk, to be managed when symptoms not causes are attacked. It is also a risk that has not been uncommon in the recent history of R&D support in CSIRO.

Clarity about function…

It should be recognised that sometimes there are conflicting and even confusing signals regarding the function of Government funded R&D activity. And questions arise on how to balance public against private good emphasis in work and funding. We recognise that the confusion entails perceptions of external as well as internal expectations, and links in part to the statutory functions of CSIRO.

…focused on public goods

We recommend that CSIRO place stronger emphasis on public good outcomes as the focus of planning. This can often involve engagement with private interest but as a means to that end – as a way to make the delivery of public good outcomes more cost effective.

Current perceptions within the organisation probably favour an excessive emphasis on commercial relative to public good outcomes. It should be clearly recognised that efforts by CSIRO to maximise commercial returns from its work can sometimes conflict with the success of the work in delivering greater public good outcomes.

The trade off between commercial returns and public good impact and returns should be recognised and managed carefully. *Cost effective delivery of public good outcomes* (including corrections for both market and regulatory failures, including in innovation markets) should be the primary objective.

Early focus on counterfactual

We also recommend that there be earlier, and more explicit consideration, of the counterfactual when research investment is being planned and reassessed. There are a number of issues here:

- In a number of the case study deliberations, CSIRO team members showed evidence of little thinking about the counterfactual as more than continuation of the *status quo*.
  - The research planning appeared substantially to be justified by the scope for enabling a better outcome than the status quo, with relatively little regard for the way that these processes are likely to develop even without CSIRO engagement.
  - In many cases – and quite understandably – the counterfactual was viewed more as the competition to be beaten than a serious challenge to the level or form of justifiable investment by CSIRO if it is looking more to dealing with market and regulatory failure problems.
    - … A level of competition is often desirable, as a spur to innovation, but if the primary rationale for CSIRO investment, especially of taxpayer money, lies with market and regulatory failure, then indications of strong competition to solve the same problems does look like *prima facie* evidence that the failures are not going to impede progress greatly.
    - … This does not contradict the 'extra irons in the fire argument' raised in several of the case studies – this argument is valid but the investment still needs to be justified in terms of the extra value delivered over the counterfactual,.
  - In other cases, we found remarkably little understanding of the 'competition', even though a good understanding could have resulted in significant change in strategy.
  - These considerations have implications for the strength of justification that can be mounted, *ex ante*, for CSIRO investment. Failure to address the counterfactual, and the focus on incremental value from CSIRO engagement, could well favour investment occurring in areas where, with more careful probing of the extra value offered by CSIRO, the investment would be questionable.

- However, probably even more important is the fact that a careful assessment of the counterfactual can provide valuable insights into how best to structure the CSIRO investment to deliver the most cost effective incremental value.
  - An understanding of the counterfactual can generally only emerge from consideration of potential market failures and regulatory constraints and from a solid understanding of related work being undertaken in Australia and overseas.
  - This very process can be expected to highlight gaps, constraints that may apply equally to 'successful' CSIRO research or that may prove less restrictive under some alternative approaches to the problem, and potential partners/collaborators as well as competitors.
    - … It may also highlight 'risks' in the counterfactual, that point to opportunities for CSIRO to play a role in offering insurance against such risks – this may well entail a quite different structure of research if maximum additional value is to be offered.
- It is also crucial to recognise that the counterfactual can involve many elements apart from the specific research objectives of a CSIRO investment proposal.
  - Broader market and policy developments are also highly relevant to any assessment of the value offered by CSIRO engagement. For example, as is highlighted in Appendix D, plausibly different outcomes in the treatment of GHG emissions in Australia and internationally have major implications for the way that CSIRO might deliver value in mitigation options, and for the value of such mitigation.

'External' testing of the counterfactual will sometimes be cost justifiable

The strategic value of a sound understanding of the counterfactual is such that, at least for larger-scale investment proposals, it would seem important to ensure that the counterfactual is seriously tested by expertise outside the team proposing the research. This could involve expertise outside the team, and possibly in some cases outside of CSIRO, in relation to policy trends and risks, economic conditions and analogous technology trends.

At the mission-oriented level of the Flagships, a serious investment in the development and testing of the counterfactual could be highly cost effective in allowing the research approach to be better structured – including in the inclusion of flexibility options designed to deal with plausible developments in the counterfactual – and could add greatly to the ease and credibility with which later impact could be demonstrated.

The same reasoning could apply to a smaller scale of activity, especially if there is high potential value in the concepts being explored and significant interest in those concepts outside of CSIRO. Similarly, in areas where there is a lot of uncertainty, not just about research success but also about relevant aspects of

the environment in which the research might be applied, we could see value in a more structured assessment of possibilities.

Cross-CSIRO consistency

Importantly also, we would see a strong case for seeking broad consistency across CSIRO in relation to common or overlapping assumptions regarding the counterfactual. CSIRO credibility in seeking to demonstrate impact and value will not be helped by different assumptions being made by different areas – especially, if the differences are biased in favour of each proposal. This would not require any deliberate strategy for it to be achieved if there is not some broad coordination required. Individual areas will tend to see opportunities through the lens defined by their research interests.

For example, a team working on climate adaptation may well know a lot more about adaptation possibilities than about the geopolitical conditions underpinning GHG mitigation policy. Nonetheless, the future mitigation policy settings are as relevant to a team working on adaptation as they are to a team working on mitigation options. And it is important that the adaptation team does not justify its work by assuming failure in mitigation policy while a mitigation team argues for the value of its work because of assumed success in establishing mitigation policy that will make the technologies competitive.

In undertaking this study, we have had to deal with very different perspectives held by different researchers – even when dealing with such overlapping assumptions. We have had the advantage of close coordination in the assessments being done – but not the advantage of surplus time and budget to refine these assumptions fully.

We do recommend that CSIRO look closely at a process that allows its planning to take advantage of progressively better and more consistent, CSIRO-wide assumptions relevant to the counterfactuals and to document impact relative to the counterfactuals. This could offer advantages of scale economies in developing these assumptions, as well as credibility advantages in demonstrating impact and value. The presence of such systems would certainly help with the type of assessment we have undertaken – but its value will be much greater if this better-coordinated information is available much earlier in the planning processes.

Centralised repository of cross-CSIRO assumptions

One way of capturing and rendering accessible such information could be via a central database or information repository covering assumptions and methods. This might exist as a single CSIRO-wide database or there may be an overarching database storing high-level 'generic' assumptions, while each major research area has its own repository, linked to the overarching database and that follows agreed protocols. Such a system could be used to record the information appropriate to impact assessment and valuation, as well as

integrating assumptions about the counterfactual. We would expect it also to help fine tune the best form of CSIRO involvement over time.

But not just a mechanical documentation process

Care would be needed to avoid creating an essentially mechanical process, or 'hoop to be jumped through', with data supplied as a matter of form but not effectively used to improve research planning and delivery as well as impact demonstration. Much of the database could desirably be free-form, to provide easier scope for contributing and capturing all relevant insights.

Accessible, maintained and coherent

A key thing is that it be accessible, that there be a responsibility for project planning and management to contribute to keeping it up to date and that there be a responsibility for project proponents to justify any decision to depart from the assumptions in the overarching database. Such departures may be justified in some cases – but they will need to be justified if the integrity of the process is to be protected, along with the credibility of the impact assessments. Protocols to ensure it is maintained and used effectively will be important – but we would favour relying heavily on incentives via internal funding mechanisms and via expectations that these processes will support CSIRO;'s general ability to sustain and, as appropriate, build its funding levels to fit the available opportunities.

Such an information repository could be seen as a major extension of the type of information assembly we found necessary in developing this report – including:

- The structured mapping and information on CSIRO activities as a whole, as summarised in Appendix B that was crucial in drawing cross-portfolio inferences;
  - Of course, CSIRO already has several ways of mapping its activities, but one that specially supports logical grouping of activities in the way we have done provides better insights into areas where there may be a need for coordination in assumptions and methodologies, while also supporting the type of inference about overall value that we sought in developing this mapping.
- As above, information on the assumed counterfactuals, recognising in many cases this will take the form of a spectrum or discrete set of plausible future outcomes, with this variation highly relevant to the risk management value of CSIRO work.
- Generic collections of economic and technical information of broad relevance to both strategy planning and impact assessment – such as Government estimates of carbon prices under an ETS, social cost of carbon estimates (as documented in Attachment D.4), official demographic projections, indicator studies relating to conservation values etc.
  - The coverage will, of course, evolve with CSIRO's overall responsiveness to perceived trends and needs.

- Explicit evaluation parameters, such as the agreed treatment of discount rates.

Aspects of the work done in developing this report provide important pointers to the structure of some of the information that might usefully be assembled in this information repository. We could, for example, see clear value in early documentation of intended impacts and periodic updates as lessons are learned. As part of the structure of the envisaged impacts, we could see value in reflecting some of the concepts we have used, including:

- the forward options created by the research and the circumstances under which the exercise of the options is seen as sensible;
- insurance against risks, such as biosecurity risks and the risks associated with locked in climate change
- the provision of information to assist policy development and program implementation
- other public good benefits, such as preventative health impacts etc

Train researchers to understand and consistently apply real options value concepts to identify impact

We recognise that research leaders (including those in the Transformational Capability Platform) are scientists and not economists. However, we can see considerable value in CSIRO developing a consistent impact assessment and valuation methodology based on the options framework and then training up researchers sufficiently to apply this framework as part of their project development and in their reporting for the proposed central impact database.

We are not proposing that such a system be designed in one hit and dropped into the CSIRO systems. However, we do see a lot of scope for relatively rapid progress in developing up sensible protocols and information provision requirements, with periodic review to guide the evolution of the process. We would prefer not to see it so much as database driven than as driven by the incentives amongst researchers to ensure their efforts are directed in high value ways, where that value is amenable to credible documentation. Such credibility should link strongly into:

- competitiveness in accessing the funds being sought,
- prospects for success in accessing options to scale up work as it progresses, if and when this makes sense during the life of the research; and
- scope for credible ability to demonstrate impact, value and value for money as part of any ex post review process that might help guide future general funding of CSIRO.

It so happens that, coming out of the current review, CSIRO is particularly well placed to continue moving in this direction. It has access to a range of up-to-date impact assessments that should be amenable to further probing in terms of the marginal returns they offer on additional funding; we have undertaken work on a range of counterfactuals, some of which should have

broader application; we have developed positions on the handling of discount rates etc that could at least afford a sensible starting point.

When we undertook our 2006 review, we recommended that CSIRO follow through in embedding options planning into its processes. While the concept was well received last time, relatively little implementation occurred. We repeat the advice this time, along with the recommendation that CSIRO look at picking up the above specific elements for testing rationale and cost justification, for imposing a level of consistency across CSIRO and for acquiring information in a form that should be better suited to the type of review we have just completed.

Like most investments, this is likely to require some up-front costs ahead of seeing the benefits. However, we are of the view that the benefits could be considerable – in terms of both greater value from the resources being used and greater scope to justify increased resourcing of some areas.