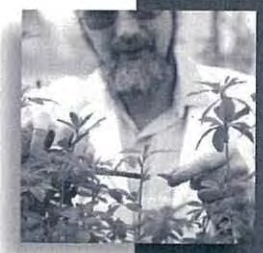
CSIRO

CSIRO Strategic Plan

2000–2001 to 2002–2003

CSIRO Strategic Plan



2000–2001 to 2002–2003

In 2001 CSIRO will celebrate 75 years of proud service to the Australian community. The nation has reaped immense rewards from its investment in CSIRO, and continues to do so through the adoption by industry and the community of its technologies and advice—bringing economic, social and environmental benefits. Rural communities have been provided new income streams, industry's profitability has been supported by new technology, employment opportunities have been created by the formation of new companies, waste products have been turned to profit and environmental benefit, and innovative solutions have been applied to address large-scale environmental problems.

The application of discoveries of science, founded on the understanding and foresight which comes from the research undertaken in organisations such as CSIRO and the universities, enable us to assess the risks and opportunities that Australia faces. Science is not just an activity for the curious; it is the vital tool with which to shape our future and claim our place in the new knowledge economy. It is critical therefore that the nation's vision be one of promoting rather than limiting the growth of scientific knowledge.

The need to lift and sustain Australia's innovation performance was the subject of the National Innovation Summit in February 2000. It is a goal that CSIRO shares and will work towards in partnership with industry, research agencies, universities and governments. It is clear that the science system as a whole needs to grow and that the investment across universities, government agencies and business programs needs to be appropriately balanced.

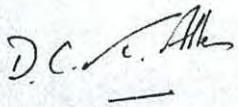
The combination of broad scientific research, development and training capability within our universities, CSIRO and industry-specific Cooperative Research Centres (CRCs), represents a unique national innovation system with considerable flexibility and responsiveness. In this regard, a major strength of CSIRO is its connectivity. In addition to technology transfer and commercialisation relationships with more than 2000 firms (including many high-technology small and medium-sized enterprises) and participation in more than 50 CRCs, CSIRO makes important contributions to the Australian innovation system through inputs to government policy, national and international scientific collaborations, and the provision of services and national facilities.

With its user-guided priority setting, a developing R&D investment culture, growing commercial professionalism, and proven capacity to partner with others to form Australia's best teams, CSIRO is a cornerstone of Australia's innovation system. Our aim is to leverage these assets and attributes to maximise the return on public R&D investment to Australia.

In doing so, CSIRO must take more responsibility for its future by maximising the uptake and impact from its scientific endeavours and optimising the commercial returns from its intellectual property. This does not mean sacrificing its intellectual base for short-term reward but rather expanding this base for its inherent value, for its long-term benefits and in response to industry and community needs. To sustain even moderate growth in our research capability, we will require a budget twice today's in ten year's time and we cannot expect all of this to be provided from the public purse.

To that end, the Board is engaged in an exercise with the CSIRO Executive to explore options and new areas for CSIRO to grow so that it can contribute to a higher value Australia—an Australia which can develop its existing industries by the clever application of information technology and biotechnologies, build new and sustainable industries to diversify our economic base, while also managing large-scale environmental issues to sustain the nation's ecological base and enhance the quality of life. Only first class science will be able to underwrite such a future, a future that will be shaped to a large degree by the government's response to its own National Innovation Summit and Science Capability Review. Wisely led, there are enormous rewards to be obtained for Australia.

Section Two of this strategic plan comprises the executive summaries of the 22 sector plans developed through a comprehensive and intensive process involving detailed consultation with CSIRO's external Sector Advisory Committees. Seventy per cent of the members of these Committees are drawn from industry and the community; 30% from Commonwealth and State government departments with a direct interest in our work. CSIRO has had to make some hard decisions on key areas of the research investment portfolio. The nature of these decisions and the strategic considerations behind them are summarised in Section One.



D Charles K Allen, AO
Chairman of the Board

July 2000

SECTION ONE: *CSIRO's Strategies for Australia*

SECTION TWO: *Sector Plans*

SECTION THREE: *The Decision Process*

Inside back cover

SECTION ONE
CSIRO's Strategies for Australia

OUR VISION: To be a world class research organisation vital to Australia's future

Values critical to our success

Satisfied customers and supportive stakeholders through application of our research	CSIRO—Unity of purpose, diversity of means	Top people, top performance, integrity, trust and respect	First class science—because it helps Australia

Operating Principles

- We determine our research and commercialisation priorities by assessing the needs of, and potential benefit to, our customers, based on an understanding of their business and the world markets in which they operate.
- We contribute our expertise to the development of science and technology policy and priorities in Australia.
- We commit ourselves to excellence in technology transfer to ensure timely exploitation of research results.
- We provide quality advice and service.
- We deliver our research and services on time, within budget and in accordance with legal contractual and ethical obligations.

- We determine priorities and implementation strategies at all levels of the corporation by a systematic process.
- We apply the highest standards of management practice in all our operations. We pay particular attention to excellence in project management. We foster a culture of teamwork.
- We evaluate all of our activities, working towards the world's best practice in quality and productivity.
- We accept accountability for our decisions on the use of CSIRO's resources and take pride in our achievements for Australia.
- We use lessons from our own and others' practices and experience to improve our performance continually.

We work together to create an organisation that:

- Seeks to recruit the best and the brightest, provides a stimulating environment to encourage individuals to develop their full potential and provides career opportunities which make CSIRO an attractive development base for future industry leaders.
- Fosters adaptability and recognises exceptional performance with appropriate rewards.
- Cares for the safety and well being of all employees with employment policies to support corporate goals.
- Fosters creativity that underpins our performance and delivery.
- Draws upon the breadth and depth of our skills to assemble excellent teams to tackle major challenges, and uses networks of special skills inside and outside CSIRO.
- Respects the unique skills, professionalism and knowledge of all our employees, and recognises that we are responsible for creating and maintaining our reputation.

- We maintain a world standard of scientific and engineering excellence in order to deliver agreed outcomes to our customers in industry, government and the community, on time and within budget.
- The quality of our scientific research enhances Australia's international standing.
- We work with Australia's education and training organisations to increase awareness of science and technology, and to enhance the supply of excellent graduates into the scientific and technical workforce.

CSIRO—AUSTRALIA'S INNOVATIVE SPIRIT

Colin Adam
Acting Chief Executive

Invigorating the Present, Embracing the Future

It is widely accepted by international investment observers that Australia needs to build up its presence in the new knowledge-based economy, fostering strong exports for companies with reliance on advanced technology and sophisticated services to complement its current strengths in the commodity export sectors.

...CSIRO will need to be flexible and to have staff who respond creatively to changing environments in different sectors.

An important question for our Board to consider is how CSIRO should evolve during the next decade in order to maximise our contribution towards a successful national response to these challenges. As external circumstances change for Australia, for Australian companies (many of whom are already part of multi-national enterprises), and for the research base of Australian universities with their own maturing relationships, CSIRO will need to be flexible and to have staff who respond creatively to changing environments in different sectors.

Positioning in relation to industry

The strategic positioning of CSIRO has been influenced by a group of 22 external Sector Advisory Committees advising the Executive on investment priorities in strategic R&D during the next three to five years. Seventy per cent of the members of these committees are drawn from industry. It is clear that these committees are willing to take a more structured approach to the general discussion of issues facing CSIRO during the next decade. We welcome that engagement and we will foster that discourse.

It is my firm belief that during the next decade CSIRO will remain a vital resource for the evolution of knowledge-based companies and solutions to national problems, but that the routes to market through which various scientific discoveries are exploited will differ in different areas of the economy and for companies at different points in their life cycle.

A recent study of Australian patenting,[1] commissioned by CSIRO and the Australian Research Council, found that Australian industry is very dependent on public sector science (90% of scientific citations versus 73% in the USA). Overall, Australia's patenting rate per dollar GDP is below world average and falling—a 70% increase in the patent portfolio would be required to match those of our competitors—and Australia's patent portfolio is characterised as largely 'old economy' with low impact and a long cycle time, but with strong science linkage. Identified areas of strength and opportunity are biotechnology and pharmaceuticals; areas of weakness and decline are telecommunications and semiconductors. These findings further highlight the need for a concerted and cooperative effort to lift Australia's presence and performance in the knowledge economy.

Positioning in relation to universities

There is a complex web of interactions between CSIRO and Australia's universities. The most fundamental of these interactions are those between individuals and teams of researchers across the various institutions. For example, collaboration over many years between CSIRO and Macquarie University on research into, and construction of, the world's first high performance wireless local area network (LAN) has led to the establishment of a start-up company—Radiata Communications.

Another significant element is the contribution CSIRO makes in complementing the role of universities in research training. In 1999 CSIRO supervised 755 post-graduate students for universities throughout Australia, 30% of these through our involvement with the Cooperative Research Centres program. Many CSIRO staff also contribute to the teaching programs of universities and other institutions.

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Over and above these strong personal links, the CSIRO Executive is working to enhance institutional relationships with the leading Australian research universities, particularly in regard to the potential use of CSIRO national-scale facilities, and the more general sharing of facilities. Significant progress has been made with a limited number of universities—such as Adelaide, Curtin and Queensland—in investments in co-located facilities. One could expect that more of

[1] *Inventing Our Future: The Link between Australian Patenting and Basic Science*, F Narin et.al., Commonwealth of Australia 2000.

these discipline-specific examples will emerge in the future as the benefits of shared capital investments, shared research facilities and joint research programs gain wider recognition.

Relationships with providers of capital will probably be an area of significant change for CSIRO in the coming decade.

Positioning in relation to financial markets
Relationships with providers of capital will probably be an area of significant change for CSIRO in the coming decade. Whereas a decade ago early stage seed and venture capital was in very short supply, Australia now has an adequate supply of capital to finance a broad range of early-stage company formations. In financial year 1998–99, Australia invested some $980 million in venture capital. The principal challenge facing CSIRO, in my view, is whether the organisation can respond quickly enough to this feature of the new economy and access available capital to support new companies using advanced technology to very quickly reach positive cash-flow and growing profitability. In many respects this represents the new game for Australia. Our ability to do this will define our position in the world's wealth-generation stakes, and our staff have the opportunity to be players who make a vital contribution.

Changing roles—diversity of means
In this environment CSIRO must strike the difficult balance between meeting the expectations of a taxpayer-funded organisation—using high-level science to solve important national problems, many related to sustaining the natural resource base—and the requirements of external providers of capital for new company formation in the knowledge economy. The appropriate strategy for the organisation is to have the capacity to do both simultaneously in response to different external markets and drivers. This is a model in which the advantages of hybrid vigour become possible. Another strength of CSIRO in this situation is that the organisation is large enough to learn from early capital-market experiments and experiences, and to share these across the breadth of markets and sectors in which the organisation operates.

CSIRO's relationship with government will be extremely important during this period of transition. The Government's general intent is that we earn more from the private sector, but this must be consistent with the achievement of the Government's overall objectives. The rationale for the organisation's 30% external income target will change if the investment of private-sector capital becomes a parallel priority. The priority and resulting funding mix will vary across different areas of research. Areas such as software development might have to move quickly to largely external investment, incubator project funding by government and spin-off opportunities. Biotechnology investments will be a challenge because of the speed of scientific advances and some community concerns about the impact of such advances. In areas of national importance to regional development, and solving large-scale environmental problems, public sector funding will be appropriate, while medically-related therapeutic research may be venture capital driven.

Taking the initiative
In attempting to meet all these challenges, CSIRO will continue to place high priority on developing initiatives that promote an innovation culture, increase the generation of new companies and bring together world class teams.

The *aXcess* series hybrid low emission motor vehicle is a powerful example of CSIRO's capacity to manage the integration of multiple technologies that position Australian industry in world markets. The outcome of a $12 million CSIRO project with the Department of Industry, Science and Resources, the Victorian Department of State and Regional Development and 102 local component suppliers, the *aXcess1* vehicle generated $730 million in exports over 18 months. The *aXcess Australia* and *Ecommodore* vehicles have followed in this series.

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Further examples of CSIRO's commitment to assembling world class teams and building critical mass with other providers include:

- Food Science Australia—a joint venture with the Victorian Government's Australian Food Industry Science Centre;
- Institute for Molecular Biology—is being developed by the Queensland Government, CSIRO and the University of Queensland at the university's St Lucia campus in Brisbane. It will be the largest facility of its kind in the Southern Hemisphere;
- Queensland Centre for Advanced Technology—located at Pinjarra Hills in Brisbane, this is a centre for CSIRO and private sector companies engaged in minerals research and its application;
- Australian Resources Research Centre—is being established at Bentley, Western Australia as a major facility for minerals and petroleum resources research involving CSIRO and Curtin University;

- Waite Institute, Adelaide—an integrated campus with Adelaide University, South Australian Research and Development Institute and CSIRO. It is a key resource for natural resource management in dryland ecosystems; and
- participation in Cooperative Research Centres (CRCs)—CSIRO is a core participant in 51 of 65 current CRCs.

Already, more than 50 CSIRO spin-off companies generate more than $200 million per annum. CSIRO will undertake initiatives to increase the number of spin-off companies where this is best commercial path. An important challenge will be dealing with the complex issues surrounding staff equity and intellectual property provisions.

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CSIRO has in place a number of programs that promote a deeper understanding of science and its contribution to the nation across the breadth of Australian society—from schoolrooms to boardrooms to parliaments—and continues to work closely with others to develop initiatives towards building a culture of innovation. CSIRO's participation in the National Innovation Summit, held in February 2000, marked an important step in this process. The organisation's submission to the summit can be viewed on the internet at the following address: http://www.isr.gov.au/industry/summit/reference/submissions/csiro.pdf.

CSIRO'S INVESTMENTS FOR 2000–03

Summary of the Investment Decisions

The decisions on sector investments (see pages 10 and 11) are the culmination of an intensive process which involved considerable effort by a great number of people across CSIRO and externally, including a major contribution by members of our 22 Sector Advisory Committees. In responding to this analysis, the Executive adopted a portfolio investment approach in judging the relative merits of research for different sectors against past performance and prospective value.

We looked particularly for cases where there are good feedback loops between market demand and the opportunities offered by science and technology. Where these are strong, we decided to increase effort or maintain effort at a high level; where they are absent or weak, we have reduced resources.

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Thus we have sought to judge where the highest return on CSIRO's dollar would arise, allowing for the fact that such return can be realised through support for wealth creation and/or public good research underpinning Australia's future welfare.

In setting the Divisional budgets based on sector plans for the triennium, we have also resolved to institute continual review of these plans by requiring that changes contemplated by Divisions be introduced following discussions with the relevant Sector Coordinators and subject to the agreement of the relevant Deputy Chief Executives and/or the Chief Executive for major changes.

Relative to the 1997–2000 sector investment profile, we are making evolutionary changes to CSIRO's sector investments in the new millennium. Some of these changes have their origins in trends already underway in CSIRO in response to changing industry circumstances. Our decisions for the coming triennium will position us for the next decade and beyond.

The major sector shifts are:

- increases to the Land and Water, Mineral Exploration and Mining, Marine, Food Processing and Radio Astronomy Sectors
- decreases to the Meat Dairy and Aquaculture, Forestry Wood and Paper Industries, and Built Environment Sectors.

The sectoral changes have been made with a careful eye on Divisional implications. Relative to forward projections on a 'steady state' basis, the direct appropriation income to Divisions for the next triennium involve some major Divisional changes:

- increases for Marine, Exploration and Mining, Australia Telescope National Facility, Minerals, and Molecular Science, with Food Science Australia and Health Sciences and Nutrition receiving a non-recurrent increase
- decreases for Forestry and Forest Products, Textile and Fibre Technology, Telecommunications and Industrial Physics, Tropical Agriculture and Animal Production.

Four clear observations may be drawn from the dialogue and decision process we have been through.

First, the planning process highlighted a level of strong and exciting demand for CSIRO's contribution to wealth creation and environmental sustainability that is far beyond our capacity to deliver given our current level of resources. CSIRO needs to grow—in partnership with industry, government and the community—for the benefit of all.

Second, the move to sector-based planning has resulted in substantial changes to Divisional and inter-Divisional research programs, improving the focus and strategic direction of research effort for the various sectors. Many improvements to sector research portfolios have already been made and others are in train. We are convinced that the benefits of the detailed review and planning process clearly outweigh the undoubted costs in terms of time and effort for those involved.

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Third, it is also abundantly clear that CSIRO is working with a more diverse range of clients and research collaborators than ever before. This has resulted in the use of a wide range of commercialisation vehicles to suit particular circumstances. Our research collaboration enables CSIRO to achieve the benefits of scale so necessary for conducting excellent and relevant science, and to provide the appropriate scientific leadership as suggested by many Sector Advisory Committees.

Fourth, scientific and engineering R&D of the highest quality underpins CSIRO's reputation and capacity to deliver research results that contribute most effectively to Australia's well being. This was readily apparent in the written material prepared for the Executive and in meetings with members of the Sector Advisory Committees and senior CSIRO staff. Everyone in CSIRO must continue to build on this commitment to excellence and to maintain the strategic research effort necessary for us to be able to meet the needs of Australian industry and the community in five years, 10 years and beyond.

The Sector Advisory Committees are helping us to do this with their valuable inputs. They have indicated a willingness to do more and we are pleased to accept their offer.

Strategic Considerations Influencing the Investment Decisions

Routes to market; achieving outcomes by ensuring the adoption of our research outputs

In nearly all sectors, it is evident that our relationships with customers and stakeholders are changing and becoming more complex. They are changing because our customer mix is changing and our customers are operating in a fast-changing world. Factors changing the business environment include:

- the globalisation of markets and development of international supply chains
- globalisation of R&D and global sourcing of technology
- market reform and deregulation in a number of industries
- changes in requirements for particular research skills
- impact of international agreements, many with environmental requirements.

These and other changes are forcing our customers to operate differently. So, the way that we do business with them has to change. We have done this to some extent, but must go further still.

For all sectors encompassing rural production it is quite clear that an effective feedback loop connecting producers and consumers—or those acting on direct feedback from consumers (retailers for example)—is essential for the long-term health of the sectors and for capturing value from research. Consequently, the existence of an effective feedback loop of this kind should be a pre-condition for CSIRO's continued investment in those sectors.

The routes to market for our research are many and varied. They can now include equity as well as royalty approaches and joint ventures and alliances with industry, government agencies and universities, sometimes via Cooperative Research Centres and sometimes directly. Each needs to be tailored to the specific customer and their specific markets. The Sector Advisory Committees are helping us to do this with their valuable inputs. They have indicated a willingness to do more and we are pleased to accept their offer.

Marketing, delivery and managing client relationships

There is a growing professionalism within the organisation on commercial matters. But we still need to improve considerably in our marketing, client relationships and delivery. These activities are intimately linked to priority setting and finding the appropriate routes to market. This need for increased attention to outcomes via better marketing and technology transfer was expressed by many of the Sector Advisory Committees during meetings with the Executive Committee. This will require increased coordination, particularly at a commercial level, between Divisions contributing to the work of sectors.

The organisational performance measurement system that we are putting in place will place particular attention on this aspect and will provide us with the sort of feedback we need to target the key business processes requiring improvement.

Structures

The delineation of the sectors and divisions, whilst not perfect, has served us remarkably well over the previous triennium. The sectors could be defined differently, and conceivably some could be merged, but there does not appear to be any strong demand to do so. Some overlap of interests will always occur, no matter how we segment our response to our customer base. We have however decided to relocate our cotton research from the Field Crops Sector to the Textiles, Clothing and Footwear Sector, in line with our desire to ensure effective feedback loops between cotton producers and the processing industry that uses cotton. We have also identified a need to move beyond general sector issues to address specific company or agency needs and develop more targeted relationships with specific customers.

Sustainability

The environmental sustainability of production systems, in agriculture, mining, mineral processing, manufacturing and the built environment, is a recurring theme. It is expressed in various ways by different industries, and impacts those industries in different ways. For the mining industry it manifests itself as maintaining a 'licence to operate'; in the fishing industry as a concern about depletion of stocks through overfishing; in the agricultural

industries as a concern about the pressures on the natural resource base and its ability to continue to support current levels of production, and to retain access to markets for clean and green products.

Environmental sustainability however is intimately linked to economic and social imperatives and hence solutions to this issue need to be framed in a holistic manner. We have decided to be pragmatic about how we deal with our research effort for sustainability. Our prime imperatives are that the issues are dealt with in a holistic manner and at an appropriate scale, and that the research conducted for it is guided by the appropriate drivers and market signals.

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We have decided that many of the land and water issues affecting the sustainability of agriculture, mining, mineral processing, manufacturing and the built environment can best be dealt with via large-scale integrated work. This work is to be clearly identified in the Land and Water Sector Plan, with appropriate advisory and management mechanisms in place to ensure that customer groups in the relevant production-based sectors can exert appropriate influence on those projects. The objective is that work will be undertaken so as to meet the sustainability needs of customers in production sectors while addressing the environmental issues through a systems approach to broad-scale land and water management.

Biotechnology and bioengineering

Use of biotechnology and bioengineering is widespread in CSIRO and has a growing role in a number of agribusiness, environmental, manufacturing and minerals sectors. This mirrors the changes, often profound, occurring in these industries and a step change in how biotechnology is conducted.

CSIRO must have access to a full set of capabilities in proteomics (protein characterisation), functional genomics, screens and molecular recognition, structural biology, microbial technologies and bioinformatics if it is to be a leader in biotechnology research and application. Access across CSIRO to such capabilities will be critical.

There are gaps and differential levels in CSIRO's biotechnology skill base, facilities and equipment. These are best filled by groups, either internal or external, which serve as a resource for the organisation as a whole. Coordination, leadership and management of the effort across CSIRO will be a significant issue, as will collaboration with other major research players in this field.

CSIRO needs to play a significant part in ensuring a balanced approach to the implementation of biotechnology research and in addressing all implications of its use, including possible risks to the environment from the release of genetically modified organisms. A major project commencing in 2000 will begin to address the current lack of risk assessment studies, particularly those at an ecological system level.

Public good research and support for policy development

Our discussions with the Sector Advisory Committees revealed support for the increasing role CSIRO plays in public good issues and the provision of scientific input for government policy development. Whilst this has been a major part of the role for environment and agribusiness sectors in the past, it has clearly extended to most other sectors over the past triennium, in a manner supported by governments and industry representatives alike.

Given the competing demands for its research, CSIRO cannot do all of this work without additional funding. Although we will draw on our research experience and expertise developed in other endeavours, we expect government and industry to provide financial support when it comes to specific studies needed to provide the particular advice to inform policy development and its implementation. Links to relevant government agencies need to be developed or enhanced by all sectors.

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Livestock research infrastructure

Following a review of livestock research infrastructure, CSIRO will strengthen its efforts on behalf of Australia's $12 billion livestock sector with the formation of a new CSIRO Division of Livestock Industries. The review group, headed by Mr John Blood, consulted extensively with industry and took a strategic perspective for the next 20 years of the facilities CSIRO would need for its research plans to meet future industry needs. The new Division will comprise the existing Divisions of Animal Health, Animal Production and livestock-related research within the Division of Tropical Agriculture. This will allow better integration of CSIRO's extensive and deep disciplinary skills to conduct research for the benefit of Australia's livestock industries.

The review group identified biotechnology as being of crucial importance to the future of the Australian livestock sector. CSIRO will act on the group's finding that the Institute for Molecular Biosciences was an ideal location for all CSIRO's research in this field. The expanded institute—which is being developed by CSIRO and the University of Queensland at its St Lucia campus in Brisbane—will cover all major livestock and plant species and will represent a significant proportion of the national biotechnology effort. It will be the largest facility of its kind in the Southern Hemisphere.

PLANNED APPROPRIATION INVESTMENT AND TOTAL EXPENDITURE BY SECTOR, 2000–01 TO 2002–03, $'000.

	2000–01		2001–02		2002–03		Triennium Total				
Sector	Appropriation Investment	Planned Expenditure	Appropriation Investment	Planned Expenditure	Appropriation Investment	Planned Expenditure	Appropriation Investment	Planned Expenditure	Share of Appropriation Investment	Share of Planned Expenditure	External Earnings Target(%)
Biodiversity	20 051	32 511	20 203	33 150	20 310	33 213	60 564	98 874	4.6%	4.6%	34
Built Environment	21 941	33 401	22 106	34 614	22 319	35 827	61 182	98 443	5.0%	4.8%	35
Chemicals & Plastics	17 943	28 589	17 325	29 648	16 565	30 345	51 833	88 581	3.9%	4.1%	35
Climate & Atmosphere	19 111	28 865	19 250	29 409	19 449	29 882	57 811	88 156	4.4%	4.1%	35
Energy	18 788	28 725	17 912	29 105	18 039	29 613	54 739	87 443	4.1%	4.0%	40
Field Crops	26 749	47 461	27 080	47 110	27 309	47 415	81 138	141 986	6.1%	6.6%	50
Food Processing	18 289	35 782	18 477	37 312	18 760	37 720	55 526	110 814	4.2%	5.1%	50
Forestry, Wood & Paper Industries	16 096	23 731	16 211	23 934	16 360	24 768	48 667	72 433	3.7%	3.3%	35
Horticulture	8 885	17 111	9 028	17 058	9 104	17 187	27 017	51 357	2.0%	2.4%	43
Information Tech & Telecommunications	19 194	32 090	19 331	32 541	19 514	33 031	58 038	97 663	4.4%	4.5%	35
Integrated Manufactured Products	30 995	47 365	31 110	47 754	31 453	48 467	97 438	147 466	7.0%	6.6%	35
Land & Water	30 342	46 838	30 552	47 303	30 835	47 564	91 729	141 705	6.9%	6.5%	36
Marine	23 647	35 637	23 823	36 585	24 297	37 148	71 766	109 370	5.4%	5.1%	30
Measurement Standards	9 460	12 288	9 527	12 592	9 613	12 751	29 309	38 339	2.2%	1.7%	25
Meat Dairy & Aquaculture	33 613	57 178	33 868	57 838	34 195	58 635	101 676	173 651	7.7%	8.0%	40
Mineral Exploration & Mining	18 474	30 615	18 589	31 664	18 732	32 121	56 389	94 994	4.2%	4.4%	45
Mineral Processing & Metal Production	25 914	40 945	26 083	42 269	26 286	43 352	78 283	126 566	5.9%	5.8%	45
Petroleum	10 853	19 028	10 930	19 494	11 030	20 043	32 813	58 566	2.5%	2.7%	43
Pharmaceuticals & Human Health	19 437	30 805	20 437	32 416	21 517	33 586	61 391	96 807	4.6%	4.5%	31
Radio Astronomy	12 443	17 975	12 526	18 514	12 631	18 872	37 600	55 362	2.8%	2.6%	15
Services	9 016	12 752	9 075	13 175	9 156	13 624	27 247	39 551	2.1%	1.8%	33
Textiles Clothing & Footwear	28 093	48 037	28 342	48 444	28 592	49 282	85 027	145 762	6.4%	6.7%	35
Sub-Total [1]	**439 333**	**707 730**	**441 787**	**721 929**	**446 067**	**734 446**	**1 327 184**	**2 163 888**	**100%**	**100%**	**38**
Corporate Support Functions	39 835	62 081	40 194	65 289	41 232	71 080	121 260	198 450			
Corporate Funds	14 739	3 024	18 522	4 547	22 692	6 801	55 956	14 590			
Capital Use Revenue	116 125		113 365		115 455		344 945				
Property Measure Supplementation			5 900	5 900	8 400	8 400	14 300	14 300			
Total for CSIRO [2]	**610 032**	**772 836**	**619 768**	**797 665**	**633 845**	**820 727**	**1 863 645**	**2 391 228**			

1. This is the total of Divisional cost centre budgets as at April 2000, reflecting Divisional commitments to Sectors as per the Sector Financial Plans.

2. As per Portfolio Budget Statements 2000–2001 for Industry, Science and Resources Portfolio, May 2000.

ALLIANCE SUMMARY (DIVISIONAL APPROPRIATION / EXPENDITURE ONLY)

Agribusiness[1]	131 725	229 301	133 007	231 696	134 320	235 007	399 051	696 004	30.1%	32.2%	43
Environment & Natural Resources[2]	93 151	143 851	93 828	146 447	94 892	147 807	281 871	438 106	21.2%	20.2%	36
Manufacturing, Information & Services[3]	140 429	215 266	141 438	221 253	142 767	226 503	424 038	662 210	32.0%	30.6%	36
Minerals & Energy [4]	74 029	119 313	73 514	122 533	74 088	125 129	222 225	367 568	16.7%	17.0%	40
Total	**439 333**	**707 730**	**441 787**	**721 929**	**446 067**	**734 446**	**1 327 184**	**2 163 888**	**100.0%**	**100.0%**	**38**

1. Includes Field Crops; Food Processing; Forestry, Wood & Paper Industries; Horticulture; Meat,Dairy & Aquaculture; Textiles, Clothing & Footwear.

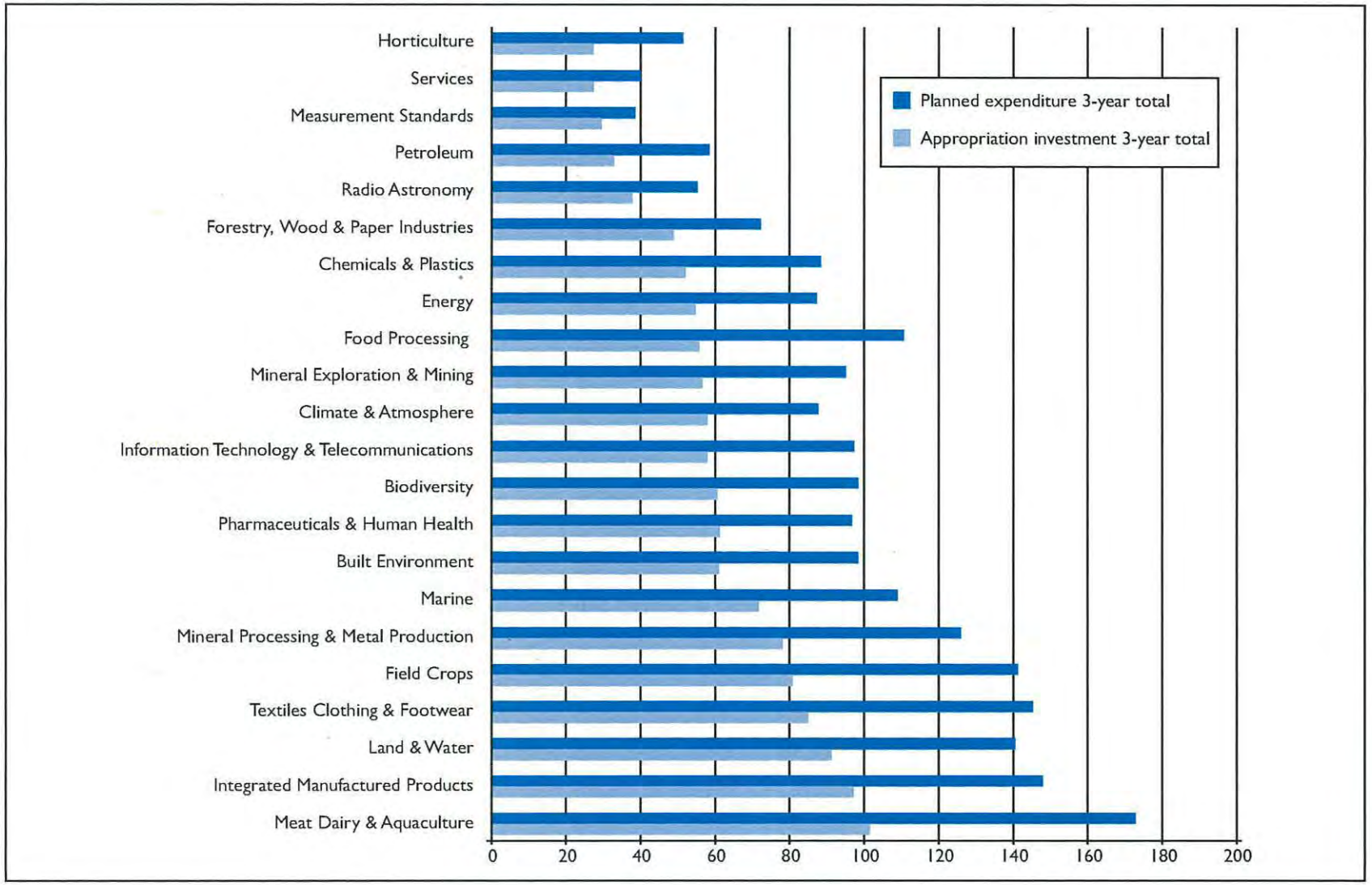
2. Includes Biodiversity; Climate & Atmosphere; Land & Water; Marine.

3. Includes Information Technology & Telecommunications; Built Environment; Measurement Standards; Radio Astronomy; Services; Chemicals & Plastics; Integrated Manufactured Products; Pharmaceuticals & Human Health.

4. Includes Energy; Mineral Exploration & Mining; Mineral Processing & Metal Production; Petroleum.

PLANNED APPROPRIATION INVESTMENT AND TOTAL EXPENDITURE BY SECTOR FOR THE TRIENNIUM

2000–01 to 2002–03, $m (excludes Corporate Support Functions)



CONTEXT, DRIVERS AND STRATEGIC DIRECTIONS

Agribusiness

The agribusiness industries are marked by a number of significant factors that impact on the strategic directions selected by CSIRO. There is a growing trend toward global supply-chain integration, with retailers requiring 'specification-based quality-assured' farm production. Continuing market reform and deregulation is changing the structure and economic status of many industries, while technology-driven change—particularly intellectual property from genetic engineering—is contributing to a radical restructuring of input-and-upstream supply relationships. Community concerns for sustainable resource management and food safety (licence-to-operate issues) overlay all of these.

In this context, CSIRO's decisions for the 2000–2003 triennium emphasise research with a through-chain approach, maintaining Australia's clean and green image, improving food safety, increasing and securing trade and market access, investing in and managing biotechnology, and the sustainable management of natural resources.

The community's concern for food safety is being addressed with the establishment of a 'Virtual R&D Centre' in partnership with industry.

Global supply chain integration and 'specification-based farm production' will be pursued through a range of initiatives. Objective measurement to define qualities of wool, cotton and leather will enhance supply chain efficiency. Other work will increase demand through the development of new consumer textiles, new horticulture varieties, and food ingredient innovation. R&D and technical support will continue for major government initiatives (for example, Supermarket to Asia/Food to Asia).

The development of new methods for rapid diagnosis and management recommendations for exotic, emergent and endemic animal and plant pests and diseases, as well as new technologies for storing grain with reduced pesticide residue and pest contamination, will contribute to maintaining Australia's 'clean and green' image.

The community's concern for food safety is being addressed with the establishment of a 'Virtual R&D Centre' in partnership with industry. The centre will make an important contribution to microbiological safety (virulence characterisation and transfer of antibiotic resistance across the food chain) and also the substantiation of health claims (through biomarkers). CSIRO will continue to provide advice to Government on risk and hazard analysis for regulation/deregulation in the food industry.

In relation to biotechnology, Australia needs to strengthen Australian-owned intellectual property (sequences and germplasm) through partnerships of local and multinational operators (for example, Graingene, Cotton Seed Distributors), and to employ the full armoury of science (diagnostics, marker-assisted selection, modification). CSIRO will play a continuing role in providing policy/legislation assistance to Government on gene regulation issues. To underpin such advice, CSIRO will undertake a major new initiative on the ecological impact of genetically modified organisms (GMOs).

To help us achieve our goals, CSIRO will emphasise co-investment (with a preference for a tripartite approach with Rural R&D Corporations and customers), dedicate greater effort to understanding the business needs of our customers, structure our resources to reflect customers' supply chains, and seek to minimise duplication and infrastructure outlay through joint ventures (such as Food Science Australia) and shared facilities (such as the Institute for Molecular Biosciences).

Other highlights of the work in this triennium include:

- releasing grain varieties with quality attributes to meet current and emerging market needs in food processing, nutrition and health, and food safety
- developing improved management strategies and deployment of agricultural plants for optimal use of water and nutrients, along with tested options for managing water and nutrients in the landscape
- developing new food processing control methods and new separation and recombination technologies, along with further development of extruded high moisture textured animal and plant protein products
- commercialising ZERO2 oxygen scavenging packaging, and developing new concepts in tamper-evident and anti-microbial food packaging, along with new and improved edible coatings of food products
- releasing remote sensing tools for assessing forest composition, structure, biomass, animal habitat and forest health, and providing scientific advice to government and industry for policy formulation and implementation

- developing higher-value primary and secondary products from young, fast-grown wood, new resins for conventional composites and new durable composites, and improved wood preservatives and preservation methods
- releasing new and improved horticultural crops to provide better variety and quality, seasonal availability and meet consumer preferences. Also reliable and increased production of tropical tree fruit and nut crops
- developing improved incursion management of exotic pests and diseases of horticultural crops, including new risk assessment and management technologies for pests including whitefly, diamond-back moth, clear-wing borer and green vegetable bug
- increasing knowledge of trends and drivers of food choice in domestic and key export markets, including aspects of risk acceptance, along with strategies to predict and respond to consumer concerns
- releasing genetic strategies to develop animals with superior yield, product quality and disease resistance, and strategies to reduce stressors and enhance animal welfare
- developing optimal wool clip preparation and consignment building methods, and instrumentation and measurement systems to completely specify raw wool and cotton
- developing new technologies for on-farm wool measurement, for processing of long low crimp wool and for improved spinning performance for cotton-wool blends.

Environment and Natural Resources

CSIRO has a unique potential to understand and meet the environmental needs of all sectors on the basis of both environmental and production-orientated skills. It aims to produce integrated and tailored knowledge and tools to help achieve various environmental management outcomes, at a variety of scales.

CSIRO's strengths in land and water management and across many aspects of biodiversity are being increasingly harnessed together to provide solutions for sustainability.

One overarching set of demands arises from 'greenhouse' requirements. Here, CSIRO provides a world-leading understanding of climatic and other factors as well as making a wide range of contributions to Australia's challenging response. This is a major example of CSIRO's role in providing the science needed to help develop timely, cost-effective responses to global drivers including international conventions.

Another high-profile area of growth and of leadership is in all aspects of natural resources management. Here, CSIRO's understanding of the nature and causes of major problems, such as encroaching dryland salinity, is an important factor in informing national policies and programs as well as providing practical management information and tools. CSIRO's strengths in land and water management and across many aspects of biodiversity are being increasingly harnessed together to provide solutions for sustainability. Tools and insights for integrated and sustainable resource management are also provided for multiple uses of Australia's vast marine zone.

There are several trademark characteristics of CSIRO's environmental activity. It derives from a disciplinary base across all elements of the environment, a breadth rarely found in one institution, anywhere. Increasingly, this knowledge is tested and applied in big, integrative, collaborative activities, focused on specific contexts, regions and problems, and delivered 'on-the-ground' in conjunction with a range of partners and co-investors. These integrated responses take account of economic, social and institutional factors and draw on relevant skills in CSIRO and collaborators. The work often involves multi-million dollar collaborative projects, putting into effect functional understanding at landscape and systems scales, to guide management, renewal and sustainability. (Examples include work in the Murray Darling Basin, the Bowen Basin, and the Ord-Bonaparte region in north-western Australia).

CSIRO's environmental knowledge and expertise will also continue to support requirements arising from new environmental legislation, particularly the Commonwealth's Environmental Protection and Biodiversity Conservation Act.

Other highlights of the work in this triennium include:

- enhanced attention to the potential ecological implications of GMOs (helping to address and inform matters of community concern)
- better environment information/knowledge management, integrating CSIRO's advanced skills in taxonomy, research and information technology
- new climate products predicting change and variability at different time and space scales including better regional and seasonal climate prediction and air pollution forecasting at the sub-city level (first demonstrated at the Sydney Olympics)
- significant contributions to the first (south-east) Regional Marine Plan
- far better understanding of the nature and value of the services provided by our biodiversity

- more work in environmental health (where CSIRO skills in areas such as both indoor and outdoor air quality and water quality are engaging with growing community awareness and demand)
- more attention on research to help in adapting and managing the impacts of climate change
- ongoing significant progress in work to deal with pests, weeds and diseases, to assist better conservation management and to assist sustainable tourism
- major collaborations with State partners in providing the information and knowledge base for multiple uses of marine regions (for example, the North-west Shelf)
- further developing the knowledge needed to address the clean up and rehabilitation of a considerable range of contaminated sites
- designing new agricultural systems that are both benign to the environment and profitable.

Manufacturing, Information and Services

There are a number of key influences affecting all parts of the information, manufacturing and service industries. Globalisation is resulting in major restructuring of firms and relationships between them. Industrial research and development and technology sourcing are also globalising. Rapid, disruptive technological change from advances in information and communications technologies and biotechnology are shaping the information, manufacturing and service industries. As a result of unprecedented decreases in both product-development lead times and product life cycles, speed in moving projects out of research and through development to market has become a key success factor. Rising community expectations about protection of people and the environment, if not satisfied, may place pressure on an industry's license to operate and become an issue in international trade.

...speed in moving projects out of research and through development to market has become a key success factor.

In the Built Environment Sector, sustainable supply of potable water is a major global issue and has resulted in a major focus on urban water systems, while concern about transport congestion and energy use efficiency has led to an initiative in intelligent transport systems, focusing around an integrated system for transport sensing, monitoring, simulation and optimisation. Environmental concerns and regulation are the drivers for a major focus on new waste reactivation technologies suitable for 75% of all solid industrial, construction and mining waste. Increased emphasis on research into the use of information technology and telecommunications in the construction industry will address the issue of poor information flows that result in major operating inefficiencies in that industry.

Advances in biotechnology are having a major impact on the chemicals and plastics industries. This is seen in major industry restructuring, marked shifts in R&D and steps towards using bioprocessing for chemical production. CSIRO will start a major effort in bioprocessing in this triennium. It will be directed towards production of high value specialty products, particularly bioactive chemicals, and remediation of toxic chemical wastes. The initiative lies at the intersection of three influences—biotechnology, increasingly stringent expectations about lower environmental impact and Australia's competitiveness in specialty or niche chemicals.

Improvements in the performance of information and telecommunications technologies continue unabated. A particularly important aspect of this is rapid evolution in communications networks, dominated by the internet. There is also very rapid growth in wireless communications. CSIRO's response is to increase its emphasis on broadband wireless access technologies, advanced networking, with particular emphasis on quality of service, internet-based service delivery and tools for building distributed computer systems.

In engineered manufactures (Integrated Manufactured Products), there are increasingly stringent community expectations and environmental regulations which are likely to affect international trade. As a result, CSIRO is undertaking a major initiative in sustainable manufacturing. Environmental concerns are also leading to a demand for lighter weight transport equipment and this area will continue to be a major focus. Manufacturing utilising nanoscale (10^{-9} metre) building blocks is an area receiving increasing emphasis worldwide, and within CSIRO work is underway to develop products based on such building blocks assembled using biomimetic engineering.

Measurement standards are of increasing importance in underpinning world trade. CSIRO's work in this area will continue to ensure that Australia's measurement standards are internationally recognised and are equivalent to those of the nation's major trading partners. To this end, CSIRO will be gaining accreditation for its calibration services within the framework of a recent global mutual recognition agreement between national measurement institutes. CSIRO will also continue to contribute to the development of measurement standards expertise within the Asia–Pacific where it has taken a leading role over the last few years.

There are considerable pressures on the Pharmaceuticals and Human Health Sector from the rising cost of health care, a shortfall in new pharmaceutical products, major advances in biotechnology, major new

techniques for drug discovery and very high costs of drug development. As a result of these pressures, the pharmaceuticals industry is in the midst of a significant discontinuity and there is major impact on research from firms pursuing drastic compression of discovery-to-market time. Against this background, CSIRO has undertaken a major international review of its work in pharmaceuticals and human health and will focus its work into fewer areas to ensure more effective science and more effective delivery of research results.

Our knowledge of the universe is changing rapidly with significant astronomical discoveries as a result of major advances in many areas of radio astronomy. The scale of major radio astronomical observatories is moving beyond the capacity of any single nation and international development of major new facilities has begun over the past few years. CSIRO's response is to maintain the Australia Telescope National Facility's world-class position and state-of-the-art instrumentation and to exploit capabilities created by current upgrades to make significant astronomical discoveries. CSIRO will also be working to position Australia for participation in future major international radio astronomy facilities, particularly the Square Kilometre Array.

Information and communications technologies are the major technologies utilised in the Service Sector. Information technology and telecommunications, particularly the internet, are leading to globalisation of the service industries, and systems integration and customisation is a key factor in improving productivity. Research directed towards the service industries is a relatively new activity for CSIRO and redefinition of the organisation's research foci will continue, based on our experience of working with services firms. A major increase in health services research is planned over the triennium with initiatives in telehealth and health care delivery in response to the rising cost of health care and inequitable access to quality health care. There will also be an initiative in electronic service delivery jointly with the Information Technology and Telecommunications Sector.

There is strong pressure to achieve continuing cost-reduction and market diversification in the face of a long-term decline in real prices and the need to process lower grade ores.

Other highlights of the work in this triennium include:

- polymer forming processes and product prototypes based on control of free radical polymerisation, reactive extrusion and conducting or photoactive polymers
- new bioactive chemicals for use as environmentally friendly safe herbicides, insecticides and fungicides
- new low-cost technology to enable high penetration of low-cost broadband wireless systems
- electronic services based on integrating existing (legacy) information systems
- environmental performance metrics of manufacturing processes for assessment of eco-efficiency
- new magnesium-casting technology with improved casting yield and significant cost savings
- modelling methods for performance analysis and stability control for distributed manufacturing enterprises
- new primary standards for high pressure, acoustics, length, time, electromagnetic compatibility and electric potential
- 'proof of concept' for an artificial cornea designed to enable permanent, but reversible, refractive correction
- clinical evaluation of an assay for the identification of prostate cancer cells
- biological sensing molecules which will enable Australian firms to compete in the expanding point-of-care diagnostic markets
- better risk analysis in the finance industry through software for pricing complex options and other derivatives
- demonstration of a home telehealth system for elderly people with frequent falls.

Minerals and Energy

Based on external advice received through the planning process, and CSIRO's own analysis of opportunities, our decisions for the minerals and energy sectors were guided by three key aspirations:

- seeking a technology edge to find first-class world minerals deposits and exploit new less accessible petroleum-gas fields
- ensuring integrated research to incorporate environment and sustainability factors in minerals and energy developments
- improving process efficiency to increase international competitiveness.

These aspirations respond to a number of key drivers in the minerals and energy sectors. There is strong pressure to achieve continuing cost-reduction and market diversification in the face of a long-term decline in real prices and the need to process lower grade ores. At the same time operators face licence-to-operate

issues focusing on concerns for safety and the environment—the marine environment and greenhouse gas being among the major issues. Research for these sectors must recognise both the global nature of these technology intensive industries—which face widespread industry reform, rationalisation and restructuring—and the Australia-specific nature of the technology challenges they face.

The strategic directions reflected in the sector plans represent a significant reshaping of many sector activities

The strategic directions reflected in the sector plans represent a significant reshaping of many sector activities. Additional resources have been directed to finding new-generation giant ore deposits and to efficiency, safety and cost in the mining, coal and mineral processing industries. There is emphasis on a whole-of-life approach to mining and the environment, on the development and transfer of new technologies to the market, and on improvement in processes and asset utilisation. Environment issues receiving attention are management of water and wastes, marine environment management, carbon dioxide sequestration, and increased emphasis on 'clean power' technologies.

Other highlights of the work in this triennium include:

- establishing a new CSIRO-wide greenhouse gas abatement program, involving a set of projects aiming to make a significant impact on greenhouse emissions through scientific innovation
- finding new generation giant ore deposits, via a Glass Earth program which seeks to make the top one kilometre of the Australian continent, and the processes operating within it, transparent
- developing new design and extractive strategies to make new types of mineral deposits accessible, and to improve access to currently sub-economic deposits
- developing new mining methods made possible by geo-sensing, communication, robotics as well as genetic engineering
- investigating novel biomineral processing techniques for mineral processing
- increasing national light metal—magnesium and titanium—processing capabilities
- contributing to the development of an integrated mine-to-mill to market approach for the minerals industry
- establishing new facilities, with State government support, which will strengthen collaboration with other research bodies and industry. These include a new headquarters for the Division of Energy Technology in Newcastle, the Australian Resources Research Centre in Bentley, Perth and a major expansion of the Queensland Centre for Advanced Technology at Pinjarra Hills, Brisbane
- increasing the efficiency of petroleum and gas exploration and extraction, notably in the North-west Shelf, through improved drilling performance and better management of risk and uncertainty
- expanding work on clean power technologies such as fuel cells, renewables and gas-based technologies
- increasing attention on reduction of environment impacts and increased sustainability of minerals and energy industry operations.

SECTION TWO
Sector Plans

FIELD CROPS

Following on from our first national forum held in Canberra in November 1997, a number of commodity and cross-commodity focus groups were activated in June 1998. The principal objective of these groups was to have industry bring their agenda to CSIRO, what they saw as problems or issues in the development of their business, and what they would like to see CSIRO researching.

The outcomes from these focus groups formed the basis of the development of our strategic plan for the 2000–03 triennium. There is to be increased emphasis on:

- genomics of field crops
- human nutritional quality and health potential in plant breeding programs
- fungal disease prevention and control
- sustainability of agricultural production
- technology transfer.

Australian industries need to be positioned with their own valuable intellectual property, enabling them to negotiate positions of freedom-to-operate in their own right and/or on appropriate terms in joint ventures with the major multinationals. Such alliances will give Australian agriculture access to the enabling technologies needed by our industries. We have an opportunity to forge these alliances largely because of the excellence of our research.

Australian companies and public breeding groups are now aware of the growing importance of quality traits and food safety in our cropping products. Product differentiation will be critical for international trade. Gene technologies, apart from their direct role in breeding new cultivars, are making major contributions to the understanding of the metabolic pathways behind many quality traits. These advances have been responsible for the increasing participation of food-processing companies in support of CSIRO research.

The significant reductions in profitability of Australia's grazing industries have led to increased cropping by many farmers in the higher rainfall zones of both eastern and western Australia. These are areas with high production potential but they will rely on coordinated research and production operations, encompassing both management of the cropping systems and the supply of specially selected cultivars.

The Field Crops Sector Advisory Committee has also recognised that our cropping industries are losing up to 20% of potential yield as a consequence of disease and pest pressures. We have identified a weakness in our research capabilities in the area of protection against fungal pathogens. This is the critical limiting factor for the growth of the grain legume industries, and it is of major consequence in cereal and oilseed crops.

Yields are also being depressed by the declining environmental health of many of our production areas, particularly those with the highest yield capacity. The major concerns are salinisation and acidification of cropping production soils. In addition to yield losses, the cropping industries are under pressure from Australian society as a whole to develop environmentally friendly agricultural production systems. We are in a position to reduce and remedy many of the problems as a result of advances made in the understanding of the processes of decline. The industry has recognised the need to develop integrated management systems for sustainability and recognition, by crop producers, to take action to improve their profitability.

The committee has emphasised efficient technology transfer in the different cropping industries that underlie these four areas of research emphasis. The increased integration of researchers with producers is fostering significant improvements in research adoption. Field-crop research has moved away from the traditional linear extension model to one in which research program designs include the delivery phase.

We are now moving to consolidate the position of the sector with a second national forum planned for mid-2000. It is anticipated that industry input and topical developments will enhance the capacity of the sector to deliver its outputs and outcomes over the new triennium.

Trevor Flugge AO
Chair, Field Crops Sector Advisory Committee

Field Crops Sector Advisory Committee:
Trevor Flugge (Chair), AWB Limited; Harry Bonanno, Australian Cane Growers; Anthony Gregson, Farmer; Michael Hedditch, Rice Growers Association of Australia; Chris Henderson, Farmer; Chris Hudson, Goodman Fielder Limited; John Lovett, Grains R&D Corporation; Don Marshall, Plant Breeding Institute, University of Sydney; Douglas Rathbone, Nufarm Limited

FIELD CROPS

The Field Crops Sector's research supports improvements in productivity, quality and sustainability of production of all broad-acre crops, except cotton, including wheat, barley, sugar, oilseeds, grain legumes, rice and coarse grains (oats, triticale, maize, sorghum). Around 80% of these crops are grown under relatively low input rain-fed conditions, whereas irrigated crops such as rice and sugar generally use higher levels of inputs and have more precise management requirements.

The major challenge to the future expansion of the cropping industries is that Australia, as a relatively small player in global agribusiness, could lose its market leadership in a number of the commodities because of the change in control of agribusinesses as a consequence of the development of new gene technologies and their related intellectual property matters.

The initial advances in gene technology depended on the manipulation of individual genes. Techniques have now been developed to engage the entire gene complement in research probing the function and development of crop plants. Genomics is based on the major international programs of genome sequencing in which we participate. The genome sequences of Arabidopsis and rice will be completed in the years 2000 and 2003 respectively. Associated powerful new techniques such as micro-arrays are changing the face of plant research. CSIRO has an important responsibility to introduce these techniques to Australia.

There are other challenges—the need for differentiation of products, reliability of supply, and the urgent need to cope with major pests, weeds and diseases. Along with these challenges is the necessity for research to be focused on the maintenance of the natural resource base.

Sector Context, Dynamics and Outlook

The prospects for growth in the industries in the sector, both in commodity quantity and in product quality differentiation, are high. Currently the sector is in a healthy condition despite depressed commodity prices. Moreover, increasing demand for food and food products on a global scale and, in particular, in markets targeted by Australian agricultural and food industries is assured.

Australia has the capacity to respond to this demand and to double the value of the present crop industry to A$30 billion. If additional research investment is made in the key areas identified by the Sector Advisory Committee and the industry continues its increasing commitment to adoption of research results, then the target time could be reduced from an estimated 15 to 10 years. This remarkable level of growth will be strongly dependent on technological advances, which we are confident of achieving and transferring to a receptive field crops industry.

New technologies will be important in lifting yield potential, making better use of water and nutrients and, thereby, minimising impact on the environment and the resource base. We are using these initially in high technology breeding, which will provide a transitional phase to the deployment of transgenic cultivars. We will work in alliances with both public and commercial breeding programs in Australia to ensure results from our high technology breeding are incorporated in new grain varieties.

These technologies will also provide us with new diagnostic tools to give us better ways of selecting quality attributes in our crop plants, effectively providing for a greater range of differentiation for our crop product markets. This will be particularly important in the first instance with wheat, and also barley where malting quality and feed varieties are characterised by markedly different quality attributes.

The cropping industries are not without significant environmental problems, which this sector will address in collaboration with the CSIRO Land and Water Sector. Many current plant production systems are not ecologically sustainable because they leak water and nutrients, which can result in waterlogging, salinity and soil degradation. More than $700 million worth of land has been lost to dryland salinity to date, representing about 2.5 million hectares with the potential to increase to 12 million hectares. Improved land-management practices must integrate annual crops and pastures with permanent perennial systems to substantially reduce ground water recharge. Research focusing on longer-term productivity and studying the landscape, soil, plant, animal and agro-ecosystems as integrated farming systems is paving the way for major improvements in crop management and development of sustainable cropping systems.

R&D dynamics: The sector faces some major challenges and changes in its operating environment. Foremost is the transformation of the large agrichemical companies into life sciences companies. The entry of biology and biological research into the patent system has transformed agriculture into agribusiness. Gene technology and its related intellectual-property situations will have a prominent role in the future of global crop production and trade. As the multinational companies invest in biotechnology, and gene technologies in particular, they are building up business systems of large dimensions where they control many enabling and generic intellectual-property positions for genetically modified crops. Despite the present profitable performance of the field crop industries, our sector faces potential market failure on a large scale as a consequence of the blocking intellectual-property positions of the multinationals.

Australian industries need to be positioned with their own valuable intellectual property, enabling them to negotiate positions of freedom-to-operate in their own right and/or on appropriate terms in joint ventures with the multinationals. Such alliances will give Australian agriculture access to the enabling technologies needed by our industries. We have an opportunity to forge these alliances largely because of the excellence of our research. We are being approached by a number of the major multinational companies to form research intellectual-property alliances. Because Australian industry is now awakening to the need to proceed with the strategy outlined above, we can build the alliances and joint ventures, and develop vertically coordinated agribusiness systems extending from research through production, processing and to marketing.

Along with the realisation of the importance of intellectual-property positions in agribusiness, Australian companies and public breeding groups are now aware of the growing importance of quality traits and food safety in our cropping products. Product differentiation will be critical for international trade. A pertinent example in wheat is the preferential sourcing by Japanese buyers of grain from Western Australia because of a mouth-feel characteristic in the udon noodle product. Gene technologies, apart from their direct role in breeding new cultivars, are making major contributions to the understanding of the metabolic pathways behind many quality traits.

CSIRO has business system alliances with:

- Goodman Fielder + Groupe Limagrain
- Grains R&D Corporation + AWB Limited
- Grains R&D Corporation + Cyanamid
- AWB Limited + Grain Handling Companies
- Grains R&D Corporation + IAMA Limited
- Grains R&D Corporation + Wesfarmers CSBP.

Uptake of R&D: The paths to adopting innovations in crop plants and management technologies will be increasingly through private plant improvement programs using proprietary intellectual property, vertically integrated production supply chains, private consultants and input vendors. Key companies are in life science, agribusiness, commodity trading and primary processing of plant products. There is now an increasing number of private breeding and seed companies entering Australian agribusiness, compared to the public breeding and seed distribution systems of the past.

Through initiatives such as Graingene—a joint venture between AWB Limited, the Grains R&D Corporation and CSIRO—it is acknowledged that Australian industry needs to co-invest in strategic basic research in order to secure a competitive bargaining position in development and deployment of new technologies. Partnerships with CSIRO are being actively pursued by both Australian and multinational companies, and Rural R&D Corporations.

There is an increasing need for the extension of public-good research on farming systems to be integrated with the marketing of germplasm and inputs. Successful adoption of improved farming systems will require early involvement of industry in research leading to refinement and ownership of outcomes. Increasingly, alliances will be formed with private consultants, agribusinesses and financial service providers to transfer innovative farming system technologies to end users.

Sector priorities: The Sector Advisory Committee has identified four areas of priority emphasis for the next triennium:

- genomics
- sustainability of agricultural production systems
- human nutritional quality and health potential of crop products
- fungal disease prevention and control.

These, together with increased attention to technology transfer built in to our research programs and ongoing core research in all sector components, underpin the strategies for investment presented in the funding scenario analysis.

The committee sees these areas as being critical for the continued competitiveness of our export-oriented crop business systems and for continued growth of the industries. Without R&D, production will decline, product quality will not meet market specifications and the environmental consequences, already evident as being detrimental to Australia's international trading position, will be of greater significance.

All of these areas require the sector to refocus its research. Part of the additional investment required has come from industry and the Rural R&D Corporations in the alliances mentioned above. These increases need to be matched with increases in CSIRO support levels in order to achieve the best possible situation.

The strategic priority issues identified for the sector are of relevance to CSIRO's other agricultural production sectors. Gene technologies and production sustainability issues will be cornerstones of developments in the future.

CSIRO's role and industry support: The sector is characterised by a series of close and committed partnerships between its various industries and research providers. CSIRO has been increasing collaborative research programs with the State government departments, particularly in on-farm operations. It also has collaborations with a growing number of agribusinesses, finance and insurance

providers, consultants and elite farmer groups, ensuring rapid adoption of research into practice.

Industry support, both from the Rural R&D Corporations and from companies, now extends to 43% of the sector's research funding. Importantly, these external partners, private and public, are supporting strategic research as well as the research addressing more immediate problems and opportunities. Rural R&D Corporations increasingly are operating as investment bankers in key research areas and frequently with co-investment from companies. This was facilitated in the first instance by CSIRO's participation in CRCs but is now recognised as an effective mode of operation in the sector. CSIRO Divisions have catalysed many of these new associations. One important development in our sector has been the entry of downstream food processing companies, in recognition that product differentiation and quality traits are crucial to the future growth of their trade.

Planned Achievements

1. Gene technologies

Outcomes: Strengthening of Australia's base in plant science and R&D capacity to ensure the international competitiveness of the export-focused cropping industries. Australian-owned intellectual property from our genomics and gene discovery research facilitates access to international intellectual property and ensures that Australia is not disadvantaged in emerging global agribusiness systems.

Outputs: Enhanced understanding of the molecular basis of crop growth and development, and stress resistance. Crop lines with improved quality and enduring resistance to biotic and abiotic stresses. Knowledge of environmental impact of growing transgenic crops.

Development of R&D capacity: Focus on more efficient genetic transformation systems and gene technologies for field crops. Enhanced capacity in gene discovery via functional genomics, proteomics and bioinformatics. Discovery and utilisation of genes for manipulation of crop quality and resistance to biotic and abiotic stress.

2. Quality crop products

Outcomes: Continued access of quality Australian crop products to differentiated and premium markets.

Outputs: Australian grain with quality attributes to meet current and emerging market needs in food processing, nutrition and health, and food safety. Novel diagnostics for defining and monitoring quality. Key intellectual-property positions for industry.

Development of R&D capacity: Building industry partnerships and alliances for development and exploitation of intellectual property, improved analytical techniques for determination of health potential. Understanding determinants of food choice.

3. Pests, weeds and diseases

Outcomes: Minimisation of economic and environmental costs associated with control of pests, weeds and diseases. Retention of market access and enhanced export potential through products with low pesticide residues, premium quality and absence of some exotic pests, weeds and diseases.

Outputs: Crop management and biocontrol options, and integrated pest management strategies. Diagnostic and marker assisted technologies for testing and diagnostic services (pests and fungal pathogens). Protocols for monitoring targeted exotic pest species. Improved knowledge of potential crop losses due to pests, weeds and diseases under climate change.

Development of R&D capacity: Identification of genetic basis of plant defence responses; investigation of potential biocontrol agents. Further develop expertise in population ecology and biotechnology in pest and disease management (especially fungal pathogens).

4. Post-harvest technologies

Outcomes: Maintenance of Australia's ability to produce, store and sell clean, dry, insect-free grain for competitive market advantage.

Outputs: Determination of safe storage limits, integrated pest management strategies, and more efficient and reliable methods for grain quality control and disinfestation.

Development of R&D capacity: Specific expertise and equipment for oilseeds quality work will be acquired.

5. Water and nutrient management

Outcomes: More efficient use of nutrients and water in cropping systems and regions. Reduced on and off-site impacts of nutrients and water usage. Regional sustainability of cropping in terms of the environment, profitability and maintenance of market opportunities.

Outputs: Improved management strategies and deployment of agricultural plants for optimal use of water and nutrients. Improved models and decision support systems for use by farmers and their advisers. New technologies to underpin precision agriculture; tested options for managing water and nutrients in the landscape.

Development of R&D capacity: Focus on increased understanding of the molecular mechanisms controlling nutrient acquisition and tolerance of acidity, salt and other soil stress factors. Multidisciplinary skills and enhanced simulation modelling to better encapsulate crop and soil processes in relation to water and nutrient supply in production systems.

6. Integrated farming systems

Outcomes: Adoption of improved ecologically sustainable whole-farm cropping systems that take account of economic, environmental and social aspects.

Outputs: New methods to integrate highly productive pastures with dryland crops. Enhanced decision support systems and modelling tools, and new data-mining tools to identify specific causes of yield limitations to underpin precision agriculture. New approaches to managing risk. Tools to assist decision making in the face of climate change and enable the carbon sequestration impacts of cropping options to be assessed.

Development of R&D capacity: Integration of new knowledge and continued development of procedures and models for managing whole-farm production systems. Development of innovative action learning approaches to increase effectiveness of research on improving farm management. Institutional linkages that make best use of strengths to deliver effective farming systems research capability.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Gene technologies	27 384	19 496	48 891
2. Quality crop products	11 821	7 790	20 283
3. Pests, weeds & diseases	11 184	7 619	18 792
4. Post-harvest technologies	4 201	5 500	10 235
5. Water & nutrient management	9 666	5 980	16 120
6. Integrated farming systems	16 379	9 678	26 904
7. Biometrics	502	247	761
Grand total	**81 138**	**56 311**	**141 986**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Centre for Mediterranean Agricultural Research	577	0	627
Entomology	9 322	9 577	19 648
Food Science	912	397	1 318
Health Sciences & Nutrition	1 451	555	2 007
Land & Water	7 379	3 801	11 392
Maths & Information Sciences	502	247	761
Plant Industry	31 537	23 919	57 754
Tropical Agriculture	26 772	15 007	43 312
Wildlife & Ecology	2 686	2 807	5 168
Grand total	**81 138**	**56 311**	**141 986**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

Sector coordinator
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FOOD PROCESSING

An integrated agri-food chain is critical to the future of Australia and has the potential to play a major role at a global level.

This is because Australia, through the CSIRO's experience and expertise, is in an outstanding position to make a disproportionate contribution to meeting the almost overwhelming challenges that lie ahead.

The fundamental issue for human survival and prosperity continues to be 'how do we feed ourselves sustainably'. By 2050, world population is estimated to increase from 6 to 9.5 million. By 2020, world grain output must increase from 1800 million to 2600 million tonnes, an increase of 45%. The Food and Agricultural Organization estimates that 25% to 30% of all produce never reaches the consumer—it is lost through spoilage and waste along the agri-food chain. (Australia's Natural Advantage, J. Cribb CSIRO, Sydney)

The Food Processing Sector, associated sectors in the agribusiness alliance within CSIRO and the Australian agri-food industry are in a pivotal position and have a responsibility to make a major contribution, not just to Australia's future but to global stability through research and development in food science and technology.

Indeed, the combination of skills and experience within CSIRO and the Australian agri-food industry is probably unique given the range of foods produced, and the range of climatic and environmental conditions experienced in Australia.

The plan for the sector for the 2000–03 triennium has been well researched, taking into consideration global outlooks, CSIRO strengths, the realities of the Australian manufacturing industry and the need for a greater focusing of resources to ensure critical mass in program activities.

However, a strategic plan for this sector must take into consideration the other sectors within the CSIRO agribusiness alliance. An integrated management plan and alignment of research priorities across the alliance is essential to future success.

The five major research components for the sector are now clear:

- understanding consumer issues
- efficient manufacture and distribution
- food safety management
- ingredient innovation
- nutritional science.

The outcomes and outputs for each of these areas are also at a high level.

The sector must now complete the process by finalising:

- key result areas for programs
- a review of weighting and prioritisation of each area
- development of milestones/timelines
- planning for specific actions in relation to resource allocation and organisational imperatives.

This management document must show linkages between Divisions and between sectors in the agribusiness alliance.

The strategic plan along with the detailed management plan will provide the basis for a significant contribution from this sector to the prosperity of Australia.

A partnership between the CSIRO agribusiness alliance and the Australian food industry has the potential to make an outstanding contribution to the development of the global agri-food industry over the next triennium.

Steve Marshall
Chair, Food Processing Sector Advisory Committee

Food Processing Sector Advisory Committee:
Steve Marshall (Chair), Goodman Fielder Limited; Geoff Annison, Australian Food Council; Ken Buckle, University of New South Wales; Robyn Charlwood, Victorian Division, National Heart Foundation; Paul Donnelly, Dairy Research & Development Corporation; Dr Alan Grant, Technology Asia/Pacific, Kraft Foods Ltd; Marion Healy, Australia New Zealand Food Authority; Dr Jan Mahoney, Agriculture Industries, Department of Natural Resources, Victoria; Hans Sidler, Petrol, Woolworths Supermarkets; Dan Southee, Nestle Australia Ltd; Tony Wharton, Q-Meat; Robert Wotzak, Arnotts Biscuits Ltd

FOOD PROCESSING SECTOR

CSIRO's Food Processing Sector provides research and development expertise to enhance and sustain the competitiveness of the Australian food processing industry locally and in export markets. It also provides objective scientific advice on food safety and nutrition for the community and industry.

Sector Context, Dynamics and Outlook

The processed food industry is a vital part of the Australian manufacturing sector, employing 20% of the sector's workforce. It is critical to adding value to Australia's primary food produce. It is Australia's largest manufacturing industry, with an annual turnover of approximately $44 billion and value added of $12 billion in 1996–97. These are predicted to rise to $59 billion and $16 billion respectively by 2001–04.

Features of the sector include diversity of business size, ranging from many small to medium-sized enterprises to a small number of multinationals; differences in product focus, from single product to multiple product lines; and differences in market focus, with some companies with domestic business only and others that are major exporters.

Despite the recent downturn in Asian economies, the longer-term outlook for exports is good. Whilst exports of food to Asia declined marginally in the first quarter of 1998–99, total exports grew by about 10%. Processed foods is the fastest growing segment of world trade, with some 75% of agricultural products expected to be traded in the form of processed foods at the commencement of the new millennium.

The industry's strengths are a reputation for food product quality, high standards of hygiene and safety, and freedom from contaminants, as well as access to a cost-competitive supply of a wide variety of raw commodities. Its proximity to the expanding food markets of the world, particularly the Asia–Pacific, together with a multicultural domestic market that demands diversity in products are further strengths that equip the industry to meet the needs of export markets.

R&D drivers: There are a number of factors that will influence the nature of R&D for and by the food industry in the medium term. Firstly, the market for food products is becoming increasingly global, with domestic and international customers increasingly able to source the products they require from a number of countries. This will demand significant improvement in the efficiency with which the Australian industry operates. Secondly, changing consumer expectations and increasing awareness of the role of diet in promoting health and protecting against disease will require the development of new products and an understanding of the factors that influence consumer choice. Thirdly, the increasing role of new technologies, particularly gene technology, in the production of novel raw materials and ingredients.

R&D investment and uptake of R&D: The participation rate by food companies in R&D has been low historically but this is changing significantly in response to a market place in which innovation plays a key role. This is reflected in the 60% increase in business investment in R&D from $149 million to $239 million in the period 1994–95 to 1996–97.

R&D providers: CSIRO and Food Science Australia (a joint venture of CSIRO and the Australian Food Science Industry Centre) continue to play lead roles for public and private R&D for the sector. This is enhanced by key roles in a number of food-related CRCs. Further integration with the Rural R&D Corporations and with CSIRO's Field Crops, Horticulture, and Meat, Dairy and Aquaculture Sectors will be critical to ensure the 'through chain' coordination of R&D priorities and directions. Many companies will increasingly seek R&D internationally, providing a strong requirement that CSIRO maintains its position in this expanding market. (Food Science Australia is successfully competing in the global marketplace.)

Planned Achievements

The sector plan is composed of five primary research components that address the following key strategic issues facing the food-processing sector in the medium term:

- Globalisation of markets—providing both opportunities to increase exports as well as challenges to withstand import competition.
- Consumerism—increasing demands for sustainably produced, safe, wholesome, convenient and affordable quality food products with health benefit attributes.
- Technology domination/transfer—advances in other disciplines (such as information technology, nutrition and health sciences) incorporated in food products and processes.
- Changing demographics—changing food requirements of ageing.
- Changing international and domestic regulation and policy—affecting food composition, production and manufacturing systems and food labelling, for example health claims.

A sixth component will focus on important emerging R&D issues related to the new food category of 'functional foods' and 'nutraceuticals', particularly the substantiation of health claims, and to microbiological food safety (a CSIRO/industry virtual R&D centre).

1. Consumer issues

Outcomes: New product opportunities. More focused and effective new product development. Increased success of product innovation and/or marketing and communication strategies in domestic and key export markets for new cereal-based products. Greater consumer understanding of microbial food safety and gene technologies in food production. Domestic and international recognition of the Australian food industry as 'clean and green'. Reduced failure rate of new products and associated reduced costs to processors and consumers.

Outputs: Scientific papers and client reports including recommendations for product development and effective communication/education strategies. Intellectual property for the development of novel consumer screening and assessment tools.

Development of R&D capacity: The key R&D development will derive from novel behavioural models and methodological tools for understanding consumer issues, supported by the development of appropriate intellectual property and associated software.

2. Product manufacture and delivery

Outcomes: More productive and flexible factories and use of novel processes to produce new products. Innovative food products with enhanced quality and shelf life. Increased consumption of higher quality domestic and export products as a result of optimised storage and transport systems.

Outputs: New packaging systems. Platform technologies and integrated process systems models for targeted industries, on-line sensing and other information technologies, new process control methods, new separation and recombination technologies, further development of extruded high moisture textured animal and plant protein products. ZERO2 oxygen scavenging packaging commercialised. New concepts in tamper-evident and anti-microbial packaging. New and improved edible coatings. Models to predict food quality, temperature, moisture and gas composition. Cost-effective storage and distribution systems.

Development of R&D capacity: R&D capacity will be enhanced through the development of information technology applications in the processing area. Expansion of knowledge of product properties and production processes, as well as expansion of working relationships with local and Asian research groups.

3. Food and drink safety

Outcomes: Company food safety plans and government food regulations based on quantitative scientific assessment of hazards. Emerging hazards identified; control strategies implemented before serious contamination crises occur. Understanding of the safety impact of new and innovative processing and production procedures.

Outputs: Quantitative risk assessments and objective criteria for food safety standards. Analytical techniques, including for risk assessment. Understanding of behaviour of food safety hazards throughout the food chain and strategies for risk reduction. Alternative microbial inactivation processes.

Development of R&D capacity: The principal area for the building of R&D capacity is for the development of preventative control measures, especially quantitative techniques and risk assessment methodologies.

4. Ingredients innovation

Outcomes: Enhanced global competitiveness by the development of new differentiated animal and plant food ingredients from natural sources. Higher quality, lower-cost or novel food ingredients and ingredient formulations adopted by manufacturers. Increased utilisation of food industry by-products and waste streams.

Outputs: Technologies to improve the quality and yield of manufactured food ingredients. New, differentiated crop types developed for natural food ingredients with novel and highly specific applications. Fermentation technology to produce food ingredients from cell/tissue cultures. New techniques for extraction, concentration and modification of food ingredients from cereals, oilseeds and grain legumes. Novel encapsulation and formulation systems, new enzyme technology systems. Improved foams, emulsions and colloidal food systems. New knowledge about physiochemical changes in dairy products during processing and functionality of grain ingredients.

Development of R&D capacity: The key development of R&D capacity will involve collaboration with other CSIRO groups to further develop an integrated, whole-of-industry approach in food ingredients research. Collaborations with external research agencies will be strengthened.

5. Diet and health

Outcomes: Australian produced high value-added foods to compete successfully, both globally and nationally, in the functional food market. Improved reliability/ veracity of health claims providing better-informed consumer choice and improved nutrition. Reduced incidence of nutritionally-related diseases.

Outputs: Provision, for the Australian-based industry, of an authoritative source of scientific evaluation of health claims for submission to regulatory authorities. Authoritative appropriate advice that links protective agents in diets to strategies to reduce overall risk of disease, for use by industry and the community. Understanding of the contribution of dietary fibre and resistant starch to bowel health, including their role as prebiotics. Understanding of novel phytochemicals as modulators of the activity of

key protective enzymes. New biomarkers for oxyradical tissue damage, genetic stability and chromosomal damage, and gastrointestinal function.

Development of R&D capacity: Emphasis will be placed on the development of the capacity to identify and test novel foods and ingredients, and to develop healthful food products. Focus will be on validated biomarkers of disease risk to underpin the substantiation program for functional foods and related health claims.

6. Virtual R&D centre

Outcomes: Enhanced ability to predict disease risk during the evaluation of functional foods and nutraceuticals. More efficient application of food safety resources. More effective and cost efficient management of food safety issues by industry.

Outputs: Understanding the potential for development and dissemination of microbial antibiotic resistance along the food chain. Biomarkers for disease risk for application in human trials of functional foods and nutraceuticals. A quantitative risk assessment framework for industry. New knowledge about the effect and impact of the use of antibiotics in animal and plant agriculture on the development of antibiotic resistant strains of bacteria capable of causing food poisoning.

Development of R&D capacity: R&D capacity will be enhanced in three areas: biomarkers of disease risk, quantitative risk assessment for food safety, and microbial antibiotic resistance. This will involve collaboration with other CSIRO research groups and external research agencies.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Consumer issues	1 337	910	2 371
2. Product manufacture & delivery	18 055	21 677	40 322
3. Food & drink safety	10 308	7 019	17 487
4. Ingredients innovation	16 374	18 477	35 741
5. Diet & health	7 286	3 205	10 786
6.Virtual R&D centre†	2 166	1 960	4 107
Grand total	**55 526**	**53 247**	**110 814**

†Funding of $200 000 will be provided in the first year to develop the concept with industry. The provision of the remaining funds is subject to a satisfactory outcome in the first year.

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Health	1 314	512	1 831
Food Science	35 790	38 159	74 817
Health Sciences & Nutrition	9 041	4 462	13 888
Maths & Information Sciences	1 015	500	1 565
Plant Industry	8 366	9 614	18 712
Grand total	**55 526**	**53 247**	**110 814**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

Sector coordinator

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FORESTRY, WOOD AND PAPER INDUSTRIES

On behalf of the Forestry, Wood and Paper Industries Sector Advisory Committee, I am pleased to present to you and to the CSIRO Executive Committee the Sector's Strategic Plan for the triennium 2000–03.

This plan has been developed through a consultative process that involved committee members at all stages. That involvement was particularly critical to the success of extensive revisions to the sector's research programs that became necessary following the Executive Committee's decision to reduce funding to the sector's value-adding research activities. A re-focusing of effort towards primary and secondary products, renewable energy from biomass, environmental aspects of wood and papermaking systems and paper products was completed in consultation with committee members, in general, and those with expertise in the relevant areas, in particular. The new directions have our full support and we commend the sector coordinator for the efforts devoted to the task.

The committee will continue to work with the sector coordinator and research managers to secure longer-term co-investment opportunities with industry partners in all strategic objective areas across the sector.

It is anticipated that as the triennium progresses there will be a need for changes to the plan and the focus of the sector's activities. The committee will provide support and guidance to CSIRO to ensure that the organisation's investment remains relevant to the needs of the sector and to Australian society.

As mentioned during our meeting with you and the Executive Committee and in several sector documents, the Forestry, Wood and Paper Industries Sector is undergoing considerable and fundamental global, regional and national change. The task of matching industry needs, market demands and research capabilities poses a significant challenge for CSIRO. I can assure you of the committee's commitment to meeting that challenge.

Please accept this strategic plan with the full endorsement of the committee.

Angus Pollock
Chair, Forestry, Wood and Paper Industries
Sector Advisory Committee

Forestry, Wood and Paper Industries Sector Advisory Committee:
Angus Pollock, (Chair), Australian Paper; Ronald Adams, Bunnings Forest Products; Tony Flowers, Fletcher Challenge Paper; Kevin J Lyngcoln, Plywood Association of Australia; Ian Millard, Forestry South Australia; Vanessa Ranken, Egaline Nursery; Richard Rawson, Department of Natural Resources & Environment, Victoria; James Witham, Treecorp Pty Ltd; Peter Yuile, Fisheries & Forestry Industries Division, Agriculture, Fisheries and Forestry—Australia; Peter Zed, CSR Timber Products

FORESTRY, WOOD AND PAPER INDUSTRIES

The Forestry, Wood and Paper Industries Sector delivers significant commercial, environmental and social benefits to Australia. The sector encompasses all stages of the value chain from sustainable management of native forests and plantations, to tree harvesting and log transportation, wood processing into solid timber and composite materials, furniture and other appearance product manufacturing, papermaking and recycled fibre processing and products. The sector contributes to Australia's ecologically sustainable development, providing direct and cross-sector benefits in activities such as biodiversity conservation, remediation of degraded land, land-based waste disposal, carbon sequestration, land and water quality, and social amenity. CSIRO applies its diverse range of skills in genetics, silviculture, ecophysiology, soil science, physical and biological modelling, wood and other materials science, and chemical and process engineering to support the sector's growth and development.

Sector Context, Dynamics and Outlook

The Forestry, Wood and Paper Industries Sector delivers significant commercial, environmental and social benefits to Australia. Industry turnover ($11 billion per year) has been increasing at 5% per year during the past decade. The area of forest plantations has been expanding at the rate of 50 000 hectares each year since 1994, equivalent to an annual investment in excess of $200 million. It will continue to grow under the influence of the *Plantations for Australia 2020 Vision* (a joint industry–government strategy to treble the area of plantations by 2020), likely demand for new carbon sinks in response to the Kyoto Protocol and firm market prospects for forest products. Significant investment in production facilities is expected to continue in response to growth in wood supply and market opportunities in Australia and overseas for value-added products.

Exports of wood and wood products are projected to rise significantly over the next five years. Wood supply will increase as softwood and hardwood plantations and regrowth forests mature. Wood-based panel production is expected to exceed domestic consumption over the medium term with a net surplus available for export. Pulpwood availability is expected to increase significantly and woodchip exports are expected to increase, with Japan taking the major portion. Paper consumption is expected to grow by 13% over the next five years, with a greater share to be met from domestic sources as new production facilities come on stream. Australia's trade deficit in forest products fell by 20% between 1994–95 and 1996–97 to $1.5 billion. Over this period the value of exports increased by 8% and imports fell by almost 10%. Higher-value pulp, paper and paper products continue to dominate imports, at 70% of the total, while lower-value woodchips dominate exports, representing 50% of the total. In 1996–97 the sector provided employment for almost 93 000 persons. With forecast annual growth of 3% over the next five years, employment is expected to increase to 102 000 by 2004.

Key drivers: Major national and international factors influencing Australia's forestry and wood-based industries include:

- globalisation, company amalgamation and global portfolio management
- sustainable production, certification and product labeling
- declining access to native forests and expansion of plantations for wood supply
- greenhouse gas emissions trading
- recognition of the capacity of new forests to supply environmental benefits such as carbon sequestration, remediation of degraded land and improved water quality
- growing recognition of forestry as a commercially attractive land-use option
- competition from steel, aluminium and plastic, and the need continuously to improve performance and quality of wood
- demand for composites and hybrid materials that maximise efficiency of resource use and have predictable service performance
- advances in printing technology
- demand for high performance, lightweight paper and board.

R&D providers: CSIRO is the largest single R&D provider to the sector contributing 15% to 20% of the sector's total R&D effort. Approximately 35% of CSIRO's expenditure of $27.5 million in 1997–98 (4.2% of total CSIRO expenditure) was funded from external sources. In-kind contributions from collaborative and contract research with forest management agencies and industry are equivalent to at least $2 million annually.

Science and technology: Trends include:

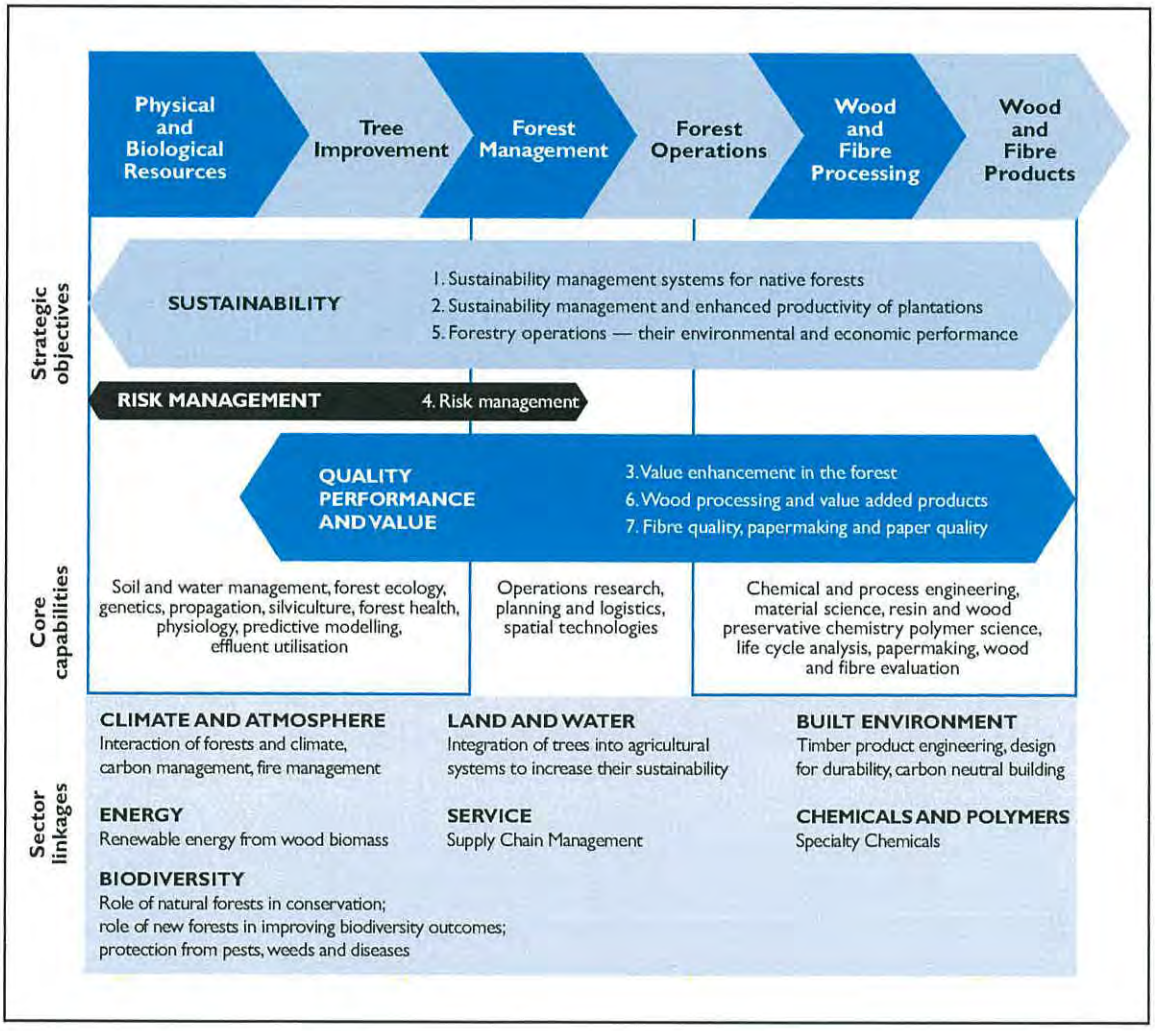
- integration of molecular biology and conventional tree-breeding strategies to improve wood and fibre properties and environmental adaptability
- new remote sensing and spatial analysis tools to aid forest planning and assessment of forest productivity, structure and health
- improved capacity to model forest productivity and quality, and changes in environmental services from forests

- advanced material science for development of new wood/non-wood composites
- technologies to handle increasing quantities of juvenile wood from shorter forest rotations and complete tree utilisation
- resource evaluation technologies to link wood properties to product properties and performance
- effects of downstream technologies (such as in printing and communications) on requirements for surface properties and structure of paper and paperboard.

R&D uptake: Major customers and users of research outputs include private companies and agencies of federal, State and local governments. The majority of companies in the sector are small to medium-sized enterprises, with a few large multinational corporations, especially in pulp and paper production. The plantations and timber-processing segments are undergoing significant changes in structure and ownership. Therefore, it is essential for CSIRO to maintain its international reputation for quality research and to promote its capability and flexibility to build relationships with a changing industry over the next decade.

Planned Achievements

The sector delivers outcomes in seven strategic areas. The scope of sector activities, including linkage to other sectors and relevant capabilities as illustrated in the accompanying diagram, are:



1. Sustainably managed native forests
Outcomes: Commercial, environmental and community benefits from ecologically sustainable wood production in native forests.

Outputs: Silvicultural guidelines for increasing productivity and carbon sequestration of regrowth forests. Models to aid prediction of impacts of harvesting on flora and fauna values. Remote sensing tools for assessing forest composition, structure, biomass, animal habitat and forest health. Scientific advice to government and industry for policy formulation and implementation.

Development of R&D capacity: Partnership in a new CRC for Greenhouse Accounting. Enhanced skills base in geographic information systems and spatial analysis, process-based modelling and greenhouse science.

2. Sustainably managed plantation forests
Outcomes: High quality wood production, land improvements and carbon sequestration through sustainable management of plantations and farm forests.

Outputs: Improved tools for predicting long-term yield response of stands to management, and assessment of the impact of management on wood quality. Sustainability criteria and indicators for a range of sites and environments. Silvicultural/production system guidelines applicable to new environments. Management models for regional hardwood and softwood forests. Strategies for integration of site/stand management with desired wood quality. Assessments of the impacts of large-scale forestry on water resources. Quantification of the impact of site conversion, reforestation and stand management on production and carbon sequestration.

Development of R&D capacity: Strengthening of regional partnership networks of plantation owners and investors. Forming industry consortiums for pre-competitive research.

3. Value enhancement in the forest
Outcomes: Profitable and sustainable planted forests and high quality uniform wood resources through development and deployment of high quality genotypes. Inbreeding lines of *Pinus radiata* incorporated into industry cooperative breeding programs.

Outputs: Advanced eucalypt breeding programs incorporating early (molecular) selection including wood property traits. Trees transformed for improved flowering and rooting. Elite germplasm of eucalypt pure-species and hybrid controlled crosses.

Development of R&D capacity: Strengthening breeding technologies for hybrid eucalypts adapted to southern Australia and molecular approaches to germplasm improvement. Development of transformation technology for eucalypt species and technologies to reduce seed-to-seed time in the breeding of commercial forestry species.

4. Risk management
Outcomes: Reduced economic, social and environmental losses from fire, pathogens, pests and drought.

Outputs: Trees with improved pest and pathogen resistance. Diagnostic molecular probes for major pathogens of eucalypts. Integrated pest and pathogen management and control strategies. Guidelines for safe work practices in forest fires. Improved fire danger rating and decision support systems. Site-specific silviculture methods to conserve ground water and reduce impacts of drought.

Development of R&D capacity: Improved capacity for the identification of key genes for pest and disease resistance. Continue to build expertise in decision support systems for fire-risk management and integrated pest and pathogen management.

5. Forestry operations
Outcomes: Improved forest planning, logging and transport systems to minimise costs and adverse impacts on soils and water. Improved management practices in private forests.

Outputs: Guidelines for improved site planning. Integrated management systems that link planning, scheduling and control of operations. Options for cost-effective land and water remediation.

Development of R&D capacity: Increased capability in forestry operations research and systems optimisation. Increased utilisation of global positioning systems and machine instrumentation. Strengthened links with users through CSIRO's continued participation in the Forest Technology Program.

6. Value-added wood products
Outcomes: Strengthened competitive position of Australian wood products industries through measures such as assisting primary processors with resource changes, extending markets, increasing efficiency in the composites segment and increasing the commercial value of residues.

Outputs: Higher-value primary and secondary products from young, fast-grown wood. Improved processing technologies. Improved products and processes for wood preservation. Methodologies for resource evaluation to enable genotype selection for product and product performance. Carbon products and energy from biomass. New resins for conventional composites and new durable composites. Improved wood preservatives and preservation methods.

Development of R&D capacity: Rebuilding of research team in primary wood products and strengthened capabilities in secondary wood products. Strengthened collaborative links with industry and other research groups.

7. Papermaking and paper quality
Outcomes: Enhanced competitiveness of Australia's paper industry by increasing papermaking efficiency and developing new and improved paper products.

Outputs: Technologies for surface treatment of paper. Evaluation of selected genotypes for product performance. Optimal raw material formulations for improving papermaking operations.

Development of R&D capacity: Development of a flexible laboratory papermaking facility for analysis of resource and process variables. Strengthening polymer and paper science for enhancing paper surface properties consistent with advances in printing technologies.

RESOURCE SUMMARY ($'000 FOR THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Sustainable native forests	5 093	2 077	7 476
2. Sustainable plantation forests	12 728	5 344	18 112
3. Value enhancement	9 185	7 050	16 225
4. Risk management	5 101	3 024	8 335
5. Forestry operations	1 275	470	1 747
6. Value-added wood products	10 036	3 511	13 568
7. Papermaking & paper quality	5 250	1 706	6 970
Grand total	**48 667**	**23 182**	**72 433**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Centre for Mediterranean Agricultural Research	330	0	358
Entomology	1 363	1 449	3 018
Forestry & Forest Products	44 196	20 404	64 629
Maths & Information Sciences	475	261	977
Plant Industry	1 486	750	2 249
Wildlife & Ecology	817	318	1 203
Grand total	**48 667**	**23 182**	**72 433**

** External revenue for research and services.*
***Includes other external revenue and retained earnings*

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HORTICULTURE

It is my pleasure, on behalf of the CSIRO Horticulture Sector Advisory Committee, to endorse the Horticulture Sector Plan for the triennium 2000–01 to 2002–03.

The opportunity to be integrally involved in planning on a sector basis was grasped firmly by the committee and the sector staff alike. There has been rapid growth and profound change in horticulture during the last triennium, and understanding and addressing these changes have ensured that CSIRO is focused on this industry, which is currently valued at more than $6 billion (farm production only).

Horticulture has doubled in value in the past seven to eight years. New investment levels are among the highest of any industry sector in Australia and the industry is expected to double again in the next five to six years. In addition, horticulture is incredibly diverse and has a broad range of products and producers. It covers both temperate and tropical Australia and is becoming a major rural employer. In the past, horticulture was seen as fragmented and having a poor focus on its customers. The committee has understood clearly the need to redress this view of horticulture in order for CSIRO to be well positioned to meet the current and emerging needs for this industry.

The planning process revealed the importance of both on-farm solutions and supply-chain management to ensure that consumer demand for healthy, fresh, natural products is met.

The sector planning process also brought into sharp focus CSIRO's leading role in genetically modified food research. The committee wholeheartedly supports the need for research in this area, both to increase knowledge about plant performance and to provide genetically-modified varieties to Australian horticulture which assist it to meet consumers' requirements for sustainably produced, safe, healthy and fresh foods.

Horticultural operators have matured in their approach to longer-term profitability with increased attention to international competitiveness and improved return on invested capital. Long-term profitability is perhaps more often thought of as long-term sustainability because it encompasses not just capital but farming resources of land, water and nutrients as well as people, skills and intellectual property. The plan acknowledges and addresses these changing perceptions of sustainability and competitiveness.

Communication with the horticultural industry remains a critical requirement. Having acknowledged the industry's diverse and widely distributed nature, it is vital to provide sufficient resources to present CSIRO's skill base and ability to do excellent research to those who influence the R&D decisions and the allocation of research funds.

There is no doubt that the horticultural industry is continuing to change rapidly in a bid to better meet the changing requirements of customers—both domestic and international. The increased maturity of the industry has resulted in shifts in attitudes toward research—particularly recognising research's fundamental role in any sustainable industry and the need for longer-term investment.

I have no doubt that the time and effort taken by sector staff and the committee to review both the horticultural industry and the sector's activities have been valuable. The resulting plan will have profound benefits for the sector through better positioning of resources and effort, and through a better understanding of the horticultural industry as the customer.

I believe the sector-based planning approach and the resulting triennium plan will prove a powerful catalyst in forging closer links between CSIRO and the horticultural industry, and assist in the further growth of this vibrant industry.

David Pullar
Chair, Horticulture Sector Advisory Committee

Horticulture Sector Advisory Committee:
David Pullar, (Chair) David Pullar & Associates; Laurence Ah Toy, Koolpinyah Station Pty Ltd; Anthony Biggs, Cardinal Horticultural Services Pty Ltd; Phillip Fitch, New Industries Enterprise Competitiveness, Agriculture, Fisheries and Forestry—Australia; Phillip Laffer, Orlando-Wyndham Pty Ltd; Brian Newman, Ausveg Board; Peter Pokorny, Fresh Foods, Woolworths Ltd; Rob Robson, Harvest FreshCuts Pty Ltd; Paul Ziebarth, Queensland Fruit & Vegetable Growers Board

HORTICULTURE

The Horticulture Sector Plan will encompass research in five broad components with a range of outcomes expected in the 2000–03 period and beyond.

The sector uses conventional and new technologies in production and post-harvest research to deliver high quality products and increase the competitiveness, profitability and sustainability of Australia's horticultural industries.

Sector Context, Dynamics and Outlook

Horticulture contributes significantly to the Australian economy. The cash value of wine, fruit, vegetable and nursery production at the 'farm gate' is more than $6 billion per annum. When the multiplier effects associated with processing, wholesale distribution and retail marketing are taken into account the total value is estimated to be about $10 billion, which includes a substantial and expanding export income. Horticulture has become a major employer in the agriculture sector and is contributing to the growth and rejuvenation of regional centres around Australia.

Exports of wine have already reached the year 2000 target of $1 billion, and the $2 billion export target of other horticultural crops is on track with exports up from $530 million to $1.1 billion in the last three years.

Significant changes are taking place in this sector.

- Actual and expected growth rates of horticultural investment are amongst the highest of any industry sector in Australia.
- Corporate, consumer and supermarket preference for food safety and quality assurance, exercised through buying power, is a major influence at the production level.
- The crop base of the industry remains diverse, but many commodity groups are developing an outlook and organisation similar to that of the wine industry. This change results from increasing corporatisation of horticultural management and product marketing.
- Sustainability issues, including water, are an integral part of horticultural investment and production.
- Genetically modified organisms (GMOs) and the associated technology are being accepted as a vital research tool.
- GMOs and their release for agricultural and food use is a major issue for the coming triennium.
- The industry components of the sector are now actively involved in the debate on GMOs, and the sector coordinator is an adviser to the Horticultural R&D Corporation's spokesperson on these matters.
- Plant health, quarantine, and pest and disease incursions will need increased attention as internationalisation of supply chains continues.
- Management of chemical inputs including IPM and environmental issues will be an increasing focus of the sector.
- Total rural industry research funding available for horticulture in 1999–2000 is about $55 million ($23 million in 1996–97).
- R&D planning, management and uptake of outcomes increasingly involves industry leaders in project teams as well as rural industry research funding bodies and researchers.
- Rural industry research funding bodies are looking for long-term plans and unifying issues to achieve balance between applied and strategic research.
- CSIRO is recognised as a leading agency in Australian horticulture with the capacity to carry out strategic and applied research on a national scale and with industry relevance.
- Outcomes and processes from CSIRO initiatives in established and emerging horticultural industries are increasingly valued by industry and collaborating research agencies.
- Collaborative research projects between inter-agency teams are becoming the expected norm.
- Co-investment with CSIRO by the public and private sectors to meet specific objectives is increasing.
- The sector is budgeted to invest around $30 million over the next triennium with an external earnings target of 43% of total expenditure.

Planned Achievements

Five components of the sector plan are:

- improving the variety, range, quality and competitiveness of horticultural crops in Australia (crop variety and quality)
- long-term, low-impact horticultural crop management for optimal productivity and profitability (crop management)
- development of new and appropriate technologies for protection of horticultural crops (crop protection)
- maintaining product quality, safety and market access post harvest (post-harvest quality)
- efficient use of water and nutrients for sustainable horticulture (water and nutrient management).

These components are not discrete, interacting one with another, and the overarching issues in the management of these components are:

- food safety
- food quality
- sustainability

driven by demands from the industries' consumer and customer base, and its production requirements.

Nevertheless, for ease of accountability, the outcomes and outputs for each of the components are listed below. In sum, the outputs will result in increased profitability and ecological sustainability.

1. Crop variety and quality
Outcomes: New and improved horticultural crops to provide better variety and quality, seasonal availability and meet consumer preferences. New grape varieties in production, increasing the profitability of the viticultural industries.

Outputs: New varieties of grapes, citrus, cashews, mangoes, melons and macadamias, conventionally bred and available for evaluation and, in some cases, commercial release. New varieties of grapes for wine, dried fruit and table grapes. Genetically modified citrus, grapes, potatoes and tomatoes evaluated.

2. Crop management
Outcomes: Reliable and increased production of tropical tree fruit and nut crops. Closer matching of viticultural and other production to processing investment and market demand.

Outputs: Crop forecasting and grapevine growth models for the wine industry. Protocols for managing flowering and fruit set in tropical fruit and nut industries. Best practice handbook for macadamia production.

3. Crop protection
Outcomes: Reduced crop losses and containment costs due to improved risk assessment and control measures for horticultural crop pests. Reduction in the number of pest incursions. Improved incursion management of exotic pests and diseases.

Outputs: New risk assessment and management technologies for pests including whitefly, diamond-back moth, clear-wing borer and green vegetable bug.

4. Post-harvest quality
Outcomes: Increased market access and penetration with increased domestic and export sales of fresh and value-added fruit and vegetables and export sales rising rapidly. Increased safety and quality of horticultural products recognised in the marketplace.

Outputs: Packaging systems to improve safety, quality and longevity of horticultural products. Predictive models to manage supply chain issues.

5. Water and nutrient management
Outcomes: More effective water, soil and nutrient use in horticultural production leading to cost containment, control of irrigation-induced salinity and reduced off-site impacts of applied nutrients and salinity.

Outputs: New methods for irrigation management and control.

Development of R&D capacity
A feature of the stabilisation and growth of the sector which has occurred in the past triennium has been the recognition by industry of the importance of strategic research and R&D capacity to focus fundamental discovery research on issues of horticultural importance. This intellectual capital aspect of the sector's plan lies behind the planned outputs and is the most important to maintain and strengthen in order to ensure a future for Australia's horticultural industries.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Crop variety and quality	11 564	8 737	21 069
2. Crop management	5 324	4 197	9 797
3. Crop protection	3 973	4 651	8 736
4. Post-harvest quality	2 384	2 678	5 179
5. Water & nutrients management	3 463	2 489	6 106
6. Biometrics	310	153	470
Grand total	**27 017**	**22 904**	**51 357**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Centre for Mediterranean Agricultural Research	82	0	90
Entomology	3 243	4 222	7 540
Food Science	805	1 370	2 207
Land & Water	1 998	1 029	3 084
Maths & Information Sciences	310	153	470
Plant Industry	20 579	16 131	37 967
Grand total	**27 017**	**22 904**	**51 357**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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MEAT, DAIRY AND AQUACULTURE

Planned research activities in the Meat, Dairy and Aquaculture Sector for the coming triennium have been enthusiastically endorsed by the Sector Advisory Committee. The meat, dairy and aquaculture industries are different in their nature and needs. The research plan is designed to provide technology options to industries that are either uncertain about how to capitalise on their future (as in meat and dairy) or are moving into a consolidation phase after rapid establishment (as in aquaculture).

In achieving this much revised research structure, the committee has been involved in extensive consultations with CSIRO staff and industry, has participated in a major industry/CSIRO workshop and a range of other industry meetings, and has considered a wide range of plans and reports. Through this process three drivers of change in the sector became evident: market access and development, sustainable development, and profitability and competitiveness. The resultant six components of the sector plan recognise these fundamental drivers that will shape the animal industries in the next decade and beyond. Each component will deliver the opportunity for long-term, sustainable competitive advantage for industry and ultimately the Australian economy.

Over the next 10 years, industries in this sector will continue to face major change and ambiguity in market signals. They will also face increasing pressure to contribute to social and environmental objectives of the Australian community and of global consumers. In this environment, industry needs effective and timely transfer of technology. The committee plans to work closely with CSIRO to assist in the development of a more rigorous process to identify paths to commercialisation for key projects, and the identification of performance indicators to track the impact of the sector's research.

The committee acknowledges that some elements of the plan are not as well developed as others. The coming triennium, for example, will see a larger effort in pursuit of ecological sustainability through the development of sustainable, integrated management systems. This is an area in which competing philosophies are very evident, and ultimate achievement of the greater likelihood of sustainability will be reached only as a result of the better understanding of production systems that research will deliver. It is an area in which rapid change can be anticipated. Similarly, market needs and potential are changing. Accordingly, the committee recognises that further work will be needed to keep the plan current. It is a living document and the committee will seek to negotiate intra-sector alterations in priorities and resource allocations with the CSIRO Executive, where appropriate.

I am pleased to endorse the plan on behalf of the committee and gratefully acknowledge the dedicated effort of CSIRO staff in its synthesis. I also thank my fellow committee members for their efforts.

Ted Christie
Chair, Meat, Dairy and Aquaculture Sector Advisory Committee

Meat, Dairy and Aquaculture Sector Advisory Committee:
Ted Christie, (Chair) Barrister at Law; Teresa Allen; Gordon French, Queensland Dairy Farmers Organisation; Robin Hart A.M., Kerwee Pastoral Co; Pheroze Jungalwalla, Tassal Ltd; Rod Kater, AMP Life Ltd; Gardner Murray, Consultant

MEAT, DAIRY AND AQUACULTURE

The Meat, Dairy and Aquaculture Sector provides strategic research to promote profitable and sustainable industries, enhance the quality and range of animal products, and improved natural resource management, including remediation. The research effort is driven by the need to provide the opportunity for sustainable competitive advantage in global markets.

Sector Context, Dynamics and Outlook

The meat, dairy and aquaculture industries are Australia's fourth largest direct export earners and are an important underpinning of the viability of the $44 billion food-processing industry. These industries also make a major contribution to national wellbeing by providing high quality and safe products, and are a mainstay of Australian rural life, social infrastructure and employment. Collectively they are highly productive and focused on performance in global markets.

Continued prosperity in this sector will come from providing premium food products to increasingly affluent and discerning niche markets. The sector is answering the challenge of profitably growing export opportunities through the development and marketing of a wider variety of quality, safe, hygienic and nutritious products. Industries are taking steps to be quality assured from paddock to plate, and increasingly are providing products to tighter consumer specifications (ranging from eating quality to responsible stewardship of the environment).

The sector is predicted to build export markets worth close to $8 billion during the next triennium, with total turnover rising to $15 billion. The red meat, dairy and aquaculture industries are export-oriented with more than 70% of overall production being exported. Pig and poultry industries have an export-replacement value of $2 billion.

R&D investment: The sector enters the triennium after a period of mixed fortune in the face of recent well-publicised difficulties in global meat markets. In contrast, dairy and aquaculture performance has been sound. Medium to long-term prospects for all industries of the sector are sound. Already beef exports are responding to better prospects in the international market, with sheep meat exports holding their ground. Globally, pig and goat meat consumption will rise significantly over the next three to five years providing new opportunities for Australian product. Dairy production, and growth in export markets, will continue strongly, achieved in large measure by further structural adjustment. Aquaculture exports demonstrate solid strength of demand, with medium-term prospects being very good, especially if the industry is able to diversify its markets.

With this recovery in global market prospects, the sector will rebound. It is anticipated that investment in R&D will return to previous levels, although structural changes and a focus on cost effectiveness will see change in the pattern of investment. The relative importance of rural R&D corporations will decline as direct, corporate investment increases.

Uptake of R&D: Concentration and competition have come into focus as the Australian food processing and agricultural sectors continue to industrialise, with farms and processing operations expanding in size, becoming more specialised, and relying more on direct contractual methods for buying or selling agricultural commodities and manufactured inputs. Concentration—a sharp decline in the number of buyers or sellers in an industry—may limit competition and affect prices, depending on such factors as ease of entry into the market, availability of substitutes for the products and the nature of rivalry among existing firms in the market.

Broad structural changes associated with industrialisation also raise issues unrelated to competition and market prices, such as environmental concerns involving large livestock operations or processing plants. It is also resulting in the top producers and processors becoming more concerned about directly capturing the benefits of R&D, and in a manner more exclusive (and thus conferring competitive advantage) than through the rural R&D corporations.

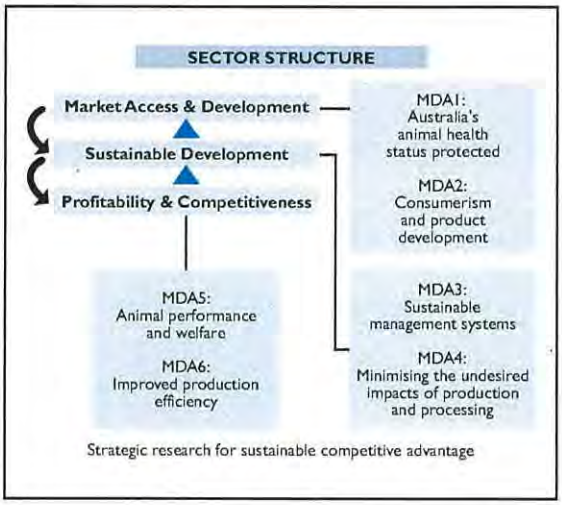
In this environment, the sector has changed the nature and scope of its relationship with the market. This has been necessary to maintain strategic, longer-term co-investment with clients in CSIRO research. This change will consolidate in the next triennium.

Other drivers: All industries of the sector face three major challenges over the next 10 years. These are to be competitive in the global trading environment, to achieve ecologically sustainable development and to operate profitability.

The sector also operates within constraints. These include a need for continuing and more rapid structural adjustment of most industries in response to global-market standards and competition, conflicts between natural resource use and conservation objectives of different stakeholders, and complex and confusing internal industry structures that result in long communication chains and relatively slow response times.

Whole-of-value chain integration remains a major challenge and opportunity for the sector's industries.

R&D providers: CSIRO has the largest research body serving the sector's industries in Australia, with a portfolio of strategic, collaborative and contract R&D. State government departments (and some universities) provide complementary R&D services and a significant extension activity. Private-sector R&D is relatively minor, but growing as industry players restructure into larger business entities. Private provision of extension (technology transfer) services is growing.



CSIRO is a major supporter of collaborative R&D efforts. Collaborative projects facilitate technology transfer and provide a cost-effective mechanism for individual producers and companies to access CSIRO's unique capabilities. There is increasing emphasis on addressing the research needs of service providers, consultants and manufactured inputs providers, rather than individual producers per se. Appropriation (government) funds support pre-competitive research aimed at delivering sector-wide benefits and national wealth creation.

Planned Achievements

The research planned for the sector aims to develop technologies and systems that will help industry enhance international competitiveness, ecologically sustainable development, reduce the risk and consequences of disease outbreaks, expand market access through product development and researching consumer demand, and enhance efficiency and profitability of the industry. The sector plan consists of six components (see diagram) that address these issues.

A major challenge for the sector is to ensure that each component relates to and complements each of the other components. It is expected as the triennium progresses that there will be an increasing flow of constituent technologies into integrated systems. For example, knowledge gained in understanding animal genetics and producing superior animals will be integrated with understanding of impacts such as grazing pressures to produce holistic, sustainable management systems. Similarly, development of pasture technologies coupled with knowledge of consumer trends will allow for better formulation of breeding objectives and management strategies.

Over the course of the triennium, it is intended that the research portfolio will shift away from a production emphasis to provide more focus on sustainable development, market access and development, and profitability and competitiveness. This requires the development of better skills of integration and a greater use of systems approaches.

The sector also has strong linkages with other CSIRO sectors. This includes joint management of the interface with the Food Processing Sector. Long-standing linkages exist with other production sectors such as Field Crops, and Textiles, Clothing and Footwear. Increasingly the sector will need to strengthen linkages with the Biodiversity, and Land and Water Sectors, thus ensuring that essential biophysical research of these sectors is integrated with management systems development within the Meat, Dairy and Aquaculture Sector.

1. Animal health

Outcomes: Protection of Australia's animal health status allowing continued trade in agricultural products and access to important international markets.

Outputs: New and improved diagnostics for detection of exotic, emergent and endemic diseases, and natural toxicants. Rapid diagnosis of and management recommendations for exotic, emergent and endemic disease outbreaks. Design of integrated farming practices that maintain animal health and reduce risks of disease outbreaks. Formulation of new plans and policies by national and State agencies for the management of animal diseases of national and international significance.

Development of R&D capacity: Increased emphasis will be placed on the development of novel means of disease investigation through the use of new technologies in recombinant DNA and molecular biology.

2. Consumers and products

Outcomes: Creation of new business opportunities identified through an understanding of consumer requirements in key markets. Marketing and consumption of new and improved products of high quality and safety.

Outputs: Knowledge of trends and drivers of food choice in domestic and key export markets, including aspects of risk acceptance. Strategies to predict and respond to consumer concerns. On-farm and off-farm production and processing strategies to respond to consumer demands in relation to both traditional and

novel foods. Innovative processing and process engineering systems for beef. Management strategies incorporating improved understanding of the linkages between on-farm and off-farm food safety. Development of new products.

Development of R&D capacity: Increased emphasis on risk management will be applied to enable better management of issues such as food safety. Skills to integrate information from consumer science with meat science and breeding and production technologies will be developed.

3. Management systems
Outcomes: Adoption of new management systems and policies that better integrate economic, environmental and social objectives.

Outputs: Improved understanding of ecosystem functioning and strategies to maintain the resource base and biodiversity. Strategies and policies that better integrate production, enterprise profitability and natural resource management. Improved capacity of landholders and other stakeholders to manage natural resources more sustainably.

Development of R&D capacity: Current strengths in the productivity aspects of sustainability at the enterprise level will be matched by development of skills at catchment and regional scales. Developing a systems approach to production, incorporating economic and social sciences.

4. Minimising undesired impacts
Outcomes: Adoption of viable production and processing procedures that minimise undesirable social, human health and environmental impacts of the sector's industries. Identification and improvement of on-site and off-site impacts affecting soil and water, biodiversity, and habitats.

Outputs: Better processes to improve identification and quantification of undesirable impacts of production and processing. Improved methods of controlling weeds and feral animals. Replacement tools and management strategies that reduce the use and negative impacts of chemicals and pharmaceuticals.

Development of R&D capacity: Greater emphasis will be placed on landscape-scale ecological relationships and resource economics.

5. Animal performance and welfare
Outcomes: Improved animal performance achieved by improving the inherent capacity of animals to resist diseases and parasites, and their suitability in modern management systems.

Outputs: Genetic strategies to develop animals with superior yield, product quality and disease resistance. Integrated technologies for the control of parasites in meat animals. Improved understanding of stress effects on animals. Strategies to reduce stressors and enhance welfare. Application of the emerging biotechnologies and gene technologies for higher animal performance.

Development of R&D capacity: Current skills will be matched by the development of a capacity in functional genomics and a strengthening of molecular quantitative genetics capacity.

6. Improved production efficiency
Outcomes: Increased production efficiency, feed utilisation and more effective feed management.

Outputs: New feeds and feeding systems. Pasture plants and crops with improved nutrient quality. Decision support tools for feed management.

Development of R&D capacity: The current skills base is adequate in most aspects of this component. However, greater effort will be placed on the integration of R&D outputs in the production of decision support tools.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Animal health	22 491	22 842	46 910
2. Consumers & products	11 536	7 104	19 066
3. Management systems	14 496	6 503	21 642
4. Minimising undesired impacts	18 618	9 206	28 517
5. Animal performance & welfare	19 648	8 684	28 824
6. Improved production efficiency	14 888	12 110	28 692
Grand total	**101 676**	**66 450**	**173 651**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Health	30 806	26 048	58 455
Animal Production	17 543	7 969	25 737
Centre for Mediterranean Agricultural Research	289	0	313
Entomology	4 371	3 296	8 002
Food Science	6 884	8 910	16 006
Health Sciences & Nutrition	2 335	986	3 327
Land & Water	803	414	1 240
Marine Research	6 677	2 914	9 607
Maths & Information Sciences	762	375	1 172
Plant Industry	5 262	3 934	10 658
Tropical Agriculture	22 880	10 359	34 574
Wildlife & Ecology	3 066	1 244	4 559
Grand Total	**101 676**	**66 450**	**173 651**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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TEXTILES, CLOTHING AND FOOTWEAR

The industries covered by the sector are experiencing great change. Wool production is undergoing changes in response to the McLachlan Task Force Report and the subsequent comprehensive analyses of the industry's future directions. The cotton industry is facing limits to its growth in the present production areas due to water availability and chemical usage, and sections of the sector's industries are adjusting and restructuring to manage the proposed tariff reductions in 2005.

The Textiles, Clothing and Footwear Sector's Investment Plan is designed to both lead and address these changes through three key drivers: product innovation in textiles and leather to meet consumer demand, diversification of the R&D portfolio and ecological sustainability of natural fibre production.

The plan for 2000–03 has been developed through the Sector Advisory Committee's active participation in the prioritisation process and its involvement with the CSIRO Sector Committee. The plan provides a template for connecting production research in wool, cotton, hides and skins with research into the processing of these fibres and raw materials, and a platform on which to structure a comprehensive R&D portfolio focused on facilitating innovation and technological development in fibre production and textile and leather processing in Australia.

The prioritisation process has produced a balanced portfolio of strategic and tactical research with technology-transfer initiatives and the delivery of services to the fibre-producing industries for textiles, clothing, footwear and leather. The plan recognises the importance of biotechnology in both sheep and plant production to address issues associated with consumer demand for unique materials and the sustainability of fibre production.

The Sector Advisory Committee supports the plan's focus and structure which emphasise the importance of information transfer and technological developments along the whole supply chain from fibre producer to consumer. In this respect, the committee welcomes the inclusion of cotton production into the sector because this is consistent with the supply-chain approach underpinning the sector's structure.

The strong emphasis on the supply chain and production innovation is complementary to the Government's policy to encourage innovative technologies, which enable the development and production of new textile products. In this respect, the committee endorses the diversification of the sector's portfolio into research on fibres other than wool and into blends of wool with cotton and synthetics. The committee is particularly conscious of the importance of R&D into the ecological as well as the economic sustainability of natural fibre production in Australia. It strongly supports the scope and content of the R&D program in these areas.

The committee will be supportive of CSIRO initiatives that facilitate outcomes from the Government's Action Agenda process and the 2000 Strategic Investment Program for textiles, clothing and footwear. The committee believes the opportunities presented by the Government's investment program can assist the diversification of the sector's research portfolio and assist the Australian industry to take advantage of the opportunities in information technology, supply-chain management, innovation and technology development. In this respect the increasing involvement of the sector with the domestic textiles, clothing and footwear industries in collaborative R&D programs is welcomed.

The committee is fully committed to the implementation of the plan and is keen to facilitate:

- the establishment of an account management system which addresses the needs of the textiles, clothing, footwear and leather industries
- marketing of the sector outcomes
- diversification of the R&D program
- promotion and adoption of outcomes which address the ecological sustainability of natural fibre production.

The committee and I fully support the plan and are confident it will set the innovation agenda for the sector and the Australian textiles, clothing, footwear and leather industries for the next decade, and look forward to facilitating its implementation.

John Blood
Chair, Textiles, Clothing and Footwear
Sector Advisory Committee

Textiles, Clothing and Footwear Sector Advisory Committee:
John Blood, (Chair) Textile & Garment Consultant; David Anthony, Auscott; David Boyd, Clyde Agriculture Limited; Trevor Dawson, Rocklea Spinning Mills Pty Ltd; Guy Fitzhardinge, Thring Pastoral Company; Collette Garnsey, David Jones Limited; Katherine Kennedy, The Woolmark Company; Margaret Moroney, Margaret Moroney Pty Ltd; Lindsay Packer, Packer Tanning; Colin Sleep, National Mutual Funds Management; Brian van Rooyen, Australian Country Spinners; Associate Professor Andrew Vizard, University of Melbourne

TEXTILES, CLOTHING AND FOOTWEAR

The Textile, Clothing, Footwear Sector delivers research outcomes that ensure the economic and environmental sustainability of Australia's natural fibre producing and leather industries and facilitate the international competitiveness of its textile, clothing, footwear and leather industries through the delivery of innovative processes and products.

Sector Context, Dynamics and Outlook

The industries represented by the sector are passing through a period of significant change—the rejuvenation of the textiles, clothing, footwear and leather industries and the restructuring of the wool industry in the light of the McLachlan Task Force Report. Increasing cotton production is creating new challenges.

The industries have changed significantly over the last decade following the reforms of the Button Plan and have been restructuring as protection has decreased. While productivity and investment are now increasing in a number of industries, such as in high quality and fashion apparel, and in interior and industrial textiles, there has been a decline in the production of cheaper apparel and footwear manufacture. It is difficult for the Australian manufacturers of such items to compete against the import of such goods from countries with lower cost structures. The turnover of the industries is increasing, now nearly $10 billion, as is the export value of goods ($3 billion) which is around 6% of that of total manufacturing. The industries account directly for 77 000 jobs (the estimated 25 000 to 50 000 outworkers and those involved in the retailing sector are not included in these data). It is Government policy to remove tariff protection in 2005. To assist the industries to adjust to the proposed reductions the Government has engaged with industry to develop an Action Agenda—a strategic plan for 2005 and beyond—and has earmarked a $770 million financial assistance package over the next five years to encourage innovation, value-adding and export growth.

Australia continues to export most of its cotton, wool and woolskins and 45% of its cattle hides in unprocessed form. The high cost structures of Australian industry and the high import duties imposed by many countries on yarns, fabrics and leather goods makes it difficult for Australian companies to compete against low-labour-cost countries. This situation is exacerbated by Australia's relatively small domestic market. Though these handicaps may diminish over time as liberalisation of world trade occurs and the cost structures of the present cheap-labour countries increase, the way forward for these Australian industries is in the production and marketing of high quality, innovative and distinctive products. The present industries will continue to grow as they become more innovative, quality conscious and producers of niche products that capture Australia's lifestyle and design capabilities.

Though wool's market share of textile fibres is about 3%, with cotton and synthetics having respectively around 43% and 53% of the world fibre market, Australia produces over 70% of the world's apparel wool. During the last decade, Australian cotton production has increased substantially and, though it is relatively small by world standards, Australia is the third largest exporter of raw cotton. While most large cotton-producing countries also process their total crop, Australia presently processes around 10% of its cotton to yarn. In addition to hides and skins Australia is also a major supplier of wet-blue leather (part processed bovine leather) to world markets. The demand for leather products, especially for shoe uppers and upholstery, has increased as living standards rise in Asia: 55%–60% of hides, 10% of woolskins and 45% of the available kangaroo skins are processed to leather in Australia. The annual export value of raw wool, cotton, hides and skins is around $5 billion.

Like all commodities, wool and cotton are experiencing downward price pressures. In contrast to the expansion of the cotton industry, wool production is declining as producers leave the land or change to cropping. While many wool producers are able to make a good return on investment by adopting professional management and business skills, up to 40% of wool growers may be forced from the industry due to unmanageable debt and the inability to manage the cultural changes required to stay viable.

The McLachlan review of the wool industry identified the need for significant cultural and structural changes to the wool business system and heralded a reform of the management structure of the wool industry with reduced Government involvement. Despite the present weak demand, raw wool exports are still worth nearly $3 billion. Only 15% of Australia's wool clip is processed in Australia to top (wool which is scoured and combed) and only around 1.5% is processed through to yarn. Wool marketing, distribution and processing are complex, and characterised by lack of vertical integration from the time wool leaves the farm gate. There is inadequate communication along the pipeline from the retailer to the wool grower and vice versa. The cost of production and inefficiencies in marketing and distribution make wool yarn 2.5–3 times more expensive than cotton or synthetic yarns. At present, there is a worldwide overcapacity in early stage processing due to the depressed demand. It is likely that a rationalisation of this element of the processing chain will soon occur with a number of major companies leaving the industry.

Planned Achievements

The sector plan is designed to encompass the supply chain from fibre and raw material production through to

the production of consumer products and is based on six strategic issues. There is a strong emphasis on the delivery of products to target markets and customers. In those strategies addressing ecologically sustainable production issues (Components 2 and 4), outputs are directed to wool and cotton growers or to companies and organisations that can translate the outputs into products for enhanced wool or cotton production. The manufacture of textile and leather products has two elements—one focused on processes (Component 5), the other on the development of new and innovative products (Component 6). The importance of maintaining an Australia free from diseases that may adversely affect wool production or wool's access to overseas markets is addressed in Component 1. The links between fibre and raw material producers, processors and the market place are encompassed in an overarching strategy (Component 3) which bridges the production, the processing and product development elements of the plan. This component addresses information flows up and down the supply pipeline as well as the movement of materials from the producer to the final consumer.

The sector has linkages with CSIRO's Meat, Dairy and Aquaculture Sector, and Land and Water Sector on issues relating to the sustainability of fibre production.

The key drivers for the sector's portfolio are: stimulate consumer demand for wool, cotton and leather by focusing on new products and enabling processes; strengthen Australian wool and leather production and processing in terms of economic, ecological and social sustainability; provide technologies for the sustainable production of high quality cotton with reduced demands for pesticides, herbicides and water; and address the technical and innovation needs of the Australian textiles, clothing, footwear and leather industries by increased activities in wool blends, cotton, synthetic fibres, leather, high quality and easy-care apparel and industrial and technical textiles.

1. Disease management

Outcomes: Consumer acceptance of Australian wool and its access to world markets based on freedom from disease agents and pesticide residues. Adoption of sophisticated diagnostic tests and services for animal diseases. Demonstrated preparedness to meet incursions of new animal diseases.

Outputs: Improved diagnostic tests for animal diseases. Technology to enable reduced pesticide usage. Regular provision of technical and science-based policy advice to national and State animal health agencies and their activities.

2. Animal fibre and leather

Outcomes: Increased use of decision support systems that assist producers of wool, hides and skins to increase profitability in an ecologically sustainable manner.

Outputs: Decision support systems for integrated grazing, nutrition, pest and parasite management. New technologies and management practices for reduced methane emissions from sheep and for improved control of foxes and rabbits and of internal and external parasite control. Release of sheep resistant to blowfly strike. New perennial grass varieties. Biological control of the free-living stages of parasitic worms on pastures.

3. Production-processing pipeline

Outcomes: Adoption of objective criteria that define the qualities of wool, cotton and leather through the supply chain and enable producers and processors to better meet the requirements of consumers. Supply-chain efficiency is enhanced by such adoption.

Outputs: Objective-based sheep breeding programs. Merino sheep producing finer wool with increased fleece weight. Optimal wool-clip preparation and consignment building. Instrumentation and measurement systems to completely specify raw wool and cotton. New technologies for on-farm wool measurement. Processing of long low crimp wool. Improved spinning performance for cotton–wool blends. A new thickness measuring system for leather.

4. Cotton

Outcomes: High quality cotton will be produced in an economic and ecologically sustainable manner through the integration of improved agronomic, varietal, pest and weed management technologies into the production system.

Outputs: Control of Helicoverpa spp. on cotton with reduced use of pesticides. An enhanced **cottonLogic** decision support system linking agronomy, pest and herbicide management and new cultivars. Models to describe the relationship between pests and cotton crops. High yielding cotton varieties. Pest and herbicide resistant cottons. Enhanced knowledge of cotton plant physiology. Dry season cottons suitable for northern Australia.

5. Innovative processing

Outcomes: Increased productivity and product quality achieved by local adoption of processing inventions and innovations. Increased local and international demand for Australian raw materials and processed goods.

Outputs: Educational programs based on technology transfer initiatives; consulting and testing service reports. Textile and leather processes that require lower inputs of water, chemicals and energy and produce less waste. Functional polymer finishes for wool, cotton and their blends. A new wool carbonising process. New dyeing technologies for wool and cotton. Non-wovens with improved web structures. New bleaching technology for cotton. Technologies that reduce processing times in leather making. Leathers with increased strength.

6. New consumer products
Outcomes: New and innovative textile, apparel and leather products that meet consumer needs and demands. New products derived from Optim[R] fibres. Machine-washable, easy-care products from pure wool and wool blends.

Outputs: New Optim[R] fibre types. A high production Optim[R] plant. New mercerising technology for cotton. New shrink-proofing technology. New yarn structures. High performance yarns for technical textiles. High speed cotton-yarn spinning systems for wool–cotton blends. Solospun technology for the short staple spinning system. New setting technologies. Acoustic and thermal insulation batts with enhanced properties. Fabrics for liquid filtration and paper making. Waterproofed leathers. Procedures for producing high quality upholstery furnishings. Test procedures for specialised industrial footwear.

Development of R&D Capacity

The sector draws on a diverse range of scientific disciplines that cover all aspects of wool, cotton and hide production, and wool and leather processing.

The development of decision support systems for both wool and cotton production increases the capacity to link issues within total production systems and identify problems that lie within them, as well as providing opportunities for innovation at the interface between information technology and complex production systems. The sector will continue development and expansion of its skills base to support initiatives for the sustainable production of wool and cotton.

Genetic modification of plants and animals, including the development of transgenic organisms, is causing a sea change in agriculture, and the sector will enhance its skills base in these areas for advantage to Australia.

The sector will also diversify into cotton and synthetic textile processing, as well as into the development of innovative consumer products including those for the interior, technical and non-woven textile sectors. Diversification will include the development of innovative blends of wool with cotton and synthetic fibres. These activities will require the development and acquisition of a wider set of skills in textile technology, textile design and textile engineering.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Disease management	3 683	2 955	6 640
2. Animal fibre & leather	19 318	8 543	28 593
3. Production-processing pipeline	16 571	6 646	23 422
4. Cotton	11 807	18 081	30 735
5. Innovative processing	9 516	6 294	15 814
6. New consumer products	23 984	16 160	40 336
7. Biometrics	148	73	224
Grand total	**85 027**	**58 751**	**145 762**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Health	3 683	2 955	6 640
Animal Production	24 688	9 100	34 134
Centre for Mediterranean Agricultural Research	289	0	313
Entomology	2 598	5 474	7 953
Maths & Information Sciences	148	73	224
Plant Industry	14 073	15 202	30 430
Textile & Fibre Technology	35 639	24 050	59 885
Wildlife & Ecology	3 910	1 897	6 183
Grand total	**85 027**	**58 751**	**145 762**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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BIODIVERSITY

The CSIRO Biodiversity Plan is an exciting package of research, which will make a significant impact on the conservation, and use of Australia's biodiversity. Demands for a reliable and credible science base to the decisions that governments, businesses and people have to make about biodiversity have never been stronger. These demands arise from the realisation that much of it is disappearing or threatened, but that we want to keep it for its cultural importance and because it is the basis for so much of our economic wealth. The new *Environmental Protection and Biodiversity Conservation Act 1999* is a major reflection of the importance of biodiversity in Australian affairs today.

Visions of a future Australia that delivers high quality, profitable food to the rest of the world absolutely depend on developing more sustainable production systems. Biodiversity, and the biological functions it performs, has a central role in renewing the resources that support sustainable production. Working with government, producers and the community, the sector will deliver integrated knowledge, understanding and practical measures to help Australia move towards achieving this vision. A new area of work, on characterising and economically valuing the services that ecosystems provide for people's benefit, will have a major impact on how Australians perceive biodiversity.

Visions of a future Australia as a major drawcard for international visitors depend on landscapes that retain their Australian identity, largely through the unique plants and animals, which inhabit them. The sector will deliver pathways for ensuring the conservation of threatened species and communities, especially in places where landscapes are used for agriculture or tourism, or where they are threatened by pests, weeds or diseases.

The sector will also deliver knowledge about the basic building blocks of our biodiversity: our native species and where they are found. Building the national collections and making the information they contain available to anyone, in easy-to-use formats, is an important CSIRO function.

Achieving on-the-ground outcomes for biodiversity requires integrated efforts on behalf of governments, the private sector and communities, built upon an accessible knowledge base. CSIRO's research in the sector balances efforts directed at all these players, drawing on its extensive multi-disciplinary expertise to help those implementing land management to deliver better biodiversity outcomes. A new area of work on assessing the ecological impact of genetically modified organisms (GMOs) will exemplify this approach. It will develop frameworks for Australia to better gauge and manage GMOs so that we capture their potential benefits without doing irreparable ecological harm. The case studies on particular GMOs that will accompany this research will deliver practical advice to governments, industries and research agencies concerned with these innovative developments.

In working with the sector to develop this plan, the Sector Advisory Committee has been impressed with the sector's plans to aim directly at the areas of greatest need for Australia's biodiversity research, whether or not these are strongly supported by paying clients.

The committee keenly supports this plan, and I look forward to following its implementation through the next three years.

Robyn Kruk
Chair, Biodiversity Sector Advisory Committee

Biodiversity Sector Advisory Committee:
Robyn Kruk, (Chair) NSW Premiers Department; Leith Boully, Farmer; Karen Grady, Business Council of Australia; Stephen Hunter, Environment Australia; Ian Kennedy, Ian Kennedy and Associates; Ray Nias, World Wide Fund for Nature; Henry Nix, Centre for Resource & Environmental Studies, Australian National University; Graeme O'Neill, Freelance Science Writer; Ian Thompson, Natural Resources Management Policy Division, Agriculture, Fisheries and Forestry—Australia

BIODIVERSITY

The Biodiversity Sector addresses the conservation, management and sustainable use of the nation's biological resources and, in particular, the links between biodiversity and ecosystem sustainability. It underpins the emerging trend in industry of triple-bottom-line reporting (succeeding financially, ecologically and socially).

Sector Context, Dynamics and Outlook

Australia's biodiversity is its greatest natural asset, underpinning sustainable use of its land and enriching the lives of its people. Its continuing loss has grown into a major national issue, not only because people's demands for conservation are growing, but because the loss also causes declines in the productivity and resilience of ecosystems. For example, loss of natural enemies (predators, parasites and diseases) leads to pest outbreaks and declines in agricultural productivity; removal of native vegetation has caused water tables to rise, threatening 15 million hectares of arable land with salinity.

Conversely, we can manage biodiversity to improve the health of ecosystems. For example, we can manage catchments and alter aquatic food chains to prevent algal blooms.

Many recent policy initiatives in the public sector reflect concerns about biodiversity:

- The new *Environment Protection and Biodiversity Conservation Act 1999* will create extra demand for services relating to ecosystem management and high expectations about biodiversity knowledge.
- The draft national Natural Resources Management Statement puts strong emphasis on biodiversity and ecosystem function, and will drive major investments in ecological design.
- The Productivity Commission (1998) identified 'lack of understanding of ecosystem services...a major impediment to improving policy' for ecologically sustainable development.
- All States now have policies and regulations that demand adequate biodiversity protection, such as the *New South Wales Native Vegetation Act 1997* and the *Queensland Integrated Planning Act 1997*.
- The Australian Local Government Association adopted a National Local Government Biodiversity Strategy in 1998, and local councils are responding with action. For example, the Port Douglas Shire, with CSIRO and tourist operators, is developing strategies to protect its biodiversity and ecosystems on which its tourism industry depends.
- Internationally, Australia has committed to actions under various treaties, such as the Convention on Biological Diversity and the RAMSAR Convention (for wetlands).

In the private sector, industries are seeking new ways of managing biodiversity and ecosystems in order to obtain or maintain their 'licence to operate'. Visionary companies, such as Bonlac, CRA and DuPont, which adopt these practices will gain:

- access to markets as consumers demand 'greener' products (emphasised at the recent regional summit convened by Minister Anderson)
- sanction to capitalise on the benefits of genetically-modified-organism (GMO) technology
- increases in profitability as natural inputs are substituted for purchased inputs
- avoidance of the costs of fixing past environmental mistakes through better ecological understanding and design.

Industry groups are also recognising biodiversity. The 1999 Tourism Industry Summit has just agreed to develop a biodiversity strategy.

In the community sector, biodiversity has become integrated into Landcare objectives, and the $1.25 billion Natural Heritage Trust supports community actions to protect and restore biodiversity.

In 1998, recognition across these sectors translated into $8 million earned by CSIRO through externally driven research for a broad set of clients. The six largest clients, representing over 40% of the demand were:

- Environment Australia
- the Land and Water Resources R&D Corporation
- the Murray–Darling Basin Commission
- AusAID
- the Australian Centre for International Agricultural Research
- Agriculture, Fisheries and Forestry—Australia.

Australians legitimately expect CSIRO to act: This burgeoning public and private interest expects government—and therefore CSIRO—to invest in research for sustaining biodiversity and ecosystems. Returns on this investment will flow to both the private and public sectors, and will be maximised by CSIRO working alongside government and industry on mutual objectives.

CSIRO makes a difference: CSIRO's knowledge is used in policy and on-ground programs. Concepts and data generated by CSIRO helped form the first national State of the Environment Report and were a key element in recent regional forest agreements, and underpinned the criteria used by the Endangered Species Advisory Council. Environment Australia's Biodiversity Group reports that its relationship with

the CSIRO sector 'is vital to the continued productivity of a large number of biodiversity group programs' (Environment Australia contracts to the sector are worth over $0.6 million annually).

Industry accrues tangible benefits from CSIRO's research. A CSIRO analysis of the sustainability of CRA's rehabilitation procedures in March 1999 brought forward its licence to operate two mines in the Bowen Basin. Genetic assessment of tree species has brought profits to commercial forestry operations, through better informed species selection and improved consistency in timber quality.

Outlook: Salinisation and other degrading processes will continue (already 560 000 hectares have water tables within 2 metres of the surface in the Murray–Darling Basin), and the habitat will become even more fragmented in agricultural areas. The demand for the rehabilitation of degraded areas is increasing; in response, ecological engineering and novel ways of managing ecosystems are emerging.

Growing markets for clean, green products will drive demand for systems for accrediting protection of biodiversity and ecosystems (such as ISO 14000). Bioprospecting will increase and the demand for sustainable agriculture will stimulate new industries based on Australia's biota.

The GMO debate will intensify and broaden its concern about possible secondary impacts on the biodiversity and ecosystem functions. As the concept of 'duty of care' becomes accepted, the Australian public will put increasing pressure on governments to better conserve biodiversity.

CSIRO's role: CSIRO conducts 15% of the national R&D in this field but achieves a disproportionately larger impact. This is because our research fills significant gaps in the national portfolio—it is more multi-disciplinary, focusing on outcomes of national significance and addressing issues at large-scale and long time frames.

Within this role, CSIRO is particularly noted for:

- Developing and applying major new technologies—CSIRO is breaking new ground internationally in applying modern technologies to conservation challenges. These include our molecular research on novel control measures for rabbits, foxes and aquaculture escapes, and our informatics research that will maximise the benefit of the information stored in our biological collections.
- Providing expert, independent advice—Governments and industries particularly seek CSIRO's advice to help resolve conflicts over natural resources, because of our high standards and independence.
- Safeguarding the national biological collections—CSIRO develops, maintains and delivers knowledge from authoritative national biological collections. This reference standard for our diverse flora and fauna underpins much of the country's taxonomic, genetic and ecological research.

This sector, along with the Land and Water Sector, will be instrumental in the key corporate aim of CSIRO achieving more sustainable outcomes for the industries they serve.

Uptake—working in partnerships: The main route to market is through developing close partnerships with all stakeholders, including end-users, from project beginning to end. This is illustrated in the following examples:

- In response to declining productivity on farms in south-east Queensland, a $2.5 million project linking native vegetation and production involves CSIRO in partnership with more than 30 primary producers, three State departments, Greening Australia and Birds Australia. Agency extension personnel are identified as the key to uptake and their role is particularly targeted in the project.
- Guava rust, a South American disease of eucalypts and their relatives, could devastate commercial plantations and native ecosystems. A new project between the Australian Centre for International Agricultural Research and CSIRO will assess the risk of guava rust in collaboration with agencies in Indonesia, South Africa and Brazil. In Australia, collaboration with state agencies such as CALM Western Australia will ensure a coordinated domestic approach.
- The Myer Foundation has awarded CSIRO $1 million towards a $3 million collaborative project to identify and value ecosystem services in four key regions. The aim is to better understand the benefits that Australia receives from healthy ecosystems. The project direction is set by an advisory board with members from Agriculture, Fisheries and Forestry—Australia, Environment Australia, the National Farmers Federation, the Land and Water Resources R&D Corporation, the Myer Foundation and CSIRO. This arrangement will facilitate uptake of policy-related outputs while on-ground partnerships in the regions will influence uptake at local level.

Influencing decisions outside CSIRO: Our advice to others is an important mechanism for uptake. Sector scientists sit on more than 60 external management and advisory committees, influencing decisions that often have widespread impact. Some examples are the:

- Commonwealth Endangered Species Advisory Committee
- Natural Heritage Trust Technical Advisory Committee

- Council for Sustainable Vegetation Management
- Farm Forestry Development Group (Western Australia Ministerial)
- New South Wales National Parks and Wildlife Service Advisory Council
- New South Wales Pest Animal Council
- Quarantine and Exports Advisory Council
- Australian Ballast Water Management Advisory Council
- Uluru National Park Board of Management.

Making information widely available: Reaching large numbers of land managers is assisted by wide dissemination of specialist knowledge in user-friendly forms. Development of interactive tools is an example: more than 2000 users, including Landcare, Bushcare and catchment management groups bought the first edition of EUCLID, a CD-ROM on eucalypt identification designed for the wider community.

Planned Achievements

The sector plan consists of outcomes in six strategic areas. The benefits of investing in these areas will flow to:

- the private and public sector through cost savings or increased effectiveness of sustainability actions (~60% of CSIRO's investment and growing, covering Components 1, 2, 3 and 5)
- the private sector, due to new economic activity (~5% of CSIRO's investment, in Components 4 and 6)
- the Australian public through preservation of Australian native species and landscapes (~35% of CSIRO's investment, in Components 1 and 4).

State and federal governments invest over $1.6 billion every year in achieving biodiversity outcomes. CSIRO's research can significantly increase the returns on this large investment.

The six strategic issues are:

1. Knowledge and informatics

Outcomes: Communities, land managers, businesses, governments and scientists better equipped to correctly identify Australia's native species and know where they are located. This represents a major quality assurance system for good decisions about biodiversity. Formation of the Global Biodiversity Information Facility, with Australia in a prestigious role.

Outputs: BioLink, integrated biodiversity information management software. Four major interactive identification products, three field guides and two taxonomic keys.

Development of R&D capacity: Develop expertise in molecular systematics and integrated data management, and modernise infrastructure and facilities.

2. Ecosystem sustainability

Outcomes: Increased profitability of agriculture through enhancing natural biological inputs from ecosystems. A feasible aim is a 5% reduction in purchased inputs such as fertiliser, pesticides and water purification—a saving of many millions of dollars.

Outputs: Cost-effective methods for manipulating aquatic ecosystems to reduce algal blooms in south-east Queensland. Management options for wheat farmers in South Australia and sugar growers in Queensland, which enhance nutrient cycling and retention. An assessment of the full set of economic benefits provided by ecosystems, for catchment committees in four key regions.

Development of R&D capacity: Develop molecular expertise in measuring soil food-webs. Better linking of aquatic ecology to hydrology and geomorphology.

3. Regional–national sustainability

Outcomes: This is strongly linked with Land and Water Sector Component 8. More sustainable land use in Australia through better linking of ecological considerations with economic and social planning by government and communities together. Investment in better planning means that Australia can make the most of its natural resources while avoiding expensive rehabilitation in the future.

Outputs: Quantified trade-offs between economic, social and environmental goals for local communities in the goldfields of Western Australia, western New South Wales and the Ord–Bonaparte region. Prediction of the benefit of revegetation in three catchments of the Murray Darling Basin.

Development of R&D capacity: R&D capacity will be enhanced by developing geographic information systems technology for trade-off algorithms. Fostering links with resource economists in other agencies.

4. Conservation and use

Outcomes: Achievement by State and federal governments of their conservation goals by securing threatened species and communities outside nature reserves. Growth of agriculture and forestry industries through the use of new native genes and species.

Outputs: Techniques that ensure the survival of small populations of endangered species in grasslands. Genetically compatible plant lines identified for use in practical restoration by State agencies. Improved germplasm that increases the yield and quality of tea tree oil for the essential oils industry.

Development of R&D capacity: Increase the use of molecular tools and developing statistical expertise in large-scale pattern analysis.

5. Pests, weeds and diseases

Outcomes: More secure conservation of species and natural communities through reducing losses caused, in particular, by rabbits and foxes, mimosa and bitou bush, and Phytophthora and guava rust. Cost savings for agencies running control programs through better techniques for assessing risks and priorities. The Victorian Government alone spends $17 million annually on environmental pests and weeds.

Outputs: Immunocontraception vaccines for rabbits and foxes at field-release stage, and development to commercialisation of sterile feral technology, for the aquaculture industry. Assessment of the potential impacts of nationally significant weeds and technologies to reduce their impacts.

Development of R&D capacity: Generate fundamental science and technologies for biological control, develop systems to integrate biological controls with other management approaches, and develop risk assessment frameworks.

6. Sustainable tourism

Outcomes: Increased revenue (~$10 million) from tourism in three regions (north Queensland, New South Wales south coast and in Papua New Guinea) with a third of that revenue used to fund conservation by substituting for public funding. Growth in gross regional product (5–10%) from tourism in three regions (in north Queensland, coastal New South Wales and south-west Western Australia) based on better tourism planning tools. National policies that better manage natural resource risk to the industry. A 1% reduction in costs due to better risk management would return $6 million per annum to Australia.

Outputs: Delivery of the Tourism Futures Simulator to Douglas Shire; analysis of the impact of different types of tourism on resource use (water, transport, waste) at different locations. A joint proposal with the Papua New Guinea Government, industry (Stanford Hotels and Resorts and P&O Resorts) and aid agencies (AusAID and the World Bank) for a large tourism development project in Papua New Guinea.

Development of R&D capacity: Closer links with the CRC for Sustainable Tourism.

7. Ecological risk assessment

Outcomes: Licence to operate for growers and companies using GMOs in agriculture. Increased public understanding of the risks of GMOs relative to other technologies. Increased capacity for quantitative risk assessments by the Office of the Gene Technology Regulator and other government agencies.

Outputs: Robust risk analysis tools for GMOs in Australia. Recommendations for large-scale monitoring of GMO benefits and impacts. Risk assessments of Bt cotton, legumes with high sulphur protein and herbicide resistant canola. Risk assessments of potential GMOs in eucalypts, rumen biota, oysters and mouse cytomegalovirus.

Development of R&D capacity: Develop theory on ecological risk assessment. Strengthen integrative skills across Divisions and sectors, particularly across the spectrum from point to regional impact.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Issue	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Knowledge & informatics	17 239	9 193	27 253
2. Ecosystem sustainability	6 891	2 778	10 006
3. Regional–national sustainability	5 382	2 377	8 081
4. Conservation & use	11 862	6 969	19 746
5. Pests, weeds & diseases	13 494	10 624	25 150
6. Sustainable tourism	2 565	345	3 031
7. Ecological risks assessment	3 132	2 094	5 607
Grand total	**60 564**	**34 380**	**98 874**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Production	50	44	94
Building Construction & Engineering	504	84	589
Centre for Mediterranean Agricultural Research	124	0	134
Entomology	10 864	10 164	22 241
Forestry & Forest Products	2 244	4 403	6 615
Land & Water	3 715	1 967	5 779
Marine Research	2 409	1 209	3 620
Maths & Information Sciences	714	395	1 277
Plant Industry	10 993	5 039	16 399
Tropical Agriculture	3 034	1 473	4 674
Wildlife & Ecology	25 915	9 602	37 451
Grand Total	**60 564**	**34 380**	**98 874**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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CLIMATE AND ATMOSPHERE

On behalf of the Climate and Atmosphere Sector Advisory Committee, I have pleasure in submitting the sector's plan for the next triennium. The committee has been closely involved in the development of the plan and has found this interaction stimulating and valuable.

At the turn of the millennium, human society has developed a clear understanding of the need to balance the exploitation of the environment and natural resources against the sustainability of those resources. Concurrently, governments and business are focusing, with increasing intensity, on the 'triple bottom line' of delivering economic, social and environmental benefits. This poses enormous challenges for environmental science to provide the knowledge to underpin sound decisions that can sustain and enhance living standards, as well as preserve a legacy for future generations. The absence of this awareness in prior generations means that the world and Australia now face a range of major environmental issues relating to sustainability and quality of life. Some are immediate and urgent; others are long-term and persistent. The sector addresses several such issues. The three main areas of research—climate change, climate variability and air pollution—are very important, and it is in the national interest that Australia has a vigorous program of research and development to actively address them.

We note with pleasure that the stakeholders and clients with whom the sector engages range from government and community to business and industry. It is this broad base of interest and support that gives the sector its external income of more than 30%, and it is the interaction with these diverse groups that gives the sector a solid link to 'real-world' problems and their solutions. The important task of (successfully) finding appropriate routes to market the CSIRO's products and services is, thus, also balanced by essential work of a 'public good' nature. It is particularly pleasing to see that the level of external funding is achieved while maintaining a high quality scientific program.

The new triennium will see many changes and new directions for the sector. The work on greenhouse gases and ozone-depleting substances will need to continue, but there is a marked additional focus on research linked to national carbon accounting and to biological sinks for greenhouse gases. Additionally, the major advances in climate model development will need to be consolidated and linked with a wide range of applications. Although currently much emphasis is placed on establishing estimates of future climate change, research leading to better forecasting of climate variability is considered to be of equal importance. Australia's highly variable climate and short historical record mean that decisions based on past experience may not cover the full range of possible extremes. For this reason, we look forward to the advances in climate science and climate modelling, and are particularly pleased to see the new emphasis on climate impacts and adaptation.

The sector is acutely attuned to the community's concern about air pollution, and is working closely with government and industry to develop objective assessments and solutions to safeguard public and environmental health, without inhibiting economic development. New areas of endeavour include research on air quality and urban planning and design, and a major emphasis on air quality and health.

While the CSIRO is clearly Australia's largest provider in all three areas of R&D (climate change, climate variability and air pollution), the committee and the sector acknowledge the limitations of what CSIRO can achieve in isolation, and are cognisant of the benefits to be gained from collaboration and partnerships. It is thus with pleasure that we note that collaborations are in place (and working well) with the Bureau of Meteorology, universities, State agencies and other R&D providers within a number of CRCs.

While much of the research effort of the sector is national, it is also focused on important international and global issues requiring both a global understanding and a global solution. As a consequence, access to international data and international collaboration feature strongly in the sector's forward plan.

The committee notes that the sector (with 13 Divisions taking part) has a large and varied membership, but also sees promising signs of both cross-Divisional and cross-sectoral interaction and collaboration. We welcome ongoing initiatives to engage and encourage CSIRO sectors to cover cross-sectoral issues.

Finally, I'd like to comment on the value of our interaction with CSIRO. The membership of the committee is diverse, and members give their views freely, without attempting to represent institutional or personal positions. Our interaction with chiefs and scientists in the sector has been open and constructive. The discussions have been exciting and robust, and have increasingly incorporated the social, political and economic dimensions and implications of the sector's work focus. It has been (and still is) a very enjoyable task in which to be involved.

Oleg Morozow
Chair, Climate and Atmosphere
Sector Advisory Committee

Climate and Atmosphere Sector Advisory Committee:
Oleg Morozow, (Chair) Santos Ltd; Stephen Corbett, NSW Health Department; Douglas Gauntlett, Bureau of Meteorology; Mark McKenzie, NRMA; Michael Rae, World Wide Fund for Nature; Peter Scaife, University of Newcastle; Roslyn Taplin, Acil Consulting; Frank J van Schagen, Department of Natural Resources, Queensland

CLIMATE AND ATMOSPHERE

Our work covers the environmental, economic and social impact of weather and climate, as well as the effect of economic and social activities on climate and atmosphere.

Issues include natural phenomena such as severe storms, tropical cyclones and large-scale drought, and human impacts such as air pollution, ozone depletion and climate change.

Sector Context, Dynamics and Outlook

Key drivers: Australians remain very concerned about their environment: climate and atmosphere issues are reflected within this. Air pollution is the community's prime environmental concern, being nominated by 32% of respondents as the most important issue. Other climate and atmosphere issues are prominent, including ozone depletion (13%) and the greenhouse effect (11%). Community interest in climate variability is also high—a media statement on El Niño was one of CSIRO's most reported releases in 1998.

- Climate change will have a major impact on the world economy over the next 50 years both as a result of the need to restrict greenhouse gas emissions and the need to cope with the impacts of climate change. A recent European study estimates that potential damage associated with a doubling of carbon dioxide would be 3.8% of GDP ($60.7 billion) in the OECD Pacific region alone.
- United States estimates of the costs of meeting international obligations associated with the Kyoto Protocol range from US$50–$180 per tonne of carbon. Australia's annual carbon dioxide emissions from the energy and industry sector are about 85 Mt of carbon. Hence the need to find measures to curb projected future emissions by 10% could cost A$600–$2000 million per annum.
- The effects of climatic variability cost Australia billions of dollars. The 1991–94 drought in Queensland is estimated to have cost $6 billion. Major bushfires can produce damage to the value of $500 million. Major floods typically cost $25 million per event. Better predictions can reduce such costs via adaptive management.
- The 1998 national environment protection measure for air identified the benefits to Australia of new ambient particle regulations as being over $4 billion per year; the cost of meeting those regulations is included in existing control programs. Based on United States data, poor air quality in Australia's homes, offices, factories and buildings may be costing as much as $12 billion a year due to ill health and lost production.
- Major collaborators with the sector include the Bureau of Meteorology, the Antarctic CRC, the CRC for Terrestrial Carbon Accounting, the CRC for Satellite Systems, the Queensland Centre for Climate Applications, the Victorian and New South Wales Environment Protection Authorities, the Queensland Department of Natural Resources and a number of university research groups. The sector also has strong links with several international research establishments.

Planned Achievements

The sector plan consists of five components, all closely related but some especially so. In some cases, outputs serve several outcomes.

1. Human impacts

Outcomes: Australia's national and international position with respect to the climate change and ozone protocols will be underpinned by CSIRO research.

Our research on greenhouse gases, ozone-depleting substances and other trace gases that play a key role in the global climate system will make a major contribution to international scientific assessments of global atmospheric change, its causes and the opportunities for global remedial action. Concurrent with the efforts of the Energy Sector, we will provide options to Australia for the control and reduction of greenhouse gas emissions as part of Australia's obligation under the Kyoto Protocol.

We acknowledge Australia's need to meet its international responsibility while minimising economic, social and environmental consequences of actions.

We will play a significant role in seeking solutions in the biosphere for managing carbon emissions, thereby complementing the role of our Energy Sector colleagues and providing scientific and technical advice on the options available with respect to carbon trading and joint implementation.

Outputs: Ongoing high quality measurements of multiple trace species, including isotopes, in the global (particularly Southern Hemisphere) background atmosphere. A method for designing networks of atmospheric observations for effective determination of global and regional sources and sinks. Prediction of ozone and ultra-violet trends from 1970 to 2100. New monitoring techniques for biospheric and urban/industrial greenhouse gas sources and sinks. Improved methodologies and analysis tools for the National Greenhouse Gas Inventory.

2. Global warming

Outcomes: Policy and other climate-related decisions by government, industry and the community will be improved by better estimates from CSIRO of future climatic change at global and regional scales. Through enhanced observations, better process understanding and improved numerical modelling science, we will

further improve climate change forecasting capability. We will respond to the national and international demand for better assessments of greenhouse induced global climate change, particularly at regional scales.

Outputs: Assessment of the radiative and climatic effects of trace gases aerosols and volcanic emissions. Quantification of the ocean's role in moderating the rate of global warming. Proof of concept of new ocean inverse model. Implementation with world ocean circulation experiment section data. Higher resolution regional climate simulations down to 20 kilometres and development of the conformal cubic grid as a stretched grid model. Development of a layered ocean model for better sea-level predictions, and complete performance test. Validation and calibration of satellite datasets with their incorporation into regional and global climate models.

3. Climate variability

Outcomes: Users will benefit from an effective climate modelling system for predictions of major climate extremes over Australia. Particular emphasis will be on the role of the oceans in Australia's variable climate, capturing major phenomena such as El Niño, the Indian Ocean dipole and the Antarctic circumpolar wave.

We will transfer our capabilities and products to agencies with forecasting responsibilities, in particular our colleagues at the Bureau of Meteorology, as well as link our capabilities directly with climate impacts and adaptation researchers in other agencies.

Outputs: More reliable datasets for atmospheric parameters, surface fluxes, surface currents and oceanic structure derived from satellite data and models. Determination of the structure of Southern and Indian Ocean climate anomalies and impact on Australian climate. Identification of mechanisms that give the climate system predictability at decadal time scales. Increasing skill in seasonal climate predictions from a succession of improved ocean-only, atmosphere-only and coupled models.

4. Impacts and adaptation

Outcomes: Industries will be enabled to better manage the adverse impacts of climate extremes through insights and tools provided by CSIRO.

With the advances in seasonal climate forecasting, there are now good prospects for delivering environmental management solutions that allow Australian industries vulnerable to climate variability to manage for the adverse impact of such climatic extremes. This management of natural risk is now part of government policy. Similarly, advances in the development and application of climate change scenarios offer new opportunities in climate impact applications.

We will bring together CSIRO's diverse range of expertise in climate impacts research, covering severe weather, water resources, rangelands, crops, pastures, pests and weeds, as well as built environment and infrastructure. Our strategy is to build a multi-disciplinary research program that offers integrated climate applications.

Outputs: Application of farming systems simulation modelling to improve the effectiveness of the agribusiness service sector (banking, insurance) in the face of climate variability. Integrated assessment of urban infrastructure and extreme events. Identification of coastal regions vulnerable to and at risk from sea-level variations. Provision of highly specific climatic change scenarios (that address issues of uncertainty) for a range of customers.

5. Air pollution

Outcomes: Air quality management will be improved through provision of air quality forecasts and strengthened knowledge of the relationship between air quality and human health.

The science of air quality is relatively mature and applications to forecasting are entering a new level of sophistication.

The new directions in this work involve the application to human health issues, arising out of recent work suggesting that fine particles in the air are a major factor in human health.

Indoor air quality and its relationship to outdoor air quality will be clarified. We will also respond to the Australian public's number one environmental concern by showing how urban developments can occur with a sustained air quality.

Outputs: An air quality model for state of the art forecasts of air pollution on a daily basis for major Australian cities. Extension to include particle levels and visibility. Aerosol formation chemistry, visibility impairment and acid deposition assessment developed and applied in models. Models of urban development including the interactions of energy, transport and emissions through research on urban environmental modelling. Application of outputs from population and personal exposure work to develop measures for medical scientists to characterise relationships between human health and air environment factors.

Development of R&D Capacity

We will maintain and further develop our laboratory facilities that are used for precision analyses of greenhouse gases, ozone-depleting substances and their alternatives, and fine particles that are important to climate and public health.

We will contribute to maintaining the Cape Grim Baseline Atmospheric Pollution Station (operated by

the Bureau of Meteorology, and jointly managed by the Bureau and CSIRO) as the world's premier atmospheric observatory for research on global atmospheric change.

We will also further our capabilities in making regional field observations of the exchanges of greenhouse gases and related fluxes of water vapour and other trace gases.

We will coordinate and expand the Australian Ocean Observing System (jointly with the Bureau of Meteorology), and maintain our ocean observing activities (jointly with the Antarctic CRC, the Antarctic Division and overseas collaborators).

We will develop further Australia's climate modelling capabilities, thus maintaining them at the forefront of global research on climate change and climate variability.

We will contribute to new algorithms and uniform procedures for collection and application of remote sensing data with applications in environmental monitoring.

We will (jointly with the Bureau of Meteorology and the Environmental Protection Agencies) develop an operational air quality forecasting system for Australia's major cities.

We will develop an integrated approach to air quality management and to climate impacts and adaptation research that brings in the much needed urban and infrastructure planning expertise.

Overarching Issues

- We recognise the public-good nature of much of our research and the outcomes from it.

We will therefore continue to provide scientific input to the development of public policy in this sector and continue to work with governments. The careful balance between this public-good work and generating benefits to Australian industry will be maintained.

- We will be internationally engaged.

Climate change and ozone depletion are potential threats to those nations not actively engaged in the international debates both politically and scientifically.

We will support the Australian Government in its negotiation of agreements that further the objectives of the agreements yet are cognisant of the economic, social and environmental impacts on Australia.

- We deliver through effective collaboration and communication.

We recognise that CSIRO's contribution to climate research is small compared to that internationally. We need to maximise the effectiveness of national expenditure through collaboration, especially between CSIRO, key international institutions, including the Bureau of Meteorology, several relevant CRCs and between CSIRO sectors. We will continue our policy of disseminating quality information about the climate system and specific issues such as El Niño, droughts, greenhouse and ozone depletion. We will use telephone response, the internet and the media.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Human impacts	19 154	8 237	27 781
2. Global warming	12 149	6 169	18 739
3. Climate variability	6 136	2 460	8 653
4. Impacts & adaptation	8 788	4 074	13 483
5. Air pollution	11 584	8 044	19 500
Grand Total	**57 811**	**28 986**	**88 156**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Production	1 583	1 080	2 659
Atmospheric Research	28 788	15 804	44 757
Building Construction & Engineering	2 815	915	3 736
Centre for Mediterranean Agricultural Research	165	0	179
Energy Technology	3 048	2 018	5 064
Entomology	612	480	1 114
Forestry & Forest Products	1 560	669	2 231
Land & Water	2 242	1 155	3 461
Marine Research	7 055	3 079	10 149
Maths & Information Sciences	1 958	770	3 191
Plant Industry	1 900	899	2 867
Telecommunications & Industrial Physics	2 502	600	3 205
Tropical Agriculture	1 842	834	2 784
Wildlife & Ecology	1 741	683	2 760
Grand Total	**57 811**	**28 986**	**88 156**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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LAND AND WATER

The Land and Water Sector Advisory Committee, through an effective process of consultation, has assisted CSIRO in developing the Land and Water Sector Plan for the 2000–03 triennium. This process has drawn on CSIRO's and the committee's collective knowledge of the major natural resource, social and economic issues facing the Australian community at present and in the future.

The plan addresses the major issues of landscape degradation, dryland salinity, water allocation, pricing and trading, together with the management of our rivers, wetlands, lakes and estuaries. Environmental flows, river restoration and reduction of pollution from urban storm water are management issues with significant economic and community importance. The committee played a vital role during the planning phase in ensuring CSIRO focused on these issues and defined desirable outcomes. The committee also ensured that the plan contains outputs and milestones that are identifiable and achievable.

CSIRO has been challenged with the responsibility of using its unique mix of expertise to find solutions that will achieve sustainable management of our land and water resources with reduced environmental degradation. To achieve these aims, ideas that are novel, innovative and acceptable to the community will need to be developed.

In most cases, integrated regional and catchment approaches will be required to find these solutions. Such undertakings will require a high level of coordination and consultation between CSIRO, the community and all levels of government. The organisation will also need to consult and collaborate more closely with private industry. There is also a desire for those involved in the sector to consult and collaborate with researchers working in other CSIRO sectors, in particular those who were represented at the Sustainability Forum on 17 September 1999.

In conclusion, I would like to express my gratitude for the opportunity to be involved in the CSIRO sector planning process. The research priorities set during the process underpin the management of the nation's natural resources, which ultimately influence the future well being and prosperity of the Australian community.

Dr. John Langford
Chair, Land and Water Sector Advisory Committee

Land and Water Sector Advisory Committee:
John Langford, (Chair) Water Services Association; Donald Blackmore, Murray–Darling Basin Commission; Andrew Campbell, Land & Water Resources R&D Corporation; John Corrigan, Filtra Limited; Wendy Craik, National Farmers Federation; Rhondda Dickson, Environment Australia; Jock Douglas AO, Pastoralist; Denis Flett, Goulburn–Murray Water; Graeme Robertson, Agriculture, Western Australia; Kathryn Tayles, Rio Tinto Limited; John Wilson, Indigenous Land Corporation; Bernard Wonder, Agriculture, Fisheries and Forestry—Australia

LAND AND WATER

The Land and Water Sector encompasses R&D supporting the management of terrestrial, freshwater, estuarine and groundwater environments and resources, with a focus on systems integration at landscape scales. The sector provides fundamental knowledge to underpin natural resource management in Australia.

Sector Context, Dynamics and Outlook

Major natural resource management challenges in Australia include dryland salinity, surface and groundwater pollution, soil erosion, soil acidification, soil structural decline and sodicity, loss of biodiversity and ecosystem function. Australia faces a number of major challenges resulting from landscape-scale degradation, the annual cost of which is estimated to be about $1.66 billion. There is a corresponding social and economic decline, especially in rural areas. Annual expenditure on environmental protection is approximately $7.9 billion (urban and rural). Annual production from the rural industry sector is estimated to be worth approximately $28.5 billion (gross value), with exports estimated at over $22.5 billion (gross value). There are an estimated 100 000 contaminated sites in Australia which require remediation. Total R&D expenditure on land and water aspects of environmental management in 1996–97 was reported to be $277 million.

The degradation of the Australian landscape is far greater than previously thought. A higher level of directed government intervention will be required to arrest and reverse the decline. This sector plan reflects that need and is designed to provide some of the R&D necessary to underpin improved management and policy development.

The community is demanding solutions to these problems. With the development of biotechnology (including in areas of remediation, for example Component 7) and the rising concern over landscape sustainability, the next century is predicted to be the century of biology.

The sector will research, develop and market broad-based knowledge and technologies that will assist the development of government policies and best management practices to ensure long-term ecologically sustainable development. This knowledge will be provided to all levels of government, private companies and the community.

The concept of the triple bottom line (economic, social and environmental sustainability) and the implementation of ISO 14000 environmental management standards are a growing concern on the part of companies which wish to retain a continuing 'licence to operate' from society. The sector will therefore continue to work closely with the production sectors of CSIRO to contribute to these issues.

The focus of natural resource management is shifting rapidly from piecemeal solutions to integrated regional and catchment approaches. Major integrative projects in Component 8, such as the Chief Executive's Murray–Darling Sustainable Land Use and Ord–Bonaparte Projects are a direct response to this trend.

The implementation of resource trading (water, carbon, salt) is having a major impact on improving environmental management. This is reflected in new natural resource management policy directions presently being drafted by the Commonwealth and State governments and by the work of the sector (for example, Components 1 and 6).

The adoption of new natural resource management concepts can be a long process (20–50 years in some cases). CSIRO's ability to influence outcomes is as much affected by social and institutional factors as it is by the development of knowledge. CSIRO will continue to provide sound information to assist the development of government policy, and work closely in partnership with R&D corporations, CRCs, State agencies and private enterprises to ensure adoption and successful outcomes.

The CSIRO Executive Committee has directed the sector to work closely with the production sectors and has tagged approximately $8 million per annum for this work. The sector will be demand-led in meeting the needs of the production sectors. A process has been put in place to evolve the sector plan over the triennium to meet these needs.

A sustainability forum of production sector coordinators and chairs has been formed to review and report on progress. The forum will oversee the development of indicators consistent with the principles of ecologically sustainable development. The development of major cross-sectoral collaborative projects (Murray–Darling, Ord–Bonaparte, Bowen Basin) over the next two years will also be a measure of the success of this process.

Regular reporting will be made to the CSIRO Executive Committee during the triennium as progress is made towards meeting the sector's objectives.

Planned Achievements

This sector plan has been constructed to focus R&D investment on major natural resource management issues in Australia. Components 1–4 address major issues in water management, Components 5–8 focus on land management and integration to regional scales. Because outcomes interact and integrate strongly, outputs in several components may serve outcomes in others and are dealt with together to some extent.

There are also strong links with other sectors including Biodiversity, Field Crops, Marine, Horticulture, and Meat, Dairy and Aquaculture.

Strategic issues and objectives
Overall outcomes sought (by 2005) are:

- Significant progress on rehabilitation of landscapes through revegetation and engineering approaches; reduced rate of increase of dryland salinity; implementation of new landscape and catchment management regimes incorporating resource trading principles for water, carbon and salt; and rural communities using new land use practices and regional approaches to improved natural resource management.
- Improvements in water quality and restoration of river ecosystems; and improvements in estuarine and river health in urban areas.
- Reduced environmental impacts through increased water use efficiency in urban and rural applications.
- More sustainable production from natural resources and reduced impact from mineral extraction, increased adoption of environmental best management practices and accreditation schemes by all sectors and development of improved reporting by industry, all achieved in conjunction with production sectors of CSIRO.
- Catchment, river and estuarine restoration, more sustainable agricultural production and improved well being of regional communities, all assisted by improved understanding of fundamental landscape processes at regional or catchment scales. This will also contribute to improved environmental performance in mining, mineral processing and manufacturing.

Component-specific outcomes and outputs are:

1. National water reform
Outcomes: Enhanced environmental, social and economic outcomes in the water field including improved quality and security of supplies through new water allocation and market reform strategies with a sound scientific basis.

Outputs: Assessments and models of ground water, surface water and climatic interactions for use by managers and policy makers in Commonwealth, State and local government agencies and private water companies for improved supply and ecological maintenance of Australia's water resources.

2. Healthy coastal rivers and estuaries
Outcomes: Acceptable water and sediment quality that supports healthy and diverse natural ecological communities, achieved through sustainable management of coastal rivers and estuaries.

Outputs: Innovative and cost-effective physical, chemical, biological and ecotoxicological assessment, modelling and management tools for the sustainable management of estuaries for use by State agencies, local government and private consultants.

3. Urban water storages and their catchments
Outcomes: Benefit to water companies, local governments and consumers through improved water quality at urban water supply off-take points and maintenance of water yield from catchments.

Outputs: New techniques that provide managers with the knowledge and tools to minimise the risk of contaminating urban water supplies. Improved methods for effluent disposal, and for removal of nutrients in maturation ponds and biologically active materials in water bodies, reducing treatment costs and improving public health.

4. Improved management of irrigated areas
Outcomes: Environmental and economic benefit in all irrigation areas of Australia through adoption by industry of best practice irrigation management and related regional land and water management policies. Improved water-use efficiency through better measurement and control of water delivery and application. A greater proportion effluent irrigation systems designed and operated to be productive while avoiding long-term pollution impacts.

Outputs: Models and analyses describing an assessment process for determining best management practices in irrigated areas. Guidelines and tools for the water industry and farmers leading to more efficient water use, environmental maintenance and to an increased longevity of Australia's irrigated areas.

5. Redesigning agriculture for Australian landscapes
Outcomes: Practical options for modifying current, or developing new, land-use and agriculture systems that will significantly reduce deep drainage, nitrogen leakage and soil acidification. An increased awareness within the farming community, industry and government of the need to redesign Australian agriculture systems, and the development and delivery of more effective policies and programs to facilitate this goal.

Outputs: Define the biophysical processes affecting deep drainage, nutrient leakage and acidification, and identify current agricultural systems at high risk of environmental and economic decline due to these factors. Modelling and monitoring tools for assessing the ecological, economic and social impacts of these factors, and options for reducing or reversing these impacts.

6. Management of degraded landscapes
Outcomes: Better management of degraded landscapes through relevant, reliable, cost-effective methods for assessing landscape condition, and better knowledge-based planning and management responses.

Outputs: Guidelines and techniques for planners, managers and policy makers which will help enhance the impact of revegetation and engineering on catchment and river conditions; restore groundwater discharge areas; control land degradation, enhance biodiversity and increase profitability through forestry; and other approaches to assessing, managing and rehabilitating large areas.

7. Restoring contaminated environments
Outcomes: More effective and better-targeted expenditure on cleanup through industry/government investment in assessment, monitoring and remediation technologies and through national criteria/protocols for assessment and treatment of waste products and contaminated sites, all based on better knowledge and technologies.

Outputs: Improved techniques and tools for regulatory agencies and industry that allow improved risk assessments and more cost-effective and socially acceptable remediation of contaminated sites.

8. Sustainable regional development and renewal
Outcomes: Improved sustainability of natural resources and their uses through adoption of adaptive land management techniques, particularly on a regional scale and taking account of social and economic factors, and based on integrated approaches involving science, economics, communities and government policy.

Outputs: Improved methodologies for assessing biophysical degradation, options for the management and renewal of degraded landscapes, and quantitative prediction of the biophysical, social and economic impact of large-scale regional revegetation programs. Research will be focused in four key areas, including the Murray–Darling Basin, the Ord–Bonaparte region, regional studies of Australia's rangelands, and the provision of national sediment, carbon and nutrient budgets to the National Land and Water Resources Audit.

Development of R&D capacity
CSIRO will continue to develop and focus its skills in key disciplines of environmental and biophysical research to ensure delivery of the sector plan. Whilst CSIRO will further develop its skills in sociology and economics to ensure effective collaboration with partners and successful adoption of outcomes, it will continue to focus primarily on the physical, chemical and biological processes which underpin work in the broadly defined area of sustainability.

The sector will continue to develop its skills in fundamental environmental science, stressing numeracy and a process understanding of landscapes and their ecosystems. The sector will continue to develop and improve its national and international standing in these disciplines. A great deal of emphasis will need to be placed on integrative skills in order to meet these objectives.

Other R&D providers
In this sector, CSIRO is the largest R&D provider in Australia, which enables it to design and deliver large-scale solutions to natural resource management problems. The sector will continue to focus on long-term, large-scale strategic issues whilst encouraging the successful, tactical adoption of its research. This will be achieved by working closely with other agencies and R&D providers. The Divisions in the sector will continue to collaborate in many CRCs and form other beneficial alliances.

Benchmarking and pathways to adoption
In order to achieve the intended outcomes of the sector, CSIRO will work in close collaboration with a diverse range of stakeholders ranging from Commonwealth agencies to individual farmers and companies. For each component there will be plans and pathways for the development and adoption of the research outputs.

The sector will put in place a process to benchmark the present state of policy in natural resource management and adherence to broad ecologically sustainable development principles in relevant areas. Independent evaluators will be used. Stakeholders will be surveyed before and during the triennium to assess impacts and outcomes from the adoption of sector outputs.

The base-line information will permit an independent evaluation of the impacts of this R&D investment and provide a capacity to demonstrate outcomes from this sector.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. National water reform	9 239	4 727	14 217
2. Coastal rivers & estuaries	10 990	6 094	17 343
3. Urban water	5 647	2 886	8 694
4. Irrigated areas	9 549	4 858	14 718
5. Agriculture for Australia	11 040	5 548	17 110
6. Degraded landscapes	16 607	8 302	25 410
7. Contaminated environments	10 007	5 327	15 599
8. Regional development	18 650	8 686	28 614
Grand total	**91 729**	**46 428**	**141 705**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Building Construction & Engineering	67	12	79
Centre for Mediterranean Agricultural Research	206	0	224
Energy Technology	3 476	2 450	5 921
Entomology	499	293	887
Forestry & Forest Products	1 209	533	1 743
Land & Water	64 335	33 184	99 370
Maths & Information Sciences	6 779	3 205	10 684
Tropical Agriculture	7 997	3 783	12 245
Wildlife & Ecology	7 161	2 968	10 552
Grand total	**91 729**	**46 428**	**141 705**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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MARINE

The Marine Sector is one of the most dynamic, challenging and important parts of Australia's economy and its natural heritage. The sector is making an increasingly significant contribution to Australia's economic future through major industries including tourism, fishing, and oil and gas production. From an environmental perspective, the extent, diversity and importance of Australia's marine environment is only beginning to be understood by the scientific community and appreciated in the wider community. Compared to our understanding of the terrestrial environment, however, our knowledge of our marine domains is very poor.

Australia is fortunate on a number of fronts: generally the quality of our marine environment is very good; we have major strengths in marine sciences with CSIRO providing the largest and most wide-ranging contribution; and we have industry sectors with an understanding of the value and importance of scientific research. Given our domestic and international responsibilities to manage these regions responsibly, there is a fundamental need for a strong scientific basis for management and policy development. We see the sector playing a critical role in providing and helping to interpret this scientific effort.

We have one of the largest Exclusive Economic Zones of any nation, and probably the largest on a per-capita basis. This fact alone indicates the challenge of carefully targeting and focusing our research effort on national priorities.

We consider that this Sector Plan achieves an appropriate balance between deepening our understanding in key areas of current interest and capability, and extending our understanding to new areas of opportunity and need. It also achieves an important balance between economic and environmental responsibilities and priorities. We are conscious also of the importance of maintaining and enhancing CSIRO's range of research capabilities and skills.

The Sector Advisory Committee has worked closely with CSIRO staff to help prepare this plan for the next triennium. We consider this an important responsibility. We look forward to a continuing close and productive working relationship with sector staff to ensure that this plan delivers the best possible result for CSIRO, for Australia and for the wider global community.

Peter Cochrane
Chair, Marine Sector Advisory Committee

Marine Sector Advisory Committee:
Peter Cochrane, (Chair) Environment Australia; George Kailis, MG Kailis Group; Bernard Bowen, Environment Protection Authority Western Australia; Geoff Love, Bureau of Meteorology; Ted Loveday, Queensland Commercial Fishermens Organisation; Rob Male, Woodside Energy Ltd; Helene Marsh, James Cook University; Conall O'Connell, Environment Australia; Nicholas Schofield, R&D Corporation; Sandy Wood Meredith, Wood Fisheries Pty Ltd; Peter Yuile, Agriculture, Fisheries and Forestry—Australia

MARINE

Research in the Marine Sector supports sustainable use of Australia's marine resources and effective conservation of marine ecosystem integrity.

Sector Context, Dynamics and Outlook

Context: Australia has unique challenges and opportunities in the Marine Sector arising from its status as a developed country that is also custodian of one of the world's largest Exclusive Economic Zones (EEZ). Under the United Nations Law of the Sea, Australia has obligations to protect, and rights to exploit and regulate, marine resources.

Our EEZ extends from the tropics to Antarctica. We are close to south-east Asia, the epicentre of the world's marine biodiversity and our southern waters support a high proportion of species that occur only in our waters. Other species may find their only refuge here, due to the extreme pressures on the seas of other nations.

Ecologically sustainable development of our EEZ and coastal waters is critical to the growth of our economy and the maintenance of ecosystem health and integrity.

Australia has demonstrated strong global leadership in these key issues through the development of:

- an oceans policy for Australia
- a marine science and technology plan
- a national representative system of marine protected areas
- ratification of international biodiversity and fisheries conventions.

These government initiatives provide the framework for CSIRO's strategic directions in the marine sector.

Dynamics: Marine industries, including petroleum, shipping, tourism, fisheries and aquaculture, are a strong and significant component of the national economy. They contribute about $40 billion a year to our GDP. They are also very significant regional employers.

They are growing faster than the rest of the economy, with an inflation-adjusted growth rate of 14.5% per year from 1990–91 to 1995–96 compared to an average growth rate of 3.4% a year in that period.

Protecting the resource base on which these industries depend, and within which they operate, requires understanding the impacts of human activities on the health and integrity of marine ecosystems, and reviewing and improving environmental management strategies.

The ability to achieve these outcomes will depend upon high quality scientific data, scientifically based management tools, and strong links between research, management and policy development.

Outlook: While the *State of the Marine Environment Report* noted that Australia's oceans and coastal waters are generally in good condition, it pointed to increasing pressures from population and urban development on the coastal margin, industrial and agricultural activities, and the impacts of offshore activities.

Government, industry and the public are growing more aware of the need to conserve ecosystem integrity and marine biodiversity in order to ensure that resource use is sustainable.

Australia's Oceans Policy will introduce regional marine planning commencing in 1999 with the south-eastern region and eventually extending through all of Australia's exclusive economic zone. The Western Australian government has also begun its own initiative for the North-west Shelf.

Research opportunities: This sector's major research opportunities fall into one or more of three categories: discovery, prediction and advice.

Discovery and exploration push the frontiers of marine science to explore Australia's EEZ and its unique marine biodiversity.

The capability to predict the behaviour of marine systems, and the consequences of human actions, requires fundamental understanding of the complex processes that link physical and ecological systems.

Provision of advice and management tools to government and industry, communicates and applies a scientific basis to planning and management, and links research results to specific problems.

Adoption of marine R&D: Ultimately, research from this sector must be adopted by industry and the public sector, either directly or through government policy and regulation. In the three to five-year term, much of the work described is aimed at supporting implementation of oceans policy and related State government initiatives.

We anticipate significant adoption of our research by the environment, fisheries, foreign affairs, resources and quarantine portfolios in the next triennium. We would like to improve adoption of our research results and capability by defence and maritime safety.

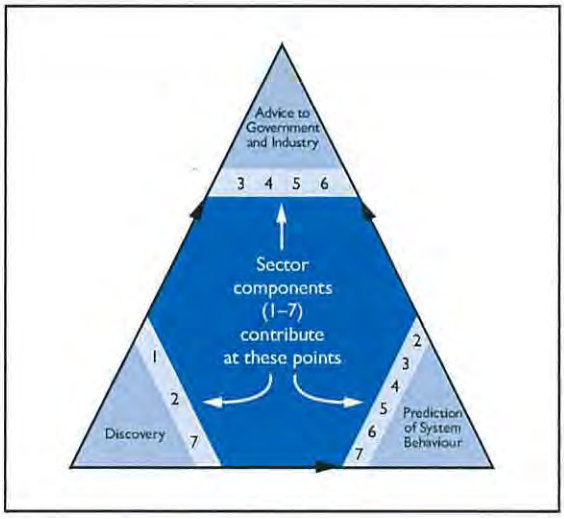
We anticipate a modest, but growing, factor of commercial adoption of our research in the triennium. We also have a small, but crucial, role in international marine programs, which generate benefits to Australia significantly in excess of our investment.

CSIRO's capacity to deliver marine research for Australia: CSIRO's Marine Sector is the largest provider of marine research in Australia. We have a demonstrated and unique capacity to undertake complex, multi-disciplinary projects, over large ocean areas.

Our growing links with the Land and Water, and Biodiversity Sectors are extending that capacity at the land-sea interface. Our link with the Petroleum Sector allows us to work with the petroleum industry, which is beginning to explore frontier areas in deeper waters.

Planned Achievements

The sector plan consists of seven research components that address the key issues facing the marine sector. Each component feeds into one or more of the primary research opportunities: discovery, prediction and advice (see diagram).



1. Exploration of the exclusive economic zone

Outcomes: Industry and government improve planning for the ecologically sustainable use of the EEZ by incorporating better knowledge of marine resources.

Outputs: New and improved techniques for rapid environmental assessment. Information on the biological, oceanographic and geophysical properties of the EEZ. Maps of habitats, natural resources and biodiversity in selected areas of the north-west and south-east regions and the Great Barrier Reef.

Development of R&D capacity: Rapid assessment of benthic habitats, using both acoustic and deep water video technology. Collaboration with Australian Geological Survey Organisation and the Department of Defence.

2. Conservation management

Outcomes: Achievement of agreed national conservation goals to maintain biological diversity and ecosystem integrity.

Outputs: Assessment of the function, dynamics and risk to key ecosystems. Methods and tools to assess and advise on threatened species and marine protected areas. Detection and mitigation of marine pest incursions.

Development of R&D capacity: Maintain existing core expertise.

3. Estuaries and coastal waters

Outcomes: Management strategies and regulatory processes that better address and promote the sustainability of estuarine and coastal ecosystems.

Outputs: Assessments of the health of key estuaries. Environmental indicators and monitoring procedures for sustainable development. Assessments of the impact of land use in catchments on estuaries and the coastal zone.

Development of R&D capacity: Skill development in multi-dimensional, multi-scale statistics, ecological risk assessment, remote sensing capabilities, data assimilation and visualisation. Collaborate with the CRC for Coastal Zone, Estuary and Waterway Management, and other key institutions.

4. Regional marine ecosystems

Outcomes: Regional marine planning for sustainable multiple use of the North-west and South-east Shelf and other EEZ regions.

Outputs: Definition of regional ecosystems and ecological units. Multiple-use impact predicted using new modelling tools. Options for ecosystem management. Sustainability indicators and performance measures. Protocols for acceptable change in ecosystems. Ecologically sustainable development indicators to comply with fishing and environmental legislation.

Development of R&D capacity: Improve skills in visualisation software, environmental risk assessment and rapid assessment of habitats.

5. Fisheries

Outcomes: Ecosystem approaches to fisheries management developed which help achievement of national policy goals and international obligations for sustainable fisheries.

Outputs: Stock and risk assessment for important or threatened commercial species. Management strategies and sustainability indicators for key and emerging fisheries. Feasibility and impacts of stock enhancement of wild capture fisheries. Environmental standards for fishery certification.

Development of R&D capacity: Enhance skills in population and ecological modelling and quantitative ecology. Enhance collaboration in economics, social sciences, climate, and fisheries policy, with the Bureau of Resource Sciences, the Australian Bureau of Agricultural and Resource Economics, and others.

6. Aquaculture impacts
Outcomes: An environmentally sound, sustainable and internationally competitive Australian aquaculture industry. An enhanced skill base in industry for site selection and impact minimisation.

Outputs: Capacity to measure the environmental impact of prawn farm effluent. Geographic information systems/DSS tools for site selection, including environmental carrying capacity. Predictive models to set environmental standards and indicators. Methods and technology to reduce waste and improve its management.

Development of R&D capacity: Enhance research links to production technology R&D provided by CSIRO's Meat, Dairy and Aquaculture Sector. Enhance skills in engineering and socioeconomic sciences through collaboration or contracts.

7. Climate impacts
Outcomes: Improved knowledge of the links between marine systems and climate, and the prediction of the impacts of climate for marine industries and users.

Outputs: Specification of the mechanisms by which climate variability affects selected fisheries. Feasibility of carbon dioxide disposal in the deep ocean (as part of an international program). Improved knowledge of regional ocean circulation.

Development of R&D capacity: Enhance capacity in hydrodynamic and biogeochemical modelling. Enhance skills in information technology and instrument engineering through collaborations with the Department of Defence, Bureau of Meteorology and NEC.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Issue	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Exploration of the EEZ	4 184	1 818	6 126
2. Conservation management	7 909	4 332	12 542
3. Estuaries & coastal waters	13 726	6 441	20 678
4. Regional marine ecosystems	7 529	3 835	11 671
5. Fisheries	18 951	11 722	31 324
6. Aquaculture impacts	1 485	814	2 356
7. Climate impacts	4 854	2 591	7 663
8. Oceanographic Research Vessel Franklin	13 129	450	17 011
Grand total	**71 766**	**32 003**	**109 370**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Production	683	166	851
Energy Technology	1 684	1 188	2 870
Marine Research	50 529	28 001	80 530
Maths & Information Sciences	3 845	1 412	5 417
Oceanographic Research Vessel	13 129	450	17 011
Tropical Agriculture	1 412	509	2 005
Wildlife & Ecology	484	277	686
Grand total	**71 766**	**32 003**	**109 370**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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BUILT ENVIRONMENT

An important feature of the last quarter century has been the emergence of environmental consciousness. The built environment is defined by us to embrace the major features of the urban environment in which most Australians live and work. It includes our transport, energy and water supply systems, and our construction and building technologies. There is strong recognition that our management of society and of population growth, and rising living standards, are causing unacceptable and unnecessary environmental damage. The built environment is performing in a far less satisfactory manner for humanity than it could be. Furthermore we are damaging the natural environment through demands for consumption within the built environment.

The next 25 years should see us translate this consciousness into marked improvement in the environment—at least in this country. The challenge is to build and re-shape the environment in which we live and work into one which is healthy, safe and congenial, whilst not placing unsustainable demands on the natural environment. Indeed, mankind should be able to look forward to improving the natural environment while progressively enhancing the built environment. A better world, both built and natural, should be an objective to which we can confidently aspire.

Within CSIRO we are working to understand environmental issues within the built environment and to develop a range of new technologies, products and total systems which will improve the built environment and reduce its impact on the natural environment.

The CSIRO Built Environment Sector Plan for the next three years involves a wide range of exciting projects, which should deliver wide-ranging improvements to the built environment and powerful economic opportunities for Australia.

There can hardly be a more important challenge for science.

Alan Castleman
Chair, Built Environment Sector Advisory Committee

Built Environment Sector Advisory Committee:
Alan Castleman, (Chair), Western Metals Limited, Australian Unity Limited; Gwen Andrews, Australian Greenhouse Office; Russell Cooper, South East Water Ltd; Michael Delaney, Leighton Contractors Pty Limited; Richard Dinham, SJPH Design Partnership; David Evans, Hunter Water Corporation; Ian Johnston, Government Property Office Western Australia; John Murray, Master Builders Australia; Vincent O'Rourke, Queensland Rail; Anthony Sive, Boral Recycling Pty Ltd; David Thomson, Roads & Traffic Authority (NSW); Stephen van der Mye, National Electricity Market Management Company; Yvonne von Hartel, Robert Peck von Hartel Trethowan; Ross Wraight, Standards Australia

BUILT ENVIRONMENT

The Built Environment Sector encompasses:

- *the key network infrastructures of cities and regions—transport (all modes), water and sewerage reticulation, and electricity and gas distribution*
- *the residential, commercial and industrial building stocks that support the Australian population and its economic activity*
- *the key design, construction and management services, including waste management and recycling, and energy conservation and efficiency, that contribute to the effective operation of the built environment.*

The focus for sector activities involve advancing the global competitiveness and environmental sustainability of Australia's built environment through a targeted portfolio of R&D which integrates the scientific capabilities of eight CSIRO Divisions.

Sector Context, Dynamics and Outlook

The built environment is the nation's largest asset. It is where all Australians live, where 95% of people work and where more than 90% of the nation's GDP is generated. The technologies available for its design, planning, construction and operation are fundamental to the productivity and competitiveness of the economy, the quality of life of our citizens and the ecological sustainability of the continent. Built environment industries—construction, transport, utilities—generate 17% of the nation's economic output, employ 15% of the nation's workforce and contribute 7% in exports.

Key drivers: Key drivers for science and technology investment in the sector are efficiency and competitiveness, environment sustainability and information technology applications (see Australian Science and Technology Council 1996: *Developing Long-Term Strategies for S&T in Australia*):

- Australia's built environment efficiency and productivity is low compared to other sectors (as measured; for example, in turnover-per-employee indicators and benchmarking studies undertaken by the Bureau of Industry Economics) indicating roles for application of information technology and automation. Its large balance of trade deficit highlights the challenge for the sector's industries in international competitiveness.
- Environmental deterioration of human settlements identified in the State of Environment Australia 1996 (poor air and water quality, transport congestion and end-use energy inefficiency) are a major public concern and constitute key government priorities (such as Living Cities).
- Information and communication technology represents the key platform for effective application of knowledge to the design and operation of transport, utilities and construction systems in Australia and globally.

R&D investment: Investment in the sector as measured by gross expenditure on R&D increased 36% between 1994–95 and 1996–97, indicative of the growing importance of research to this sector. There is, however, considerable year-to-year volatility in private versus public outlays.

The sector has a low R&D intensity index (0.1–0.4) due to the sheer size of the denominator (turnover). However, there are signs of improvement on a segment-by-segment basis:

- Construction, with a 10% increase in R&D (based on Australia New Zealand Standard Industry Classification, 1994–95 to 1996–97), is beginning to realise the potential of research and innovation in the context of sweeping information technology reforms designed to deliver significant benefits to industry. Key firms (Leightons, Lend Lease, Autodesk etc.) are linked with CSIRO and the National Building and Construction Committee in developing key technologies (refer Department of Industry, Science and Resources 1999: *Building for Growth*).
- Transport is also a rising star (30% increase in R&D) reflecting increased importance of distribution networks in metropolitan, national and global economies. The research priorities established by Austroads in their 1997 report *Strategy for Traffic Management Research and Development*, and ITS Australia in *National Strategy Statement for Australia's ITS* (1995) are providing the basis for the foundation of a research consortium (Austroads, the Road Transport Authority and CSIRO) to develop Australia's first intelligent transport systems corridor.
- Building product manufacturers retain high and increasing levels of R&D investment and are linked to several of the sector's strategic research objectives in the area of new materials and waste reactivation.
- Utilities are currently experiencing a privatisation shakeout. Sector involvement is focusing on key organisations (such as the National Electricity Market Management Company) and key technologies (energy end-use and superconductors).

By comparison with Australia, the United States has clearly recognised the fundamental nexus between urban infrastructure investment and international competitiveness. Built environment R&D in the United States in 1996 was equivalent to US$50 per head of population versus US$14 for Australia (National Science Foundation 1997).

Industry outlooks: Outlooks provide a range of science and technology opportunities. Peak industry bodies have established priority research directions to which this sector is closely aligned. These include the

National Building and Construction Committee and the Royal Australian Institute of Architects (implementation of information technology in design and construction), Water Services Association of Australia (standards for quality and delivery of water), Property Council of Australia, the Australian Greenhouse Office and the Australian Building Control Board (requirements on energy efficiency of buildings) and Austroads (national strategy for transport and intelligent transport systems).

A sector-commissioned National Institute of Economic and Industry Research study 'Prospects for Construction, Utilities and Transport Research' (1999) provided an independent outlook for the decade ahead. For construction: the focus for developed markets will be for innovative design, quality products and services, energy products and development of performance-based codes to facilitate exports. For emerging markets: cost-effective building materials, prefabricated structures, engineering construction technology, and design and technology for low-cost housing. For electricity: priorities are for new technologies with high conversion efficiencies and low emissions, improved efficiencies in transmission and distribution systems, improved end-use technologies, and improved metering and billing systems. For transport: research to improve transport system efficiencies, to contribute to congestion, accident, fuel and emission reductions, and for intelligent highway vehicle systems, freight movement scheduling and integration of transport.

CSIRO's role: CSIRO conducts approximately 11% of the total private and public R&D in this sector and provides national leadership for science and technology in construction, niche materials, urban water systems, energy end-use and, more recently, intelligent transport systems. Wide representation is also provided to government, industry and standards bodies in respect of independent and objective scientific advice.

Planned Achievements

The sector plan consists of 12 strategic research opportunities which emerged through a new sector process which involved industry roundtables, a sector investment review process and Sector Advisory Committee involvement throughout. Funding is now more strategically targeted through the 12 research opportunities which are responsive to one or more of the sector's three key drivers (see diagram).

1. Intelligent transport systems
Outcomes: Reduced congestion and improved safety of Australia's transport systems.

Outputs: An integrated system for transport sensing, monitoring, simulation and optimisation.

2. Infrastructure network optimisation
Outcomes: Improvements in efficiency, environmental performance, resilience and adaptivity in infrastructure networks such as transport, telecommunications, electricity and water.

Outputs: Optimisation tools for road, rail, telecommunications, electricity, water and air networks, and integrated landuse–transport planning.

3. Integrated design and construction
Outcomes: Reduced time and costs on design and construction projects.

Outputs: Information technology applications for automated building code checking. An internet building product gateway. Simulation models of the building construction process.

4. Smart coating technologies
Outcomes: Extended life and performance of steel and plastic products.

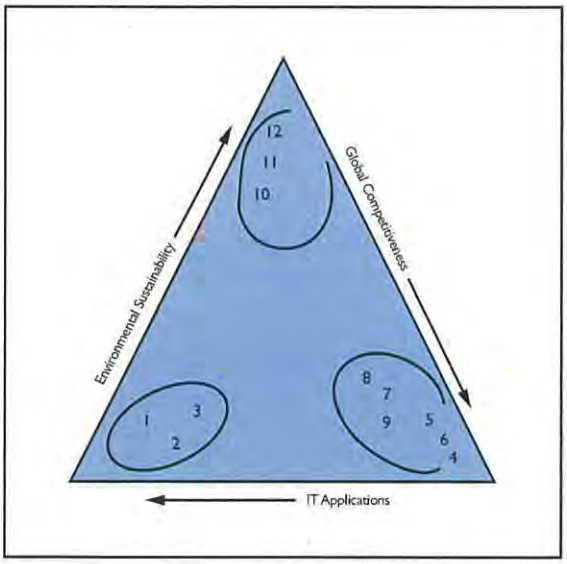
Outputs: Coatings to extend life of steel products; coatings to enhance adhesion of paint to plastics.

5. New building materials
Outcomes: Increased use of waste materials in new engineered products. Increased service life based on more durable plastic building products.

Outputs: High performance crumb-rubber composites and cellulose fibre composites. Model of plastic pipeline failure and methodologies for rehabilitation.

6. Fire science and technology
Outcomes: Reduction in fire risk to plant and buildings at lower cost.

Outputs: Performance-based building codes. Fire-safe materials. Improved fire simulation and risk models. New fire suppression technologies.



7. Infrastructure service life
Outcomes: Reduced life-cycle and maintenance costs for building and infrastructure assets.

Outputs: Models for predicting service life performance of building materials. Material selection system for Australia.

8. Urban water technologies
Outcomes: Reduced cost and improved quality of urban water services.

Outputs: Treatment technologies. Recovery/re-use technologies. Methods for monitoring and rehabilitation of urban water infrastructure. Techniques for monitoring water quality. Techniques to minimise cost of water system infrastructure. Techniques to minimise undesirable impacts of water systems.

9. Indoor environment
Outcomes: Reduced energy consumption and CO_2 emissions and improved indoor air quality and ventilation in buildings.

Outputs: Personal cooling system. Design tools for indoor environment assessment (thermal, air quality). Efficient hybrid ventilation systems.

10. Low energy accelerated processing
Outcomes: New cost-efficient, low environmental impact concrete production.

Outputs: Process model for microwave curing of concrete products. Prototype model for a new rotary kiln.

11. Solid waste reactivation
Outcomes: Higher levels of recycling and decreased solid industrial, construction and mining waste.

Outputs: New waste reactivation technologies suitable for 75% of all solid industrial, construction and mining waste. New materials produced from quartz-bonded, carbonate-bonded and silicate polycondensation reactions.

12. Re-engineering windows and facades
Outcomes: Improved quality of thermal, sound and air quality aspects of indoor environments through use of new facade systems.

Outputs: New building facades with solar, heating and ventilation control. Active noise control system for windows.

Development of R&D capacity
The sector is developing its R&D capacity through:

- explicit definition of its core science and technology capabilities
- integrating science and technology capabilities across CSIRO Divisions and sectors more extensively than in the 1997–2000 triennium
- developing new science and technology capabilities (such as design science and fire science) to pursue new strategic research initiatives
- extending network of strategic alliances with industry partners for collaborative research and commercialisation
- CRCs and membership in national and international research networks
- science responsiveness to national priorities established by government (such as greenhouse, water, air quality and congestion).

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Intelligent transport systems	4 903	2 419	7 429
2. Infrastructure networks	2 537	1 414	3 967
3. Design & construction	2 800	1 494	4 294
4. Smart coating technologies	4 683	4 440	9 105
5. New building materials	2 551	1 242	3 794
6. Fire science & technology	6 278	4 980	11 243
7. Infrastructure service life	7 581	4 205	11 882
8. Urban water technologies	12 366	7 219	20 761
9. Indoor environment	5 745	3 707	9 446
10. Low energy processing	4 133	1 876	6 017
11. Solid waste reactivation	3 631	747	4 390
12. Windows & facades	3 975	2 144	6 113
Grand total	**61 182**	**35 888**	**98 443**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Building Construction & Engineering	44 052	26 139	70 171
Entomology	757	701	1 514
Forestry & Forest Products	671	300	971
Land & Water	4 115	2 119	6 352
Manufacturing Science & Technology	1 521	801	2 323
Maths & Information Sciences	3 385	1 668	5 218
Molecular Science	4 613	3 199	8 907
Telecommunications & Industrial Physics	2 069	960	2 987
Grand total	**61 182**	**35 888**	**98 443**

**External revenue for research and services.*
***Includes other external revenue and retained earnings*

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CHEMICALS AND PLASTICS

The Australian chemicals and plastics industries are facing a number of challenges arising from major changes in the international scene. The 'triple bottom line' of economic viability, environmental sustainability and social responsibility is driving the behaviour of the industry in its search for opportunities in new technologies, new markets or innovative business systems.

The globalisation of markets and advances in information systems have made national boundaries almost irrelevant. Australian businesses in the sector now must at least match the best of imported alternatives, desirably becoming truly global in their own right by succeeding in international markets, or by seeking other ways to make a living.

Growing international concerns about the sustainability of some traditional technologies are influencing product and process development in our customers businesses as well as our own. Recent developments in the biological or life sciences are seen as offering new solutions to meeting these challenges. Australia's capability to participate in these developments is a major issue.

To reduce risk and cost, local and/or international enterprises are aggregating within product groups and technologies, and we are seeing constant restructuring and the emergence of some very large traditional chemical firms and vertically integrated life science companies. These changes will undoubtedly change the ownership pattern and business ambitions of the sector in Australia.

In this context, the local industry continues to search for growth in regional markets or international niches where competitive advantages can be created and exploited. Opportunities to replace bulk chemical imports and possibly export to the region will remain on the agenda given the nation's balance of payments, and the industry has sought to make this case to government. The Plastics and Chemicals Industries Association's Chemical Industry Investment Study concluded that higher investment is the key to sustainable growth. There has been some recognition by government that chemical industry investment will have a substantial favourable impact on employment, trade deficit and growth.

But it is the Sector Advisory Committee's view that it will take more than that to ensure the future of the industry in Australia. The bulk chemicals and plastics manufacturing businesses will, in this country, face a daunting competitive environment in which, other than the natural protection of importing to Australian markets, local advantage is hard to identify. We need to build businesses with a higher knowledge content and a level of innovation that our competitors find hard to match and which enable Australian firms to compete in less mature markets with attractive growth prospects. Such a future clearly demands an internationally competitive R&D capability in interdisciplinary team-based research.

The committee has held these considerations uppermost in its mind whilst working to enhance the dialogue and interaction between CSIRO and the industry. It has also made a significant contribution in setting the research activities for the coming triennium. The sector's research plan now addresses many of the issues facing industry and features a significant leading-edge push in bioprocessing, substantial research activity in new polymer development and performance as a basis for adding value to this segment, continued research into innovative application areas such as smart packaging and specialty chemical products, and an enhanced focus in the applications of cleaner chemical processing technologies.

With the immediate triennium planning effort behind us, the committee's agenda is changing. Notwithstanding the planning cycle, the committee will seek to continue to influence the shape and ensure the ongoing relevance of the research portfolio. Our agenda for the immediate future is indeed a challenging one. It includes providing a more complete view of industry development needs in a sector that is very diverse; ongoing advice and assistance with routes to market, particularly for pre-competitive research; developing a perception of the industry as dynamic and exciting through various mechanisms and to a range of audiences; development of position papers on industry issues (such as chemical effects on human health) leading to fora to determine related needs and directions; stronger links to industry associations; and strengthening links to other sectors to identify synergies and opportunities.

Alan E Seale
Chair, Chemicals and Plastics
Sector Advisory Committee

Chemicals and Plastics Sector Advisory Committee
Alan Seale, (Chair) Consultant; Doreen Clark, Organic Crop Protectants Pty Ltd; John Dean, Department of Industry Science & Resources; Andy Denver, USF Filtration and Separation Group; Greg Healy, Nufarm Limited; Leo Hyde, DuPont Australia Ltd; Roger Karge, ITL; Margaret Matthews, PACIA; Ian Rae, University of Melbourne; Andrew Rath, Abbott Laboratories; Roy Rose, Orica Australia; John White, Australian National University; Nicole Williams, Plastics and Chemicals Industries Association

CHEMICALS AND PLASTICS

The Chemicals and Plastics Sector encompasses commodity chemicals, bioactives (such as pesticides and herbicides), surfactants and cosmetics, paints and ink, other specialty chemicals (such as dyes and explosives), plastic resins, rubber and plastic products, and synthetic fibres. It is a significant provider of materials for manufacturing, mining and agriculture as well as supplying products directly to consumers.

Sector Context, Dynamics and Outlook

The chemicals and plastics industry in Australia is characterised by a few large local companies, a few large foreign multinational companies, and a large and growing number (around 2500) of small to medium-sized companies employing fewer than 50 staff each. Australian industrial operations are not large on a world scale, and local companies are generally better able to compete internationally in specialty or commodity niche areas. (Specialty chemicals have a product focus and generally involve lower capital cost processes.)

This sector is the second largest manufacturing sector behind food and beverages. Sector indicators include:

- The largest segment is plastic products (35% of the total).
- In 1996–97, turnover was $24.9 billion. Trends during 1992–97 show a steady rise in turnover.
- Conservatively, predicted growth for 2001–04 is 1.8% per annum.
- Value-added in 1996–97 was $4.85 billion, representing 1% of GDP. This is projected to increase to 1.2% in the period 2001–04. Trends during 1992–97 show a steady rise in the value-added for each segment. Most rapid growth of 17% was in the bioactives segment.
- Imports ($12.1 billion, 1996–97) and exports ($3.5 billion, 1996–97) have both shown marginal increases. Import penetration for the sector in 1996–97 was 58%—the highest rate across Australian industry. Export propensity was steady at 15% during 1994–97.
- During 1996–97, the industry employed around 90,000 people—representing 1.1% of the workforce. Employment is predicted to decrease marginally over the next triennium.
- Australia's R&D intensity (business expenditure on R&D/revenue) is low at 0.9% or about one-third the level in the United States.
- R&D expenditure in Australia (1996–97) was $175.3 million consisting of private industry (82%), CSIRO (10%) and other public research (8%).

Divisions serving the sector have a diverse customer base comprising various-sized multinational and local companies who are manufacturers and downstream users of chemicals and plastics. Links to CRCs provide intellectual and financial leverage and represent a significant proportion of our research portfolio. We also benefit from the education programs associated with CRCs. There are also strong links to universities and a range of industry associations and government departments.

A major factor affecting the sector is sustainability—the triple bottom line of economic viability, environmental sustainability and social responsibility. Innovation will be a key in our response to this issue.

To address the economic aspect we will: focus on the expanding and R&D-intensive designer materials, bioactives and specialty technologies segments of the industry; ensure that our research portfolio includes projects with selected small to medium-sized enterprises which can move faster to exploit innovation; and include international research collaborators and sources of capital to assist in commercialisation.

The United States' Chemicals Manufacturers Association and Australia's Plastics and Chemicals Industries Association have both recently committed to zero injuries, incidents and waste. This will become an increasingly important driver: sustainability will require meeting increasingly stringent community expectations for protection of people and the environment. To address the social and environmental aspects of the issue we will: adopt a cradle-to-cradle/life-cycle analysis approach to products and processes to identify opportunities (such as cleaner production, waste minimisation etc.); and focus on areas where there may be potential discontinuities (such as food, energy, water, pharmaceutical diagnostics and biomaterials).

The triple bottom line combined with advances in technology is changing the industry worldwide, with a marked trend towards biotechnology development and life science initiatives. A feature of the industry, both in Australia and overseas, is major restructuring into traditional chemical firms and vertically integrated life science companies. It is expected that biotechnology will have a major impact in the more traditional chemical production and processing activities as well. The chemical industry worldwide is a mature industry and the trend to life sciences heralds a marked shift in R&D. This change is being mirrored in significant change within CSIRO—away from traditional approaches to crop protection products (the largest existing area of activity in the sector) toward new biotechnology-based approaches to bioactive molecule discovery and a bioprocessing initiative involving scale-up and downstream processing, protein purification and engineering, and large-scale cell cultivation.

Bioprocessing routes to industrial chemicals fit well with the speciality chemicals focus of the Australian chemical industry.

Research in the triennium will capitalise on strong industry links and exploit our world leading position in a number of research areas: polymer technology, environmentally benign processing methodologies and technologies, and in crop and seed protection biopesticides and fumigants.

Planned Achievements

There are nine strategic research components which will address the key factors affecting the sector and which reflect priorities determined in consultation with the Sector Advisory Committee. There will be: a significant leading-edge push in bioprocessing—this component represents the second largest effort in the sector; substantial research activity in new polymer development and behavior as a basis for maintaining industry competitiveness; continued research into innovative application areas such as smart packaging and specialty chemical products; and enhanced focus in the applications of cleaner chemical processing technologies.

1. Cleaner production

Outcomes: Financial and environmental benefits for non-commodity chemical manufacturers.

Outputs: Improved catalysts for existing chemical processes. New production methods for waste conversion (such as manufacture of catalysts from red mud). Generic processes for enzymatic reactions under microwave heating. New cascade and tandem reactions. Novel surfactant formulations.

Development of R&D capacity: Building and strengthening core competencies in catalyst and catalytic process development.

2. Polymer performance

Outcomes: Longer service lifetimes of specialty coatings, composites and engineered polymers used in the mining, infrastructure and transport industries.

Outputs: Data, tests and techniques to predict the rate of ageing changes in different environments and to predict critical polymer breakdown mechanisms.

Development of R&D capacity: On-line instrumental techniques and mathematical modelling to evaluate polymer breakdown.

3. Innovative polymer products

Outcomes: Manufacture of new and improved products by polymer-use industries.

Outputs: Polymer forming processes and product prototypes based on control of free radical polymerisation, reactive extrusion and conducting or photoactive polymers.

Development of R&D capacity: Develop a better knowledge of structure–property relationships for polymeric materials. Better define the scope and chemical mechanisms of our inventions.

4. Smart packaging

Outcomes: Increased global markets for Australian manufactured and agricultural goods through the use of innovative packaging.

Outputs: Novel concepts, improved processes and products for use in environmental packaging, food packaging, and authentication and security devices.

Development of R&D capacity: Enhance skills in the area of chemical synthesis, spectroscopy and nanotechnology. Develop a network with physicists (optical, magnetic, antennae) and biologists (molecular recognition).

5. Specialty chemical products

Outcomes: Substantial increases in export competitiveness and the development of significant new product markets by Australian-based enterprises.

Outputs: Design and formulation of high added-value specialty chemical products or processes via control of nanostructure and of surface functionality through chemical and biomimetic routes, particularly in water/wastewater treatment, cosmetics and coatings.

Development of R&D capacity: Product formulation technologies (especially in the areas of electronics and bio-products) and in biomimetic molecular modelling capabilities.

6. Chemicals for grain storage

Outcomes: Retain Australia's market advantage for export grain through continued use of phosphine and commercial use of new fumigants.

Outputs: Registration of new fumigants and formulations of fumigants (a phosphide, ethyl formate, carbonyl sulphide, cyanogens) for specific applications.

Building R&D capacity: Improved knowledge-based methodologies for evaluating new fumigants, enhanced expertise in mammalian and insect toxicology.

7. Crop protection products

Outcomes: Crop protection with socially, ecologically and economically acceptable products that address unique Australian agricultural problems.

Outputs: New bioactive chemicals for use as environmentally friendly safe herbicides, insecticides and fungicides (for example, chemicals with lower mammalian toxicity and persistence). Biopesticides for insect control in Australia and overseas.

Development of R&D capacity: Enhance fermentation and formulation skills and infrastructure.

8. Bioprocessing
Outcomes: Revenue growth for the Australian bioprocessing industry based on a new range of world competitive products, including exports of high value bioprocessing products.

Outputs: Candidate proteinaceous insecticides. Pesticide and mycotoxin bioremediation enzymes. Biopolymers from food processing wastes. Bioactive plant products of pharmacological significance. Support for bioprocessing scale-up.

Development of R&D capacity: Build skills in functional genomics, proteomics and bioinformatics, plus some key downstream capabilities in enzyme structural biology. Expertise in scaling up fermentation for commercial production of plant-derived pigments and pharmacologically active plant products.

9. Surface engineering of polymers
Outcomes: Cost-savings, reduced waste and extensions of product lifetimes through improved control of surface properties.

Outputs: Novel concepts and cost-effective technologies in the areas of surface engineering of polymers and electro-conductive surfaces with application in painting, packaging, membranes, biomedical devices, corrosion resistant coatings, opto-electronics and display devices.

Development of R&D capacity: Establish and optimise the mechanisms for controlling the spatial structure and physico-chemical properties of reactive and electroconductive interphases.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Cleaner production	4 656	1 730	6 846
2. Polymer performance	5 014	2 650	8 023
3. Innovative polymer products	5 314	5 640	12 100
4. Smart packaging	6 512	3 625	10 497
5. Specialty chemical products	5 474	4 469	10 526
6. Chemicals for grain storage	2 314	2 095	4 478
7. Crop protection products	11 753	5 164	18 428
8. Bioprocessing	8 015	5 098	13 777
9. Surface engineering of polymers	2 781	1 040	3 907
Grand total	**51 833**	**31 512**	**88 581**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Building Construction & Engineering	4 618	1 225	5 855
Entomology	11 415	8 848	21 055
Food Science	2 399	2 075	4 523
Manufacturing Science & Technology	7 260	4 177	11 438
Molecular Science	26 141	15 187	45 710
Grand total	**51 833**	**31 512**	**88 581**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector.*

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INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS

The trade and business press reports, almost daily, new major investments to create or acquire intellectual property in the Information Technology and Telecommunications Sector. The Australian Government has this year announced major changes to its taxation policies designed, in part, to improve Australia's relative attractiveness as a location for venture fund investments similar to those being made in California's Silicon Valley. However, the almost magnetic attractiveness of the sector for R&D investment poses a dilemma for the CSIRO and this dilemma has figured strongly in the deliberations of the Sector Advisory Committee during this past year.

Recent estimates have quantified the Australian sector as follows:

- revenues of $66 billion representing 7.5% of the total Australian economic activity
- exports exceeding $4 billion
- growth of 60% over the 1990–96 period making information technology and telecommunications the fastest growing industry sector in Australia.
- employment of about 500 000 staff with a particular focus on highly skilled roles.

However, in an economic sense, the tide seems to be running against Australia as the balance of trade for these products and services is currently estimated to be in deficit by $8 billion with an expectation that this deficit may exceed $30 billion in five years time. In a sector dominated by foreign-owned multinationals and an increasingly global marketplace, it is not immediately obvious how the R&D efforts of the CSIRO can be translated into outcomes which reverse this trend through the creation of new Australian-based businesses and wealth creation within the Australian sector. Gaining better insight into this strategic issue is highly important to CSIRO's information technology and telecommunications research given the dilemma that, in the absence of a suitable strategy, the relevance of the CSIRO's R&D efforts in these areas will undoubtedly diminish over time.

The Sector Advisory Committee is highly committed to the potential of the sector and the value of relevant R&D. In its reviews with CSIRO management and staff, the committee has concluded the research portfolio proposed for the 2000–03 triennium effectively exploits the organisation's existing skill base and is well aligned with both key science trends and key market trends anticipated over the period. The committee also believes that industry interaction and collaboration is at a significant level and diversified across a range of reputable partners, thereby improving the opportunities for commercialisation of the results of the proposed research. In short, the committee endorses, without any reservation, the planned work program as constrained by the overall R&D funding allocations determined by CSIRO's top management for the sector.

The committee also supports the appropriateness of the overall funding allocation for the sector as determined by the CSIRO's top management. This conclusion may be somewhat surprising in that the R&D allocation over the triennial period is relatively stable, an outcome at odds with the anticipated potential of the sector. Higher R&D allocations could be justified given a clearer understanding of how outcomes in the form of new Australian-based businesses and wealth creation within the Australian sector could be derived as a result of those higher allocations. In this regard, the committee notes that the CSIRO has largely structured its industry commercialism partnerships so that it performs as a subcontractor providing contract R&D, licensing and/or consulting services to major industry partners who carry the majority of the risks but also the majority of the benefits associated with the research effort.

While such relationships are not without merit, they are unlikely to lead to outcomes that extract, for both the CSIRO and Australia, a true market value for the intellectual property contributed by the CSIRO. Such relationships may inhibit higher R&D allocations should they generally fail to deliver returns to Australia commensurate with the value of the CSIRO R&D effort. The committee would urge the CSIRO to give greater consideration to incubation of spin-off companies and other similar commercialisation models because the committee believes such approaches are better aligned to the expectations of the marketplace and, more to the point, that such approaches would hold much stronger potential for delivering outcomes that would provide long-lasting benefit to Australia.

John Kranenburg
Acting Chair, Information Technology and Telecommunications Sector Advisory Committee

Information Technology and Telecommunications Sector Advisory Committee:
John Kranenburg, (A/g Chair) Fujitsu Australia Limited; Rod Badger, Australian Department of Communications, Information Technology and the Arts; Ian Chessell, Defence Science and Technology Organisation; J B Clarke, Nortel Networks; Rob Durie, Australian Information Industry Association; David Merson, Mincom Pty Ltd

INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS

Companies in this global industry sector design and manufacture products and services for the infrastructure (information and telecommunications) necessary to support all other sectors of the economy, particularly the Services Sector. Increasingly, competitiveness relies upon the ability to access, store, share and transmit information. The sector comprises software developers, telecommunications carriers and their equipment suppliers.

The strategic objectives presented represent a level of vertical integration and skills to address problems from the user application layer to the physical transmission layer necessary for Australia to remain competitive in the global sector.

Sector Context, Dynamics and Outlook

The medium-term global outlook for the Information Technology and Telecommunications Sector is sustained high growth.

In 1997, the sector revenues totaled $66 billion and represented 7.5% of the total Australian economic activity, employment was about 500 000 and exports exceeded $4 billion. Information technology is the fastest growing industry in Australia and the world, with a 60% increase in revenue over the period 1990–96.

The balance of trade in these products and services is running against Australia; our deficit estimated to be $8 billion in 1995–96 was forecast to exceed $30 billion by 2005.

With appropriate investment Australia can create import-replacement technologies more suited to Australian requirements, generate exports and employment in the rapidly growing information technology and telecommunications industries.

Key drivers: Telecommunication networks are currently undergoing rapid evolution which is both driving and being driven by user demands for new services. The major forces at work include:

- personalised services
- portability and mobility (wireless access)
- decentralisation of network intelligence
- increasing separation of network control and data switching
- fundamental change in transport mechanisms from circuit-switched networks to packet switching
- vastly increased traffic volume, particularly for data transfer
- growing interdependence of the media, communications and computing sectors
- the internet—a major driver for change in the provision of services (Australia is the third highest per capita user of the internet behind the United States and Finland)
- scalability of systems—the operating environment can now encompass a few users or thousands or even billions of simultaneous users
- given the accessibility of information, the need for content processing and its automation
- the global market trend of deregulation and privatisation of the telecommunications industry
- rural telecommunications—will change significantly over the next 3–4 years through systems enabling new services such as electronic commerce, telemedicine and enhanced distance learning.

The sector will continue to realise the synergy between the information technology and telecommunications disciplines within CSIRO. The strategic objectives for networking for the information economy and seamless mobile communications are examples in which the combination of expertise will provide world-class outputs.

Our combination of skills, from the physical layers through the networking layers and to the application layer, enable a level of vertical integration that is unique global and valuable to Australia. In many cases this sector is the only non-proprietary source of knowledge for government and industry.

The scope of activities allows the provision of complete end-to-end solutions to industry needs at present and in the future.

We have established research activities with the Services Sector, such as the Hospital Without Walls projects, and are actively encouraging other cross-sector projects.

Planned Achievements

1. Broadband wireless systems

Outcomes: An Australian-based design and manufacturing capability in advanced broadband wireless (point-to-point and point-to-multi-point) systems. New technology to enable the high penetration of low-cost broadband wireless access.

Outputs: Antenna, mm-wave integrated circuits, modem designs and system architecture for broadband wireless systems at substantially lower costs than at present.

2. Networking

Outcomes: Design tools and techniques to enable more cost effective use of Australia's telecommunications network infrastructure by government and industry.

Outputs: Demonstration test-bed networks deploying advanced networking technology to improve current and next generation internet applications.

3. Corporate memory
Outcomes: Improved organisational effectiveness and efficiency through effective electronic record-keeping and systems incorporating corporate-memory services. Australian-based firms supporting and supplying corporate-memory solutions within the global knowledge-management software market.

Outputs: Technology components that automate capture and storage of contextual information. New models and information technology components for lightweight workflow which allow the integration of documents and the processes which apply to them.

4. e-matching and e-negotiation
Outcomes: A strong Australian-based on-line broker market producing new service providers and on-line services for global markets. An Australian-owned electronic-market infrastructure which significantly reduces the cost of transactions in all sectors.

Outputs: Generic agent technologies supporting broker automation to be applied in direct trading by 2001 and negotiated trading by 2003.

5. Federated information systems
Outcomes: Improved organisational effectiveness and efficiency through early deployment of electronic services requiring integration of existing (legacy) information systems within and between enterprises. Australian-based firms supplying software and systems integration services in the global market for systems providing integrated access to existing legacy systems.

Outputs: A model, software components and tools for developing electronic services based on integrating existing information systems.

6. Maximum usability
Outcomes: More efficient and effective use of information systems through engaging, fit-for-purpose, intuitive interfaces.

Outputs: Software toolkits, interfaces and training systems for three-dimensional imaging and haptic (touch feedback) devices.

7. Tools for distributed systems
Outcomes: Reduced risk and cost of building scalable, distributed information systems leading to more rapid deployment of major distributed systems and reduced investment in system migration.

Outputs: Consulting service and tools for modelling and optimising software architectures to improve scalability, speed and reduce cost in distributed business and government networks.

8. Seamless mobiles
Outcomes: Increased mobile access to on-line applications and information systems in both rural/remote and commercial areas. The focus will be on rural or remote areas.

Outputs: Applications, algorithms and hardware to improve third-generation mobile and satellite communications.

9. Dual-use microwave systems
Outcomes: Australian-industry-supplied sensor systems for both defence and civilian applications.

Outputs: High power devices. Miniaturised radio subsystems. Compact wide-band antennas and components. Wideband electro-optic devices.

10. Content tailored on demand
Outcomes: Operational efficiencies for Australian business, government and Australian internet-based service providers created through the ability to implement adaptable and highly individualised products and services.

Outputs: Technologies to merge and process data from documents and media sources and to automatically synthesise and deliver content satisfying a specific client group need.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Broadband wireless systems	10 723	11 896	22 319
2. Networking	5 769	2 110	7 893
3. Corporate memory	3 077	1 516	4 743
4. e-matching & e-negotiation	3 385	1 668	5 217
5. Federated information systems	5 539	2 729	8 538
6. Maximum usability	1 539	758	2 372
7. Tools for distributed systems	4 001	1 971	6 166
8. Seamless mobiles	8 628	6 240	14 751
9. Dual-use microwave systems	9 530	7 350	16 651
10. Content tailored on demand	5 847	2 880	9 012
Grand total	**58 038**	**39 118**	**97 663**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Maths & Information Sciences	26 466	13 038	40 791
Telecommunications & Industrial Physics	31 572	26 080	56 871
Grand total	**58 038**	**39 118**	**97 663**

Component 1 includes $6 780 000 for services provided to NASA
Component 8 includes $3 500 000 for services and research done for the CRC for Satellite Systems
**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector.*

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INTEGRATED MANUFACTURED PRODUCTS

The current Integrated Manufactured Products Sector Plan is the result of a lengthy process of collaboration, analysis and synthesis undertaken by the Sector Advisory Committee and CSIRO's research leaders in the sector. This is a journey willingly embarked upon by both and is one which we believe has yielded a rigorous framework for more sharply focusing current and future research into those areas of maximum advantage for large and small Australian manufacturing firms.

The nine strategic components of the plan are anchored in what we believe will be the fundamental forces that will shape global manufacturing in the next decade and beyond. These are: the need for sustainable manufacturing processes; the creation of new value chains, manufacturing systems and process improvements included in which are global enterprise operations; and the need for fast response to market changes, and micro and nanoscale manufacturing.

The components of the plan cover many individual projects, which in turn reflect the diversity of the sector. Dealing with this diversity has been a challenge for the committee and it remains a key issue for the future.

The committee views the current plan as representing a well balanced research portfolio but recognises that further work needs to be done to better match research priorities and resources with market needs and potential, and to alter priorities and resources accordingly where appropriate. As well, the committee plans to work closely with CSIRO's researchers to develop a more rigorous process to identify the paths to commercialisation for key projects and also to identify performance measures to track the impact on industry of the sector's work.

The committee endorses the sector plan that follows, believing it represents an important milestone in ensuring that CSIRO's research is more closely aligned with industry needs.

The committee gratefully acknowledges the leadership of Dr Ian Sare, the sector coordinator, and the dedication of all the CSIRO staff who attend meetings and support the committee, without which our work would not be possible. The committee also wishes to acknowledge the significant contribution of Dr Don Williams, the previous chairman, who laid the foundations of the current plan.

Robert Trenberth
Chair, Integrated Manufactured Products
Sector Advisory Committee

Integrated Manufactured Products Sector Advisory Committee:
Robert Trenberth, (Chair) Ernst & Young; Mark Albert, MTM Pty Ltd; Patricia Crook, Dynek Pty Ltd; Frank Cunningham, BHP Research Laboratories; Keith Daniel; Roger James, Department of State Development, Victoria; Barry Murphy, British Aerospace Australia; Victor W Perkin, AMCOR Food Cans Australasia; Stuart Romm, HPM Industries Pty Ltd; Victor Sidebotham; Cec Stubbs; Garry Wall, Department of Industry Science & Resources

INTEGRATED MANUFACTURED PRODUCTS

The Integrated Manufactured Products Sector is specifically concerned with elaborately transformed manufacturing and manufactured products, predominantly metal-based. It covers machinery and equipment, instruments, metal-based manufacturing methods, manufacturing processes and the operation of distributed manufacturing enterprises.

Sector Context, Dynamics and Outlook

Integrated manufactured products is a key industry sector, vital to Australia's economic growth and international competitiveness. Manufacturing is the main game of global trade and Australia has the second largest manufacturing trade deficit in the world after the United States. The sector comprises about one-half of Australia's total activity in manufacturing. It is the largest importer and third largest exporter of all industry sectors.

Key sector drivers and dynamics: A major paradigm shift has been occurring in the sector. Globalisation, coupled with the increasing deregulation trend, increases our market size and opportunities through the economies of scale required for efficient low-cost production. On the other hand, globalisation also increases competitive pressures on Australian manufacturing. The sector has always suffered heavy trade deficits, with imports exceeding exports by over $25 billion in 1996–97. On the other hand, the sector has performed well in the recent period in terms of export propensity and import penetration trends. Its export propensity of 19% in 1996–97 compared quite favourably with the all-sector average of 10% while its import penetration decreased from 57% in 1994–95 to 55% in 1996–97. A key challenge facing the sector is the ability to develop globally competitive companies in key growth industries. Targeted R&D is crucial to achieving this ability, and CSIRO has the potential to play a leading role in supporting the industry to meet this challenge.

Other market and competitive drivers: A recent market study found the top R&D decision drivers to be profitability increases (that is, economic–market conditions), customer demands and cost reduction (both of which represent competitive pressures) and new product development.

The competitive climate, made stronger by communication and knowledge-sharing technologies, will require rapid responses to market forces for business survival. Product development lead time and product life cycle are now almost half of what they were 10 years ago.

Sophisticated customers will demand products that are customised to their needs and local conditions.

Rapid pace of technology change is also narrowing the window of market opportunity and altering the industry's concepts of long-term and short-term research by shortening their time frames.

Key science and technology drivers: These include: adaptable, reconfigurable and integratable manufacturing products and processes; manufacturing processes that minimise waste and energy consumption; biotechnology for manufacturing; system synthesis, modelling, and simulation for all manufacturing operations; technologies to convert information into knowledge for effective decision-making; product and process design methods that are transparent to organisational and national differences and can address a broad range of product requirements across organisational and national boundaries; enhanced human–machine interfaces; and software for intelligent collaboration systems and concurrent engineering tools that integrate cross-disciplinary and enterprise-wide involvement to reduce time-to-market and improve quality. Two breakthrough technologies are submicron manufacturing and enterprise simulation and modelling. Many of the research areas are applicable to several priority technologies and multi-disciplinary in nature.

R&D investment: Manufacturing as a whole has the second highest R&D intensity of all sectors. This sector is relatively highly R&D intensive with a business R&D intensity of 1.6%. It compares very favourably with an all-sector average of 0.4%, consistent with a research finding that the propensity to innovate is highest for export-intensive industries. However, the sector compares unfavourably with its OECD equivalent whose R&D intensity is 3.4%. The sector's R&D expenditure represented 27% of the all-sector total in 1996–97, a decrease from 30% in 1992–93.

Capture of benefits: Major barriers to the ability to capture R&D benefits are, according to a recent survey of industry leaders: lack of venture capital; short-term focus of Australian business investment; lack of government incentives for the high-risk first commercial-scale application of a new technology; taxation arrangements; and small domestic market base.

Nevertheless, there has been a strong track record of technology uptake in the sector as a result of competition that necessitates increasing creativity and innovation in all aspects of the manufacturing enterprise. Collaborative R&D has always been an important and effective vehicle for technology transfer and market adoption paths.

R&D providers: CSIRO effort in terms of total expenditure in the sector in 1997–98 was $47.3 million, representing 6.7% of the all-sector total. The majority was in fabricated metal (27%), instrumentation (21%) and basic metal (21%).

CSIRO has an excellent track record of achievements in this sector including a number of world-first research outcomes. However, its share of public sector R&D decreased from 30% in 1992–93 to 28% in 1996–97 against the background of a stable share of higher education institutions and increased share of business enterprises. This clearly indicates the need for CSIRO to increase its research effort to maintain its leadership role in manufacturing R&D in Australia.

The paradigm shift occurring in the sector means that the competitive environment facing manufacturing enterprises in the future will be significantly different from today. To be successful in this climate, Australian manufacturing will require significantly improved and different R&D-driven capabilities. Research studies have clearly shown that innovating firms tend to grow faster, gain more market share and achieve higher growth in profits, than non-innovative firms do. Assisting the industry in attaining these new and improved capabilities represents the challenge facing CSIRO.

Planned Achievements

The sector plan consists of nine research components directly addressing this challenge and reflecting a change in research emphasis towards:

- Sustainable manufacturing processes and products, including integrated methodologies for whole-of-life approaches to manufacturing and lighter weight and more energy-efficient vehicles and transport equipment.
- The creation of new value chains through development and commercialisation of new, differentiated products and value-adding to natural resources and raw materials.
- Improvements to manufacturing systems and processes to increase productivity and quality and to reduce costs and time-to-market through greater use of advanced computation and simulation technologies, software and theoretical concepts. These include new methodologies and tools to enhance the operational agility and global networking capabilities of Australian manufacturing firms to increase their international competitiveness.
- Micro and nanoscale manufacturing.

Research activity included in the plan is selective and focused on R&D-sensitive areas where research outputs will benefit Australian firms operating globally, where CSIRO can establish strong competitive advantage as well as clear paths to adoption, and where high multipliers can be obtained for its work with small to medium-sized enterprises.

The following are some key examples of CSIRO's planned achievements in individual components of this diverse sector.

1. Sustainable manufacturing

Outcomes: Processes and products with lower environmental impact for use by Australian manufacturing industry.

Outputs: Environmental performance metrics of targeted processes for assessment of eco-efficiency to prioritise research activity. A framework and life-cycle model for cast magnesium products to identify environmental issues and appropriate solutions. Industrial-scale demonstration facilities for medium/large-scale surface coating of industrial components for increased performance against wear.

Development of R&D capacity: Redirection of some resources towards an integrated study of processes, products and manufacturing systems within an environmental framework. Refocusing of some projects to include eco-efficiency aspects.

2. Lighter-weight transport equipment

Outcomes: More energy-efficient transport vehicles. Increased quality and productivity in manufacturing processes used in transport equipment manufacture. Manufacture of welded aerospace structures unachievable with current technology. Research outcomes here could include increased exports of aircraft structural assemblies from Australia to the United States and European original equipment manufacturers.

Outputs: A low-emission vehicle using CSIRO technology for international marketing of CSIRO technologies. New magnesium-casting technology with improved casting yield and significant cost savings. New and improved technologies for the joining of materials used in the marine and aerospace industries.

Development of R&D capacity: Retraining in high temperature mechanical performance of magnesium alloys. Involvement in the CRCs for cast metals manufacturing and welded structures.

3. Integrated minerals-metal production-manufacturing chain

Outcomes: Higher quality in titanium alloy and magnesium alloy products. Higher productivity in welding titanium and magnesium alloys.

Outputs: Low cost high quality fabrication technology for titanium and magnesium alloys. Optimised system for SF_6 usage in magnesium die-casting furnaces. Magnesium die-casting scrap recycling tested in a pilot-scale recycling device.

Development of R&D capacity: Build expertise in non-ferrous welding and joint quality assessment.

4. Manufacturing process and product improvements

Outcomes: Major improvements in the competitive position of Australian small and medium-sized

enterprises through reduced manufacturing costs, increased productivity and improved product quality supported by innovative software.

Outputs: Software based on smoothed-particle hydrodynamics and computational models for manufacturing applications. New/improved technologies for the joining/welding, forming, fabrication, heat treatment and quality assurance of products. New cermet composite systems with enhanced properties and processing methods.

Development of R&D capacity: Acquire new equipment (for example, for metal forming). Upgrade skills and equipment in alloy processing, composite development, quality assurance and tribology. Strengthen international networking linkages.

5. Measurement and inspection tools
Outcomes: Improved quality of materials, products and structures. Systems manufactured in Australia for monitoring physical and micro-structural properties of materials and for metering fluids.

Outputs: Technologies for measuring visco-elastic and adhesion properties of thin film coatings and for evaluating the microstructural properties of materials. Advanced pre-production prototypes of instrumentation systems.

Development of R&D capacity: R&D capacity will grow through ongoing strategic research within the component and through strategic collaborations with University of Auckland, Sydney University and a group of NASA-sponsored United States laboratories.

6. Sensing and monitoring products
Outcomes: Discovery of untapped ore bodies with more sensitive sensors for geophysical exploration. Substantial cost savings through better control of films on rolled metals. Export sales of sensor equipment.

Outputs: Real-time control of thin film thickness on fast moving surfaces such as in rolling mills or offset-printing machines. Highly sensitive atom interferometer suitable for detecting gravity fields and gravity gradients.

Development of R&D capacity: Consolidate resources for more targeted research in superconductivity. Acquire ion-beam etching equipment and automated optical coating systems. Build external and cross-sector linkages (for example with NASA, the Information Technology and Telecommunications Sector, and the Mineral Exploration and Mining Sector.

7. Micromanufacturing
Outcomes: Lower cost of existing micro-manufactured products. Production of new, differentiated high value products for global markets. Enhanced export position for Australia through intellectual-property generation and associated collaborative and licensing linkages between Australian manufacturers and international suppliers.

Outputs: Development of novel anti-counterfeiting microstructures. Defence-related radio frequency microstructure components. Development of novel applications of ultra-fine particle technologies.

Development of R&D capacity: Acquire new e-beam machine.

8. Nanoscale building blocks
Outcomes: Products for global markets based on nanoscale biosensor technology. New, differentiated high-value products for global markets based on manufacturing utilising nanoscale building blocks.

Outputs: Self-assembling integrated circuits (instant chips) on non-semiconductor substrates such as paper. Smart-skin antennas. Devices that are wavelength switchable or fixable.

Development of R&D capacity: Collaborative work inside and outside CSIRO to leverage nanotechnology capability. Maintain R&D linkages with AMBRI Pty Ltd.

9. Enterprise structure and operation
Outcomes: Higher production quality and productivity through advanced, reconfigurable, flexible and robust manufacturing systems. Improved enterprise flexibility and agility through application of open (inter-operable) information, knowledge management and decision support systems. Industry projects demonstrating the elements, methodologies and technologies of concurrent engineering practices, new control architectures and migration paths to adoption.

Outputs: Modelling methods for performance analysis and stability control for distributed enterprises. Design principles for multi-agent manufacturing systems. Generic-enterprise reference architecture for dynamically changing global enterprises.

Development of R&D capacity: Establish computer modelling and simulation capability for multi-agent concurrent systems. Build expertise and infrastructure in communication technologies to support geographically separated collaboration.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Sustainable manufacturing	11 968	7 715	19 620
2. Transport equipment	17 242	9 329	26 501
3. Minerals-metal production chain	4 181	2 287	6 470
4. Manufacturing improvements	18 101	9 717	27 990
5. Measurement & inspection tools	11 091	5 001	15 891
6. Sensing & monitoring products	11 666	5 170	16 719
7. Micro-manufacturing	6 491	4 901	11 592
8. Nanoscale building blocks	6 288	370	6 576
9. Enterprise structure & operation	10 409	5 673	16 106
Grand total	**97 438**	**50 163**	**147 466**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Building Construction & Engineering	1 203	552	1 756
Manufacturing Science & Technology	61 348	36 081	97 659
Maths & Information Sciences	3 816	1 880	5 882
Telecommunications & Industrial Physics	31 070	11 650	42 169
Grand total	**97 438**	**50 163**	**147 466**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

Sector coordinator
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MEASUREMENT STANDARDS

The National Measurement Laboratory has been declared a national facility within CSIRO, reflecting both its statutory role and its outstanding reputation for excellence amongst all international measurement facilities. The laboratory is dedicated to maintaining the primary measurement standards for Australian industry and commerce and to ensuring that they are constantly updated and relevant to new applications. As examples, the safe use of ultrasound and lasers in medicine are dependent on accurate calibrations in increasingly more sensitive applications. Likewise, the ability to measure and, hence, both monitor and control electromagnetic emissions is critical to the use of all electronic equipment. Internationally the recognition of our standards and procedures is fundamental to the certification of aircraft maintenance carried out in Australia as well as to the acceptance of test certificates for trade, including environment and safety.

A critical issue facing the world today in measurement science is that of metrology in chemistry. Regulations concerning impurities in the food chain and the environment are becoming dominant issues for international trade and compliance with international agreements. Greenhouse emissions and carbon trading are major issues. Yet the level of accuracy in these measurements is frequently less than the absolute levels mandated. This is an area of research in which the laboratory is participating along with other Australian and international research bodies. Already atmospheric research has benefited from the preliminary word.

The CSIRO planning process is an attempt to establish both financial and community priorities in competing for scarce funds. The Board of CSIRO is to be complimented on their patience and thoroughness in weighing the diverse issues raised in this process. I speak on behalf of all committee members from this sector in expressing satisfaction at the balance achieved in the strategic plan.

Bruce R Kean AM
Chair (1996–99), Measurement Standards
Sector Advisory Committee

Measurement Standards Sector Advisory Committee:
Chris J Whitworth, (Chair) Transfield Pty Ltd; Steven Anderson, Southern Pathology; Alex Baitch, Integral Energy; John Birch, National Standards Commission; Vicki Brown, Business Department of Industry Science & Resources; Brian Frizell; James Galloway, Australian Electrical & Electronic Manufacturers; John D Gerard, Gerard Industries Pty Ltd; John Gilmour, National Association of Testing Authorities, Australia; Sandra Hart, General Manager, John Hulbert, Joint Accreditation System of Australia & New Zealand; Bob Phillips, Department of Defence; Ross Wraight, Standards Australia

MEASUREMENT STANDARDS

The Measurement Standards Sector provides the national standards of measurement for Australia and measurement traceability for industry, commerce, trade and defence. Its activities embrace elements of a broad range of industry sectors and underpin Australia's standards and conformance infrastructure, international trade and international trade agreements.

Sector Context, Dynamics and Outlook

CSIRO effort for the sector: The Measurement Standards Sector within CSIRO is comprised entirely of the National Measurement Laboratory. The return on investment in the sector is difficult to quantify fully because of the pervasive impact of the laboratory's activities. One of the laboratory's main contributions to the sector is the provision of measurement traceability to the national standards of measurement through the provision of calibration services. The laboratory issues approximately 1000 calibration and test reports to approximately 300 clients per year at a return of $1.1 million. Sample data indicate that for every instrument or artefact calibrated by the laboratory there are between 50 and >2000 calibrated directly by the clients. The laboratory therefore directly supports 50 000 to 2 million calibrations at the second level in the national measurement system. The value of this calibration business is estimated to be greater than $250 million and this is independent of any added value generated by the measurement traceability provided.

The added value of measurement in a developed economy has been estimated to account for between 3% and 6% of GDP. Even the lower figure of 3% translates into about $15 billion in the Australian economy. In addition, a recent study in the United Kingdom emphasises the value to industry of advice, training, assistance and transfer of technology provided by a national metrology institute, and estimates that the value of these activities may be even greater than the added value from calibration and measurement traceability.

Sector client base: There are approximately 800 clients in the sector and these are distributed (by socioeconomic objective code) through services (34%), manufacturing (29%), defence (17%), minerals (13%) and the National Measurement Laboratory (7%). About 230 clients' calibration laboratories are accredited by the National Association of Testing Authorities, Australia, and these form the basis of the national measurement system. There are approximately 11 national measurement institutes from within the Asia–Pacific region that derive measurement traceability to Australian standards to support measurement in their own economies. Other clients seek calibrations for testing or to meet specific manufacturing requirements.

Services provided: The National Measurement Laboratory offers approximately 350 standard calibration services; provides technology transfer to industry through training and by consultancies; provides assessors and technical expertise in support of the National Standards Commission, the National Association of Testing Authorities and Standards Australia; and seeks to capitalise on its specialised skills through contracts to develop metrological capabilities in other national measurement institutes, particularly within the Asia–Pacific region.

International recognition: There is a growing demand for global assurance in measurement to underpin test results and statements of conformance used in international trade. The National Metrology Institutes (NMIs) are the key institutions that assure global measurement compatibility by maintaining national standards that are compared internationally and disseminating these standards nationally through their calibration services. A global mutual recognition arrangement between NMIs was signed in October 1999 by the directors of 40 national institutes. To give technical effect to that arrangement, the number and variety of international comparisons of national standards have increased more than two-fold. National metrology institutes must perform satisfactorily in the international comparisons to demonstrate capability at the primary standards level, and must also demonstrate that their calibration services are well-controlled by complying with international criteria for technical competence and quality system control. The National Measurement Laboratory is addressing these challenges to support the acceptance of Australia's test and conformance data in international trade.

Key drivers: The key drivers in this sector are:

- Government—the *Science and Industry Act 1949* and the *National Measurement Act 1960* Commonwealth—the CSIRO memorandum of understanding on the National Measurement Laboratory Government policy—APEC, ASEAN and Australia/New Zealand memorandums of understanding, trade/trade agreements
- manufacturing industry—process control, product quality, production efficiency
- services
- defence—agreement to support defence standards requirements (1979)
- legal metrology, regulatory authorities
- Treaty of the Metre, Asia–Pacific Metrology Program
- globalisation of trade
- global mutual recognition arrangements on standards and calibration certificates, testing and quality

- other environment, health, scientific research issues
- the National Measurement Act—recent revisions call for legal traceability of utility metering. This is expected to lead to the demand for increased calibration services in electricity, water and gas metering. (Electrical energy metering alone accounts for $12 billion worth of energy per year, with sales to eight million customers).

Planned Achievements

The sector plan consists of ten components that address the strategic issues in the sector.

1. Basic standards R&D

Continue to undertake leading-edge R&D to maintain international credibility for Australian measurement standards.

Outcomes: International credibility for metrology in Australia and Australian measurement standards underpinning the nation's trade and trade agreements. Access to major international metrological developments undertaken by other national measurement institutes through acceptance of the National Measurement Laboratory as a significant international contributor.

Outputs: A new frequency standard. An atomic-based mass standard with an accuracy of 0.1 parts per million. A new impedance standard for Australia.

2. Primary standards R&D

Continue to develop and maintain primary standards for which there are legal units, as required under the *National Measurement Act 1960.*

Outcomes: Legal traceability of measurement in Australia will be maintained to provide a basis for fair trading, regulation and litigation. A technical basis for entering into arrangements for mutual recognition of measurement standards and for recognition of test results presented by Australian exporters in overseas markets. Reduced need for re-testing in customer economies.

Outputs: New primary standards for high pressure, acoustics, length, time, electromagnetic compatibility and electric potential.

3. International recognition

Continue to ensure that Australia's measurement standards are internationally recognised, are equivalent to those of its major trading partners and do not represent a technical barrier to Australian trade and trade agreements.

Outcomes: An internationally recognised technical basis to support Australia's international trade and trade agreements. International acceptance of Australia's standards and calibration certificates and of Australian test results and product quality. Elimination of technical barriers to trade. The National Measurement Laboratory's reputation as a credible high-level national measurement institute will be maintained.

Outputs: Recognition for Australia's capability through ongoing participation in the global mutual recognition arrangement noted earlier.

4. Gas mixture standards

Establish standard gas mixtures for carbon-based gases in support of environmental and industrial measurements and to act as a base for Australia's position in international carbon trading.

Outcomes: Australia will have the ability to quantify its carbon trading position in internationally unambiguous terms. A legal basis for gas composition measurements in environmental, industrial and regulatory areas.

Outputs: Establishment of a versatile preparation facility for reference gas mixtures traceable to national standards.

5. High-flow standards

Extend the range of standards for gas-flow measurement to provide legal traceability of utility metering in gas distribution.

Outcomes: Gas meter manufacture will be to a uniform standard, simplifying production and providing a firm basis for export. Gas reticulation companies and their customers will have confidence in the equity of the charges for gas bought and sold.

Outputs: A gas-flow standard to 250 cubic metres per hour. A calibration facility for higher gas flows available to Australian industry.

6. Metrology in medicine/health

Develop new standards and techniques to increase accuracy and reliability of medical diagnosis and therapy.

Outcomes: Increased confidence and effectiveness in the use of ultrasonic therapy in Australia. Improved competitive position for Australian manufacturers of therapeutic equipment.

Outputs: A portable ultrasonic power standard, available for use in Australia by 2001.

7. Standards and calibration services

Continue to provide an effective calibration service to underpin testing, quality and product development in Australia.

Outcomes: Effective and efficient manufacturing, trade and regulatory control through measurement assurance and credibility in testing. Manufacturing process control and improved product quality. Traceability of measurement in the national measurement system.

Outputs: An efficient, effective service for testing and calibration over a broad range of physical quantities and values. Training and consulting programs for

industry and the region based on expertise in metrology and advanced instrumentation.

8. Accreditation of services
Gain accreditation to ISO Guide 25 in support of Australia's entry into the global mutual recognition arrangement on standards and calibration certificates.

Outcomes: Increased trade opportunities for Australian manufacturers because of international recognition for the National Measurement Laboratory's calibration certificates.

Outputs: Accreditation of calibration services to ISO Guide 25.

9. National measurement system
Continue to provide leadership in measurement and support for other elements of Australia's standards and conformance infrastructure to ensure a coherent national system.

Outcomes: A strong Australian measurement system in which traceable measurements made in every sector are efficient and fit for purpose. An effective technical Australian infrastructure: supporting industry, trade, health and safety, environment and regulatory control, and also providing a competitive edge in attracting multinational investment and manufacture in Australia.

Outputs: Provision of technical services to the National Association of Testing Authorities, Standards Australia and the National Standards Commission, through technical assessment of accredited laboratories and representation on national and international committees.

10. Technology transfer
Capitalise on the sector's expertise in metrology for the benefit of Australian industry and Australia's regional interests.

Outcomes: Dissemination of metrological expertise to Australian industry and within the Asia–Pacific region. Elimination of technical barriers to trade within APEC.

Outputs: Technical infrastructure development services for Asia-Pacific economies. Contract R&D services for Australian industry. Training courses in specific metrological areas as well as management courses to facilitate participation in international trade.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)**

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Basic standards R&D	4 725	0	4 652
2. Primary standards R&D	4 578	825	5 324
3. International recognition	3 249	0	3 198
4. Gas mixture standards	1 132	500	1 610
5. High-flow standards	246	0	242
6. Metrology in medicine/health	925	0	911
7. Standards & calibration services	12 569	3 450	15 796
8. Accreditation of services	1 959	0	1 930
9. National measurement system	960	0	946
10. Technology transfer	-1 034	4 800	3 729
Grand total	**29 309**	**9 575**	**38 339**

**External revenue for research and services.*
***Telecommunications and Industrial Physics is the only contributing Division.*

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PHARMACEUTICALS AND HUMAN HEALTH

I have pleasure in providing the Strategic Research Plan for the Pharmaceuticals and Human Health Sector for the forthcoming triennium. The Sector Advisory Committee endorses the refinements made to the plan subsequent to the priorities exercise and the distribution of resources across the sector. It commends the sharper focus in the various research components and the planned review of each of the component areas.

The research activities in pharmaceuticals, nutraceuticals, biomaterials and diagnostics are in line with the core competencies within the sector and are targeted towards major unmet medical needs with high potential market-share value. The choice of target diseases is confirmed by the activities of major pharmaceutical companies.

The largest value-adding step in product development is the discovery process, and a significant proportion of the sector's activities is in this stage. Basic discoveries in biological sciences are the springboard for new advances in health care. CSIRO's role in this process is unique; it is able to address a variety of health-related issues from disease prevention through initiation and diagnosis to therapeutic intervention. It is characterised by the multidisciplinary teams that can be assembled for specific projects.

The committee recognises the need for new infrastructure and equipment. We would encourage a critical review of the investment required to maintain CSIRO's pre-eminent position in Australian research. We would also encourage an expanded effort in the emerging technologies of bioinformatics and functional genomics.

On behalf of the committee, I commend the sector plan to your Board and look forward to contributing to its implementation.

Professor John Funder
Chair, Pharmaceuticals and Human Health
Sector Advisory Committee

Pharmaceuticals and Human Health Sector Advisory Committee:
John Funder, (Chair) Baker Medical Research Institute; Malcolm Eppingstall, Consultant; John D Flack, AMRAD Operations Pty Ltd; Ian Gust, CSL Limited; Patricia Kelly, Department of Industry Science & Resources; Graham Mitchell, Foursight Associates Pty Limited; Hugh Niall, Biota Holdings Limited; Ian Pitman, FH Faulding & Co Ltd; Graham Thurston, Australian Diagnostic Manufacturers Association; Denis Wade, Johnson and Johnson Research Pty Limited; Des Williams, Sigma Pharmaceuticals Pty Ltd; John R Zalcberg, Division of Haematology & Medical Oncology; Peter MacCallum, Cancer Institute

PHARMACEUTICALS AND HUMAN HEALTH

The Pharmaceuticals and Human Health Sector drives research and development expertise to enhance and sustain the competitiveness of the Australian pharmaceutical industry and the food-related pharmaceutical industries. It provides objective scientific advice on aspects of nutritional pharmacology and preclinical drug development for the community and industry.

The following eight component areas which constitute the Pharmaceuticals and Human Health Sector are identical to those described in *Strategic Directions for the New Millennium 2000–03*. While they have been refined and reshaped over recent months, it should be noted that the entire portfolio is currently being reviewed and that an international assessment is included in this review.

Sector Context, Dynamics and Outlook

The pharmaceutical industry, including food-related pharmaceuticals, is a growing component of the Australian manufacturing sector. In 1996–97 the industry accounted for $3.6 billion turnover and value-added of $760 million; exports were $915 million and imports $903 million. The growth of exports in 1990–94 averaged 34% and recent strong growth has averaged 13% per annum Collectively, this represents one of the fastest growing sectors of the Australian economy.

There are 140 companies in the Australian pharmaceutical industry, including a significant number of majority-owned Australian companies such as FH Faulding, Sigma, CSL and AMRAD. A number of multinationals maintain Australian-based subsidiaries and 90% of the pharmaceutical companies in Australia engage in R&D activity at significant levels. Employment growth has exceeded the average of the Australian manufacturing sector. Data to 1996 shows a 3.7% per annum growth rate in the pharmaceutical sector compared to –0.8% for total manufacturing. In 1993–94 the industry was responsible, directly or indirectly, for 20 000 full-time-equivalent jobs.

The pharmaceutical and health industries are global industries that take up new technologies rapidly in the discovery phase and invest substantially in R&D activities, both in internal and external programs. Moreover, many large diversified companies are now moving towards a life-sciences focus. Consistent with these trends is the emergence of products (nutraceuticals) directed towards disease risk reduction. Biotechnological approaches are an additional and fundamental component of this industry, particularly in areas of disease diagnosis and treatment.

R&D drivers: The principal drivers for R&D in the pharmaceutical industry are the discovery process, the characterisation of disease states and the design of therapeutic agents based upon that characterisation.

In addition, there is a significant role for the pharmaceutical industry based on consumer needs in therapeutics and in the emerging area of nutraceuticals. Impacting on all of these areas is the role of new technologies, particularly those relating to gene technology and the production of novel therapeutic entities.

R&D providers: Products of discovery are accessed internationally from R&D institutions, including universities and research institutions as well as from in-house R&D activities. Participation by pharmaceutical companies in R&D is high and CSIRO plays a substantial role for R&D generation in this sector. The current scope of CSIRO's health-related research is substantial. It provides insights into the initiation of disease, and its prevention, diagnosis and treatment. Many companies are increasingly outsourcing R&D, providing a strong requirement for CSIRO to maintain its position in this expanding activity.

Planned Achievements

The sector plan is composed of eight components that address the following strategic issues:

1. Anti-infectives

Outcomes: Revenue growth for the Australian-based pharmaceutical industry based on new anti-viral agents. A decrease in the emergence and spread of antibiotic resistance.

Outputs: New chemical entities with anti-viral activity and for anti-viral screening. Greater understanding of the mechanisms and spread of antibiotic resistance. A candidate drug for hepatitis B in clinical tests.

Development of R&D capacity: In the next triennium, the screening capability at AMRAD will be increased and the CSIRO anti-viral effort will be aimed not only at hepatitis but also other viruses such as herpes, CMV and HIV.

In antibiotic resistance, the capacity would be built best by developing a multi-sector project involving particularly meat processing in the Meat, Dairy and Aquaculture Sector and food safety in the Food Processing Sector.

2. Bioactive molecule discovery

Outcomes: Revenue growth for the Australian-based pharmaceutical industry based on new compounds for cardiovascular and infectious disease.

Outputs: New lead compounds, including novel fatty acids, for cardiovascular health and for acute care in heart attack. New antimicrobial compounds. Novel receptor-based screens and integrated approaches to lead generation.

Development of R&D capacity: The R&D capacity will be enhanced by numerous activities ranging from further test development to value-added approaches.

3. Biomaterials

Outcomes: Vision correction as alternatives to spectacles that are competitive with current techniques of refractive surgery. Increased penetration into the extended-wear contact lens market by the provision of improved biocompatibility to the Focus Night and Day Contact Lens™. Revenue growth of enterprises that rely on existing CSIRO technology. These include Elastomedic, Biocure and BioNova.

Outputs: 'Proof of concept' for an artificial cornea designed to enable permanent, but reversible, refractive correction. It will also be applicable for the replacement of diseased corneal tissue. A biocompatible injectable lens material, with mechanical performance that permits distortion of lens focus by ciliary muscle activity. New generation coatings for use in soft contact lenses, based on anti-infective or low deposition surfaces. Successful polyurethane scale-up and materials suitable for a fully synthetic trileaflet heart valve. Scaffold biomaterials and methods of controlling tissue response suitable for defined clinical applications, such as cartilage repair. A patent position in hybrid materials that influence cell population and organisation into selected tissue architectures. An intellectual property package for one or two niche product 'demonstrator projects' in the field of tissue engineering.

Development of R&D capacity: Within the sector, a working group will examine potential synergies with other components for the development of bioactives, particularly growth factors and cofactors, for use in biomaterials. Interactions with the Chemicals and Plastics Sector to identify mutual areas of interest will also occur.

4. Cancer

Outcomes: Revenue growth for Australian-based industries based on nutraceuticals aimed at optimising vitamin B status, preventing DNA damage and improving bowel health. A database on DNA damage rates and the impact of diet and the environment on cancer risk. Improved cancer diagnosis resulting in more effective therapeutic intervention and improved patient outcomes. More effective cancer treatment and reduction of drastic side effects of current treatments through therapies targeted to specific molecular features of cancer cells.

Outputs: Definition of optimal vitamin B intake for minimising DNA damage and of specific food fractions or ingredients that can improve vitamin B status. An automated micronucleus assay for assessing DNA damage. An assay for the identification of prostate cancer cells in blood or semen and clinical evaluation in approximately 200 patients. Evaluation in animal models of a gene therapy treatment for prostate cancer which, if satisfactory, that will lead to a phase one clinical trial. Development and testing in animal models of second-generation gene therapy treatments with specificity for targeting to or replication in prostate cells and tumour neovasculature. Validation in animal models of the anti-tumour efficacy of specifically targeted lytic peptides. Lead compounds and specific ligands for IGF-R and EGF-R as direct anti-cancer agents and as agents for targeting therapies to cancer cells.

Development of R&D capacity: The R&D capacity will be enhanced with appropriate collaboration.

5. Diabetes

Outcomes: New therapies for type I and type II diabetics. Improved quality of life benefits for diabetics from improved therapeutic practice, better disease management and freedom from complications. Revenue growth for Australian companies involved in drug development and marketing. Reduced costs in the Australian health system and a reduction in the impact on the community of diabetes and its complications.

Outputs: Intellectual property on the three-dimensional structure of the insulin receptor and its complex with insulin and other mimetic molecules. Novel targets for diabetes treatment identified from the study of biochemical pathways involved in regulating insulin-mediated metabolic responses. New lead compounds capable of generating insulin-like responses by activating the insulin receptor directly or activating downstream metabolic pathways.

Development of R&D capacity: The R&D capacity will be built very much on the interaction and collaboration between the BRI and CSIRO.

6. Delivery of therapeutic agents

Outcomes: New business opportunities for the Australian-based pharmaceutical industry based on generically applicable technology for enhancing the delivery of a wide range of agents including classical drugs, bioactive molecules and gene therapeutics. New business opportunities for the Australian chemical and biotechnology companies based on the opportunity to provide new delivery agents and conjugated therapeutics for sale globally.

Outputs: Tris-conjugated methotrexate for the treatment of rheumatoid arthritis commercialised. The effects of tris-lipidation on the delivery profiles, pharmacokinetics and biodistribution of lead drug compounds determined. Intellectual property based on the validation of new gene-therapy delivery systems in animal models. Targeting systems for directing drug and gene delivery to specific tissues, and associated intellectual property.

Development of R&D capacity: Opportunities for delivery will be defined through consultation with industry and appropriate external interactions.

7. Diagnostics

Outcomes: Revenue growth for the Australian diagnostics industry based on a new range of reagents for clinical and veterinary assays and for biosensing devices.

Outputs: Improved diagnostic and therapeutic proteins that will provide industry with new lead reagents against refractory targets as well as a cost-effective route to new markets and early entry into functional genomics. Control reagents as substitutes for human immune serum in diagnostic assay kits. Multimeric antibodies for in vivo imaging which will improve cancer and thrombosis diagnoses and allow earlier, more effective therapeutic intervention and improved patient care. Biological sensing molecules which will enable Australian industry to compete in the expanding point-of-care diagnostic markets. Intellectual property for protein libraries and affinity maturation. Therapeutic reagents based on the patented humanised V-domain scaffold. Generic control reagents for a variety of diagnostic kits. Validation of multimeric antibodies as effective in vivo targeting reagents leading to commercial development of specific products.

Development of R&D capacity: R&D capacity will be enhanced by ongoing external relationships.

8. Tissue growth and repair

Outcomes: Increased rate of healing of difficult wounds, such as diabetic leg ulcers and bed sores, which will alleviate suffering, improve the management of patients and substantially reduce the associated costs to the health care system. Improved healing of connective tissues in tendon, bone and skin with better recovery of normal function. Healing without adhesions and scarring will reduce the costs of industrial and other accidents and allow quicker resumption of normal functions after injury. Reduced morbidity of IGF-I responsive diseases such as diabetes, certain cancers and neuropathies. Reduced costs and downstream processing loads in industrial cell culture systems which will result from the use of novel growth factors in serum-free media by the pharmaceutical biotechnology industry.

Outputs: Formulations containing growth factor mixtures for enhanced healing of chronic surface wounds in clinical trials. Growth factor-based bioactive agents to stimulate connective tissue regeneration and repair in skin, tendons and ligaments. Novel growth factors for pharmaceutical and industrial cell culture applications. IGF-I receptor agonists and antagonists to modulate cell growth and survival in a number of clinical conditions.

Development of R&D capacity: The R&D capacity will be enhanced through multidisciplinary links with key partners.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Anti-infectives	8 852	8 701	14 023
2. Bioactive molecule discovery	10 450	1 562	12 502
3. Biomaterials	10 022	13 600	19 790
4. Cancer	14 290	7 436	21 909
5. Diabetes	4 918	2 114	7 399
6. Delivery of therapeutic agents	4 892	1 927	6 937
7. Diagnostics	4 863	2 513	8 258
8. Tissue growth & repair	3 103	2 887	5 989
Grand total	**61 391**	**40 740**	**96 807**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Animal Production	745	237	1 004
Entomology	1 567	232	2 060
Health Sciences & Nutrition	32 689	15 981	49 844
Marine Research	770	336	1 107
Molecular Science	25 620	23 954	42 792
Grand total	**61 391**	**40 740**	**96 807**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

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RADIO ASTRONOMY

The Radio Astronomy Sector is almost identical to the Australia Telescope National Facility (ATNF). As a result, the ATNF Steering Committee, which is appointed by the minister responsible for science, also serves as the Sector Advisory Committee. This sector is also unusual in that its primary objectives are directed towards pure research. The membership of the ATNF Steering Committee includes several leading astronomers from overseas, so the committee is able to give a balanced external assessment and an international perspective on activities in the sector.

The ATNF is one of the most advanced and powerful radio astronomy facilities in the world and, by far, the largest in the Southern Hemisphere. These factors lead directly to the main objectives of the sector: to carry out research at the current frontiers of knowledge, to maximise the output of the existing equipment, to attract the best young researchers and to build on Australia's expertise by playing a leading role in future multinational facilities.

The plan set out here should achieve all these objectives. The most important aspect for the longer term future is involvement in the planned Square Kilometre Array. This project will involve most of the world players in radio astronomy and will be one of the major new scientific facilities of the 21st century. There is a strong case for a large part of this facility being physically located in Australia, which has a number of geographical and practical advantages over other countries. But even if this does not eventuate, it is crucial for the future of Australian radio astronomy that the CSIRO play a leading role in the design and construction of the array.

ATNF's intention to devote more resources to outreach activities is also a key part of the strategy, because ultimately the success of the facility will depend on the calibre of the researchers using it.

One aspect of the CSIRO strategic plan is of concern—the external income target of 20%. In practice, the ATNF has been successful in achieving this level of income in recent years. However, the pursuit of radio astronomy does not lead directly to the short-term generation of wealth; the opportunities for external earnings tend to be unexpected and of a one-off nature. Thus for planning purposes, the 20% goal may be achievable on average over several years, but not on an annual basis. The Steering Committee feels strongly that the ATNF must not be diverted from fundamental research if it is to maintain its world-leading position, and that external contracts should only be entered into if they help to promote that primary objective. If there are commercial or industrial spin-offs from ATNF developments, it would seem more appropriate for these to be exploited by Telecommunications and Industrial Physics, which is co-located on the Marsfield site.

Russell Cannon
Chair, Radio Astronomy Sector Advisory Committee

Radio Astronomy Sector Advisory Committee:
Russell Cannon, (Chair) Anglo-Australian Observatory; Brian Boyle, Anglo-Australian Observatory; Bob Frater, ResMed; Paul Goldsmith, Cornell University; Kwok-Yung Lo, Academia Sinica; Peter McCulloch, University of Tasmania; Prof Menten, Max-Planck Institute fur Radioastronomie; Elaine Sadler, University of Sydney; Ron Sandland, CSIRO; Peter Scaife, University of Newcastle; John Storey, University of New South Wales

RADIO ASTRONOMY

The major contributor to the Radio Astronomy Sector is the Australia Telescope National Facility (ATNF), one of the world's leading radio-astronomical facilities, which operates under guidelines for national research facilities. Major activities include enabling the best science possible with ATNF's existing facilities while planning a future that will enable Australian radio astronomy to remain at the forefront of the field.

Sector Context, Dynamics and Outlook

Around 90% of the radio astronomy in Australia is performed by the Australia Telescope National Facility (ATNF), meaning that CSIRO has a leadership role in this field. The ATNF has close interactions with the other significant players operating radio observatories: the University of Sydney, the University of Tasmania, and NASA's Canberra Deep Space Communication Complex. Because the ATNF is the only CSIRO Division with a prime involvement in radio astronomy, it is the major contributor to the sector. COSSA, a unit within CSIRO Mathematical and Information Sciences, is a minor contributor to the sector at the 0.6% level.

The ATNF operates under guidelines for national research facilities, proposed by the Australian Science and Technology Council in 1984. An ATNF Steering Committee is appointed by the responsible minister and meets annually, to set policy guidelines and establish procedures for allocating observing time. This committee is also the Sector Advisory Committee for radio astronomy.

The ATNF operates three different observatory sites, each of which has unique radio astronomy facilities that are recognised internationally. The Parkes and Narrabri telescopes are operated 24 hours per day every day of the year. The current user community includes 740 scientists from 115 institutions in 28 countries. International demand is high and overseas astronomers use 40% of the time available. Proposals for time on both telescopes currently exceed available time by 240%.

A high number of publications result from research using the ATNF. Amongst radio-astronomical facilities worldwide, the ATNF ranks second in terms of publications obtained using the facility. A recent analysis by the Department of Industry, Science and Resources, based on a citation analysis by the Institute for Scientific Information, ranks astrophysics as one of Australia's highest impact scientific disciplines.

Major uncertainties for Australian radio astronomy include the weakening support for universities and increasing radio-frequency interference. The ATNF is addressing both issues. The problem of interference is being attacked through regulation and policy (both national and international), and the development of interference-excision technology. The university support problem is being addressed through our outreach program and by university collaborative programs.

Key drivers and constraints: The primary goal of the sector is the advancement of knowledge; research carried out using ATNF's facilities is already at the leading edge of worldwide radio astronomy, and during the past ten years has resulted in a distinguished string of achievements. ATNF's overall goal is to continue to enable the best science possible with its current facilities while planning a future that will enable Australian radio astronomy to remain at the forefront of international astronomy.

To achieve this future, it is essential to maintain a strong, state-of-the-art engineering development program. A major constraint to future development is that, with a limited budget, the resources needed to continue operating a first-class national facility must be balanced against those needed to develop the next generation technology.

R&D: Radio astronomy in general, and the ATNF in particular, has a proven track record as a leading-edge customer of Australian high-technology industry. Such leading-edge customers drive innovation in the industry by demanding a level of technology well above that required by a domestic market, and by working closely with industry to achieve this. This will continue with future ATNF upgrades, and by participation in the development of major international radio astronomy projects.

ATNF's engineering staff are recognised internationally for their expertise in systems engineering, being active in the areas of microwave engineering, cryogenics and digital systems. A close association with CSIRO Telecommunications and Industrial Physics assists in technology spin-offs from developments within the ATNF. As a policy, the ATNF will only become directly involved in external contracts that are aligned with its mission as a national facility.

Artists' impression of an element of the Square Kilometre Array, which is the next generation radio-telescope to be built in about 2010 by an international consortium, and in which Australia plans to be a key player.

Science and technology trends and issues: To maintain its front-line position on the world stage, the ATNF is in the process of upgrading its facilities to operate at millimetre wavelengths. This upgrade, to be completed in 2002, has been funded by the Commonwealth Government's Major National Research Facilities program.

In this triennium, the ATNF will start to exploit these new and unique observational capabilities, at wavelengths as short as 3 millimetres. The upgraded facilities will yield discoveries not possible from any other telescope on Earth, and will enable ATNF users to tackle two key challenges facing current astrophysics:

- the formation and evolution of galaxies and quasars in the early universe
- the formation of stars and planets in the Milky Way and nearby galaxies.

The ATNF will need an increase in talented young scientists, particularly post-doctoral fellows, to take maximum advantage of the opportunities.

Further upgrades will also continue to occur, because the success of the Facility depends totally on using state-of-the-art equipment and on continually introducing new instrumentation. These upgrades enable important but evolving radio astronomy questions to be addressed.

These upgrades will enable the ATNF to maintain a leading position for at least five years. However, in the longer term Australian radio astronomy could be eclipsed by two major international radio astronomy developments. To maintain its position, capitalise on investments in Australian radio astronomy and position Australia for future radio astronomy developments, the ATNF needs to be involved in these projects.

For one of these projects, the Square Kilometre Array, ATNF's triennium budget now includes an additional $1.5 million to be used in technology development. Strong participation in the project will enable Australian scientists to have a major influence on the goals and shape of the project, and will increase the likelihood of Australia hosting the instrument—it already has a clear geographical advantage.

For the other international project, the Atacama Large Millimetre Array, the ATNF already has expertise in several key technologies, and will capitalise on this expertise and the continuing international use of its facilities to gain future access to that array.

Challenges: The ATNF plans to:

- maintain its position among the world's top two or three radio astronomy observatories
- take a leading role in shaping the design and objectives of the Square Kilometre Array, and maximise Australia's chance of hosting it
- develop an active strategy and effective partnerships to maximise the commercial prospects of suitable technology development
- enable Australian radio astronomers to develop their expertise so that they can successfully access other international front-line astronomical instruments.

Planned Achievements

The sector plan consists of five components, which address key strategic questions for Australian radio astronomy:

- How should the ATNF be operated to enable the users of its existing and planned facilities to carry out leading-edge radio astronomy?
- What developments should the ATNF be planning to enable future 'big questions' in astronomy to be tackled?
- What will be the future major international astronomy facilities and how can the ATNF take a leading role in positioning Australia for involvement in them?
- How can the ATNF best contribute to an enhanced public appreciation of science?

1. Operate the ATNF

Outcomes: New knowledge about the universe. High visibility of Australian radio astronomy through efficient operation of the ATNF and the top-quality science flowing from it. High prestige of Australian science flowing from the radio-astronomical discoveries as demonstrated by high overseas demand for access to the ATNF. Leverage for Australian involvement in overseas projects from continued access to the ATNF by overseas scientists. The ATNF regarded as a benchmark national facility in Australia and internationally.

Outputs: Radio-astronomical observatories operating at a high level of efficiency, producing cutting-edge observations leading to new discoveries about the universe. Maintenance of the number and quality of publications. Strong international links in astronomy, engineering and computing. The only 3-millimetre-array observational facility in the Southern Hemisphere. ATNF instrumentation used as a prominent showcase for Australia's engineering capabilities.

Development of R&D capacity: Increased knowledge of high-frequency (millimetre wavelength) technology, image processing and visualisation techniques. Interference mitigation procedures.

2. Upgrade the ATNF

Outcomes: Significant astronomical discoveries because of the state-of-the-art instrumentation. Continued high visibility of Australian radio astronomy with continuing benefits to Australian science.

Outputs: New wide-band millimetre feeds. Three, 7 and 12-millimetre monolithic microwave integrated circuit receivers, high-speed digital circuitry, using indium phosphide technology. Object-oriented control and image-processing software using modern software engineering techniques. Interference-excision techniques.

Development of R&D capacity: Development of technologies and expertise corresponding to each of the expected outputs.

3. Exploit upgraded ATNF

Outcomes: Advances in astronomical knowledge. An enhanced reputation for CSIRO. Prestige for Australia's science and technology from high-visibility discoveries.

Outputs: Significant new discoveries about the universe, which are not possible from any other telescope on Earth. An increase in the number of significant papers published in international refereed journals.

Development of R&D capacity: The ATNF will develop expertise in millimetre-wave astronomy, to be able to exploit next generation instruments, and will position itself as an indispensable collaborator for the science accessible with the next generation instruments.

4. Developments for the future

Outcomes: An increased likelihood of Australia hosting the Square Kilometre Array. Leverage to gain future access to the Atacama Large Millimetre Array based on ATNF's expertise in key technologies for that array, together with foreign use of the ATNF.

Outputs: Development of technology to become a key player and credible host for the Square Kilometre Array and to demonstrate the advantage for Australia to host it. A powerful and innovative design for the array. A study of suitable Australian sites for the array. An internationally recognised radio-quiet zone for the location of the array. Development of relevant technology and contributions to the Atacama Array's working groups.

Development of R&D capacity: The ATNF will stimulate and exploit technological developments to become involved in the Square Kilometre Array, ensure that array technology is transferred to Australian industry, develop interference mitigation techniques, and develop antenna technologies suitable for the array.

5. Outreach program

Outcomes: Increased public awareness of scientific achievements. More young people attracted to a career in science.

Outputs: An upgraded Parkes Observatory Visitors Centre, including its audiovisual presentation. Media interviews, talks to schools, universities and community groups by ATNF staff. Effective outreach material on the internet. Press releases on research results. Participation in the CSIRO Discovery Centre.

Development of R&D capacity: Further development of educational activities.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Operate the ATNF	21 089	0	36 453
2. Upgrade the ATNF	10 161	1 649	8 859
3. Exploit upgraded ATNF	1 094	1 008	2 096
4. Developments for the future	3 130	2 100	5 221
5. Outreach program	2 127	0	2 733
Grand total	**37 600**	**4 757**	**55 362**

The planned expenditure entry for Component 1 (operation) includes $13.9 million over the triennium for depreciation on the telescopes. This is the cause of the difference between income and planned expenditure.
The expenditure for Component 3 does not include the cost of operating the telescopes for the observations made by CSIRO scientists. Including this would raise the expenditure for science to about 12% of the total budget.
The revenue received from operation and outreach activities is not included in this table, because it is not classified as R&S revenue.

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Australia Telescope	37 358	4 757	55 116
Maths & Information Sciences	242	0	246
Grand total	**37 600**	**4 757**	**55 362**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

Sector coordinator

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SERVICES

The industries that comprise the Australian Service Sector have undergone a revolution in the past decade.

As the new century commences services are more competitive, more focused on the international market place, and more savvy about strategic partnerships. De-regulation, transfer of key utilities to private ownership and the impact of competition policy have opened up new business opportunities and brought international players into sectors which had been long-term monopolies.

However it is the 'new economy' that is turning the service sector on its head with dramatic implications. The internet and imminent convergent technologies are revolutionising service delivery rapidly, profoundly and irreversibly. It is challenging traditional business models, and re-writing investment rules and strategies. Service delivery and the systems that back them are increasingly sophisticated and increasingly the source of value for companies.

Innovation, global competition and speed are the drivers of these new knowledge-based services. Australia has the opportunity to become a niche player in the global services market, and to build effective partnerships with the dynamic Asian economies as they rapidly take up new technology. But these opportunities are not likely to be realised if Australia does not invest more seriously in education, innovation and knowledge. These are the raw materials of the new economy.

The CSIRO Service Sector Plan for the 2000–03 triennium has the potential to add significant value to the service economy. The program with its emphasis on intelligent systems, telehealth, logistics, risk management systems and their application in key sectors is targeted at productivity improvement, cost reduction and new business development. The program is premised on strong private sector participation. This partnership will help aggregate the complementary strengths across public and private sectors.

I look forward to working with CSIRO in the implementation of the sector's plan and thank the Sector Advisory Committee members for their interest and valuable contribution.

Judith King
Chair, Services Sector Advisory Committee

Services Sector Advisory Committee:
Judith King, (Chair) Australian Coalition of Service Industries; Steve Armstrong, Fujitsu Australia Limited; Garry Campbell, Coles Myer Pty Ltd; John Craven, Craven Innovation Corporation; Carmel Gray, Suncorp Metway; Michael Mannington, ID Tours; Peter Morris, Department of Industry Science & Resources; Roger Nairn, National Australia Bank; Peter O'Grady, Quality Consultant; John Primrose, Department Health & Family Services; Victor Skladnev, Polartechnics; Barry Westlake, Australian Stock Exchange

SERVICES

The Service Sector covers activities related to the provision of services including wholesale and retail trade, finance and insurance, property and business services, health services, education and training, community and public services, recreational and other commercial services (including travel, tourism and commercial security). Service functions are widespread in all sectors of the economy, for example, warehousing and distribution within a manufacturing firm. The sector includes generic service functions regardless of sector of application.

Sector Context, Dynamics and Outlook

Globalisation is transforming service industries worldwide, and the vehicle of change is information technology and telecommunications, in particular the internet. In many cases this means that the process of seeking a service and the means of providing it can be initiated offshore. The rapid growth of this technology and the wild market capitalisations being reported for internet service providers indicate a strong belief in the continuation of these trends.

The sector dominates the economy, in terms of GDP, employment and employment growth. In 1996–97 it contributed $15 582 million in exports.

The need for innovation: Firms operating in the sector are increasingly being driven by competitive pressures to drive costs down, for example through electronic and internet transactions, and to differentiate product offerings through personalised service provision, for example tailoring services to match the needs and perceived preferences of individual customers. Both of these pressures, particularly the latter, drive innovation in the service delivery process.

Hardware is a less important determinant of success than software and its effective integration with business systems. Telecommunications is a key enabler; telecommunications companies are increasingly seeing services rather than the physical network as their primary focus.

Social trends are also playing an important role. The major consumers of services of all types are the money-wealthy but time-poor. The internet provides almost infinite capacity to discover the need for, resource and provide such services.

The sector includes a vitally important health services segment which is running at 8–9% of Australia's GDP and growing. Australia's large rural and remote populations have poor access to quality health care relative to those in cities. Modern technology can help to bridge the gap, by providing 'telehealth' services to remote patients and peer support for remote practitioners. It can also be used to enhance the care of elderly and chronically ill patients, allowing them to be cared for at home. Cost pressures on the national health budget are immense; hence, the key driver in health services is to use technology to facilitate the provision of high quality health services at a small fraction of the cost.

Australia's dynamic tourism industry is a major contributor to export revenues and a positive balance of trade in services.

Financial services industries are increasingly knowledge intensive. Banking (relying on the ability to capture, add value to, store, retrieve and transmit data/information) increasingly resembles nothing more than a telecommunications company. And given the global hegemony of the internet, it is likely to be the company that masters the connection of the technology to the needs of the customers that will be successful.

The Australian response: We are beginning to see in the local service industry a transition from simply adopting technology developed elsewhere through adaptation of such technology to meet specific company needs to invention of technology to provide a competitive advantage. We are now talking to companies whose focus is fully on the invention process (Polartechnics, Viator, Silicon Graphics, State Revenue Office of Victoria). This trend from incremental to transformational change is a *sine qua non* for the long-term health of the sector in the Australian (global) economy.

Whilst the sector is well placed in terms of its investment in information technology and telecommunications hardware, there is increasing understanding of the need to leverage these assets to provide real business advantage. A recent Wharton School study, Innovation in Retail Banking, demonstrates that it is more critical to invest in knowledge workers who can integrate and effectively use information technology than in equipment. The creation of truly innovative and successful businesses in the sector relies on technological R&D just as much as it does in, say, manufacturing.

Medium-term outlook: The sector will continue to dominate the Australian economy. Annual export growth in key segments of the sector from 1987–88 to 1994–95 have been impressive: travel and tourism, 10.6%; finance and investment, 23.5%; property and business services, 11.9%; and education and training, 21.3%. In each of these, the growth of exports significantly exceeded that of imports. Australia has a positive trade balance in services: $1.29 billion in 1994–95 growing to $2.63 billion in 1996–97.

Services also dominate employment in Australia, providing 5.3 million jobs in 1996–97, 62% of jobs available. Most recent job growth (1996–98) has been in services (Australian Bureau of Statistics).

Recent Australian government initiatives, including the formation of the National Office of the Information Economy and the Australian Information Economy Advisory Council, have at least as much significance for the Service Sector as they do for information technology and telecommunications.

R&D Investment: United States data on R&D in the sector indicate the way forward for Australian companies hoping to compete in this market. Reported United States R&D funds as a percentage of net sales for 1997 include: wholesale and retail trade (2.4%); finance, insurance and real estate (0.7%); health services (5.2%); and technical services (10.8%). These figures are minimally an order of magnitude ahead of equivalent Australian figures. Although the sector in Australia is not R&D intensive, it has significant R&D requirements in absolute terms (8.3% of total BERD).

The Australian service industry's innovation culture has been weak up until now, but global competitive pressures are expected to intensify the need and desire for innovation. Innovation and R&D are increasingly the focus of the Australian services network within the sector. CSIRO is well poised to make the most of this opportunity.

Planned Achievements

The sector plan consists of nine research components addressing key strategic issues facing companies in the service industries.

1. Risk and yield management

Outcomes: New financial products and more working capital for finance-sector companies through better risk analysis.

Outputs: Software for pricing complex options and other derivatives, and for the evaluation of the potential exposure to risk with an under party.

Development of R&D capacity: Further development of educational activities.

2. Information strategies

Outcomes: Better informed decision-making and better identification and improvement of areas critical to performance as a result of better use of data and enhanced management information and knowledge. Improved international competitiveness for Australian organisations based on greater customisation of services.

Outputs: Documented methodologies and implemented organisational performance measurement systems. A system for managing information in scanned document legacy systems. Development of computer and web-based learning approaches for small organisations implementing OPM® systems.

Development of R&D capacity: Develop and test an approach to OPM® that will be relevant to disaggregated organisations.

3. Health care delivery

Outcomes: Clinical, managerial and policy decisions informed by sound information about projected health outcomes and health utilisation by particular populations. Reduction in the iatrogenic effects of medication taken in pregnancy on the unborn child. More effective strategic and operational planning and accountability through enhanced management understanding of the future performance of the health system.

Outputs: Design of a disease-state management system capable of identifying and predicting health outcomes. Comprehensive model for resource demand and utilisation in a hospital, and a system for dynamic scheduling of resources. Methodology for developing performance measures aligned with stakeholder objectives for health care.

Development of R&D capacity: Develop tools for: the analysis and correlation of multiple time series analysis in health databases; selecting predictor variables; filtering high-risk cases; and risk-rating profiles. Development of commercial software capable of probabilistically linking large health datasets at unit record level.

4. Telehealth

Outcomes: Improved access, quality and efficiency of health care, particularly for the aged, chronically ill, and rural and remote populations.

Outputs: Demonstrate the efficacy and cost-benefit of tele-ultrasound system. Demonstrate initial home telehealth system (for elderly people with frequent falls).

Development of R&D capacity: Identify requirements for new biosensors and develop (or adapt) appropriate skills. Gain access to skills in distributed systems information technology, human factors analysis and health evaluation.

5. Clinical decision support

Outcomes: Increased diagnostic confidence, more accurate and repeatable measurements, improved treatment and lower costs through use of advanced signal and image processing, and decision support technologies.

Outputs: Melanoma system licensed. Chest X-ray and aortic aneurysm systems licensed. Generic knowledge-based image analysis technology licensed and incorporated into radiology workstation. Ultrasound technology for improved image quality and blood flow measurement.

Development of R&D capacity: Develop skills in outcomes analysis, cost-benefit studies and design of clinical trials. Gain access to technical and clinical skills through collaboration with industry and health providers.

6. e-matching and e-negotiation

Outcomes: Optimum matching between the needs of several buyers and the availability of goods or services from a variety of sellers leading to more effective service and product suppliers and industries, and the better use of resources, particularly in complex arrangements. New on-line service providers. Reductions in the cost of transactions in all sectors.

Outputs: Development of an intelligent itinerary planner with Viator. A generic matching tool which can form the basis of a market engine in other industries.

Development of R&D capacity: The CSIRO research capability related to this objective comprises a number of pre-existing research groups. These groups have independently achieved significant recognition. The objective requires the development of inter-disciplinary interests and effort to be fully successful.

7. e-logistics

Outcomes: Significantly more efficient industries through improved cooperation between partners in the supply chain based on clear understanding of their contribution and performance. Better use of scarce and competing resources, particularly in complex environments.

Outputs: Methods for determining performance measure, and software for evaluation of alternative configurations of a logistics chain. Software for demand forecasting and planning the optimal utilisation of equipment and inventory.

Development of R&D capacity: Improved methods to support the solution of larger, more complex and realistic problems. We seek models that consider both demand uncertainty and dynamic aspects of supply chains.

8. Vision-based asset protection

Outcomes: Lower costs for businesses through the more effective protection of assets and the provision of asset-based information. More efficient and secure movement of people and baggage in airports and transport systems.

Outputs: Access control and identification systems. Multi-modal systems for the detection of drugs, firearms and explosives for baggage security at airports, other transport systems and public events. Intelligent biometric interfaces for electronic banking using ATM and EFTPOS terminals.

Development of R&D capacity: Enhanced skills in high-speed image capture. Real-time image processing based on content and knowledge, data fusion techniques.

9. Intelligent asset monitoring

Outcomes: More effective and efficient budgeting, whole-of-life estimation and asset management through improved use of objective data on asset condition. International sales of Australian asset monitoring products.

Outputs: A new generation of machine vision-based systems for precise imaging and object illumination for the high speed monitoring of products and infrastructure assets. An automated condition monitoring system for remotely controlled data acquisition and processing as input to network optimisation models for financial planning and maintenance.

Development of R&D capacity: A technical challenge exists to link the existing separate tools into a single system, integrating data, and developing and incorporating new asset monitoring and processing technologies.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Risk & yield management	2 915	1 364	4 366
2. Information strategies	3 165	3 025	5 952
3. Health care delivery	2 462	1 213	3 795
4. Telehealth	3 190	980	4 109
5. Clinical decision support	4 563	1 431	5 994
6. e-matching & e-negotiation	1 569	519	2 017
7. e-logistics	1 077	531	1 660
8. Vision-based asset protection	4 950	1 831	6 742
9. Intelligent asset monitoring	3 356	1 507	4 915
Grand total	**27 247**	**12 401**	**39 551**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Manufacturing Science & Technology	1 367	708	2 076
Maths & Information Sciences	12 033	7 578	19 882
Telecommunications & Industrial Physics	13 574	4 095	17 411
Wildlife & Ecology	272	20	181
Grand total	**27 247**	**12 401**	**39 551**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

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ENERGY

Energy is a key driver of the Australian economy. It has fuelled GDP, export and population growth over the past 25 years. Political drivers to reduce unemployment will reinforce economic growth over the next decade. Such growth requires competitiveness to be sharpened, not just sustained.

Energy input costs are a key factor. Improvements in energy efficiency will be needed to respond both to changes in domestic consumer behaviour driven by electricity and natural gas competitive markets, and to global market liberalisation and policy decisions on greenhouse gas emissions. The Kyoto greenhouse abatement protocols require Australia to achieve a substantial reduction in emissions against 'business as usual', let alone stronger economic growth. This shift to environmentally-constrained energy raises fundamentally difficult issues.

Innovation in energy supply and use is a key to resolving this dichotomy of challenges. Emerging energy technology may rival information technology for impact on markets and community lifestyles. Australia's economic health and standard of living will be affected adversely if we lag developments overseas, or to competitive advantage if we can pursue development faster or better than overseas. Most emerging sustainable energy technologies are unfamiliar to Australian energy suppliers and end users—many technological problems will need to be resolved to achieve their successful adoption in the domestic economy. Significant investment in innovative sustainable energy technology and in improved conventional fossil fuel technology is needed, amidst unprecedented changes to energy markets, domestically and internationally, and the emergence of 'green consumerism'.

My involvement with the CSIRO Energy Sector suggests that its future role is not based on prospect, but on proven performance and innovation that has been taken up by the industry. Many of these accomplishments are documented in the booklets *Commitment*, *Collaboration* and *Impact* and in the mid-term review of the sector. The sector is involved in projects worth over $50 million in conjunction with the START program. Strategic Advisory Committee members commented that 'CSIRO was becoming more flexible and responding to the turbulent times of the energy industry' and was 'changing its R&D profile and redirecting its resources' accordingly. Committee member suggestions for areas of improvement included better links between sector plans and budgets and divisional operating systems, with monitoring of actual versus planned performance, and of cost/benefits and returns on investment. These are part of the next triennium process.

The sector is now building for this changing future. CSIRO has a unique opportunity to partner business in addressing the spectrum of innovation required to meet these challenges. The senior CSIRO staff in the sector have interacted widely with committee members, sought views from numerous other external sources—individual experts, companies, industry associations and so on—across the energy spectrum, and have taken into account energy policies and comprehensive R&D strategies in numerous countries relevant to Australia.

The triennium process called for 'thinking outside boxes, 'new topics and areas for growth and decline', 'make shrewd judgements about what is needed 5-10 years from now', 'changes to priorities even within a zero change budget'—all these have been addressed in the resulting sector and component plans and budgets. Half the components represent major variations or extensions of established activities and some are completely new initiatives that will be developed over time. Part of the challenge is to recruit world class leaders and specialists to complete the springboard into the future, while staying in business through the transition period.

Finally, the planned relocation of the lead Division's headquarters and energy R&D to a world class energy centre in Newcastle is a concrete demonstration of national commitment to advanced energy and environmental technology development.

Keith Orchison
Chair, Energy Sector Advisory Committee

Energy Sector Advisory Committee:
Keith Orchison (Chair), ESAA Ltd; Margaret Beardow, Benchmark Economics; Robin Bryant, Department of Industry Science and Resources; David Cain, Rio Tinto R&TD; Ted Campbell, Department of Mines & Energy, Queensland; Philip Harrington, Australian Greenhouse Office; Peter Laver, Strategic Industry Research Foundation; Bruce Robertson, Shell Coal Australia Ltd; John Sligar, Sligar & Associates Pty Ltd; Jack Taylor, The Green Energy Corporation Ltd

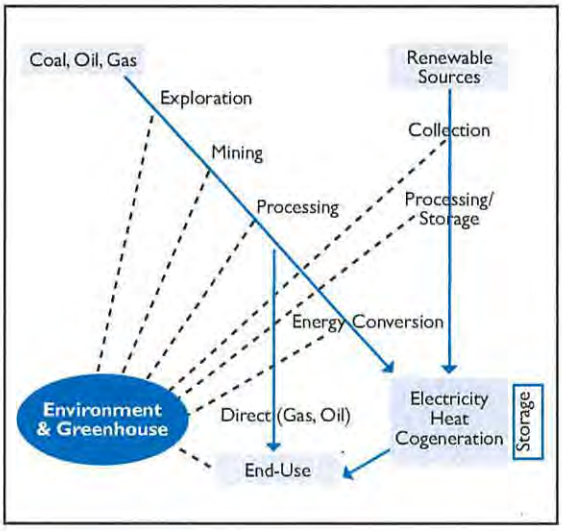
ENERGY

The Energy Sector encompasses:

- *energy resources—the exploration and extraction of coal, coal seam methane and oil shale, the processing/upgrading of energy resources, and the assessment of renewable resources including biomass and wastes*
- *energy supply—the conversion of fossil and renewable resources into electricity, thermal energy, chemicals, and the storage of electricity or thermal energy.*

Much of the resources and supply activities are also important in mitigating greenhouse gas emissions.

Energy end-use efficiency, and additional greenhouse and other environmental issues are covered in collaboration with other sectors.



The energy chain
The past emphasis has been on fossil resources and traditional power generation based on pulverised coal technology. The future emphasis will be increasingly on emerging energy technologies and greenhouse.

Sector Context, Dynamics, Outlook

The Energy Sector underpins domestic and international competitiveness and is a dominant contributor to exports. Energy resources and supply is stated to be a $60-billion-per-annum sector, directly employing 60 000 people.

- Australia is the world's largest coal exporter and coal is the nation's top export at $10 billion per annum. Growth is projected at 3% per annum, but is acutely subject to international competition and price pressures.
- Gas utilisation in Australia is forecast to double and to grow from 18% to 28% of primary energy by 2015. The projected investment in pipeline and utilisation processes is ~$16 billion.
- This growth in gas will be realised through power and cogeneration applications (forecast to rise from 9% to 21%) and industrial, commercial and residential use. Exports of appliances and services will also grow.
- The power industry anticipates at least $12 billion investment and a 37% increase in capacity to 2010. Although $4 billion of this investment is targeted at renewable energy, assisted by green power schemes, clean coal technologies will remain the major basis, and gas will be the commercial choice for new supply.
- Energy end-use efficiency will become prominent across industry, transport and buildings, with increased scope for new and future practice and associated R&D.
- Opportunities, flowing largely from the Kyoto Protocol, for technologies in the clean coal, renewable energy and other areas should see increases in exports of mining and energy equipment and services.
- Emissions trading will encourage overseas (especially Japanese) investment and uptake of emerging international technologies.

Greenhouse gas emissions have already exceeded the +8% Kyoto commitment. A major reduction on business as usual will be required. The sector (including energy use in transport) produces nearly 80% of emissions and must be the focus of future greenhouse gas mitigation efforts.

The more general environmental areas associated with energy, such as regional air quality (particulates, air toxics and smog) and mine site rehabilitation, plus local aspects such as power station emissions control, will also increase in importance. This is reflected in the National Environmental Protection Measure and possible externalities accounting.

The overall outlook is for major energy and associated environmental challenges, in parallel with far-reaching structural and economic changes across the energy industry. Ownership, market liberalisation, globalisation, electricity and gas convergence, and integration of upstream resources with downstream supply and utilisation businesses are radically altering the market itself. Governments are also heavily involved in market reform, greenhouse and other environmental policy.

R&D opportunities: Arising from all the above trends and issues are needs for more cost-effective and environmentally-acceptable technologies and processes

across the energy chain. In the context of global invention/local capture, the sector needs to become more knowledge-oriented, able to identify, select, modify/adapt, and help to broker and demonstrate the best relevant international and Australian technologies. This complements the traditional CSIRO role of research and innovation, provides for niche developments on a wide technology base, and emphasises CSIRO's breadth and leadership role, in collaboration with existing and potential new CRCs. Technological advances will themselves be a major driving force for energy and environmental markets, and for industry and government responses.

The main/potential users: The main users of this sector's outputs comprise:

- the energy resources industry
- electricity generators and private producers, distributors and retailers
- gas transmission, distribution and utilisation companies
- integrated energy companies
- equipment and technology suppliers across fossil and renewable energy
- energy end-users especially energy-intensive industries
- industry associations and peak bodies for most of these categories, including the Australian Coal Association Research Program
- federal and State government agencies including the Australian Greenhouse Office.

The disaggregation process has created numerous small to medium-sized enterprises, and there is an associated loss of critical mass and expert personnel in the industry. Market barriers also exist and are being addressed via environmental regulations, renewable energy targets, efficiency standards, and possible emissions trading schemes and/or carbon taxes/credits.

CSIRO and governments thus need to support energy R&D and technology demonstration/implementation during this uncertain and difficult transition period, to assist the development of a privatised industry that will have R&D and technological advance as a major basis of competitiveness.

Some 70% of Australian energy resources are exported. Energy technology imports (as well as exports) will increase, while overseas companies dominate the utility privatisation process. Together with future international emissions trading, this makes overseas links, particularly with Japan, vital.

Overall outcomes/benefits: Economic growth, sustained financial investment and employment, enhanced export income and environmental amenity through world competitive performance in costs and quality, and reduced greenhouse gas and other emissions.

Planned Achievements

1. Energy modelling

Outcomes: More technologically-informed and objective planning and policy advice to government and industry, with economic and greenhouse benefits in a deregulated, emissions trading regime.

Outputs: Overall and individual energy systems models and predictions, and greenhouse/life-cycle analyses, incorporating economic and technological factors. (Main collaborator the Australian Bureau of Agricultural and Resource Economics).

2. Coal mining

Outcomes: Reduced costs, enhanced productivity and ability to mine new/difficult coal deposits (indicatively a $1 per tonne saving equates to $150 million per annum across the industry; while a single 2-million-tonne-per-annum new mine equates to revenue of $100 million per annum).

Outputs: New and improved technologies and procedures for deposit delineation, mining risk assessment, gas drainage; for open cut, highwall and underground mining; for access to thick-seam, multi-seam, steep dipping and deep deposits.

3. Coal preparation

Outcomes: Reduced costs and new value-added products (indicatively a 1% extra recovery equates to >$100 million per annum across the industry).

Outputs: New and improved technologies and procedures for fine coal cleaning, dewatering and plant control, plus binderless briquetting and ultra clean coal.

4. Coal safety, health and environment

Outcomes: Lower costs via reduction in shut-down times and injury rates, plus improved on-site amenity and greater community acceptance (licence to operate).

Outputs: New and improved technologies and procedures for control of mine strata, methane gas, dust, temperature, outbursts and fires; for integrated visualisation and safety management; for communication, sensing, remote operation, automation and emergency response; and for mine site rehabilitation and subsidence management.

5. Clean coal power

Outcomes: Containment of costs of domestic electricity production, together with improved environmental performance. Improved access to overseas markets for Australian thermal coal exports.

Outputs: Modelling and optimisation software and demonstration, where appropriate, of coal and biomass combustion and gasification processes, emissions control processes for air quality (fly ash, air toxics and trace elements), and water quality and solid residues. These cover both conventional and advanced power generation systems, and include characterisation techniques, on-line instrumentation and underground gasification. The main collaborators are the Australian Coal Association Research Program and the two CRCs for black and brown coal.

6. Distributed energy (gas)
Outcomes: Industry demonstrations and commercial acceptance of emerging gas-based distributed energy technologies that have high energy efficiency, low greenhouse gas emissions and projected low costs. Anticipated applications are for power, heating and cooling across industry, transport, commercial and residential sectors.

Outputs: State-of-the-art technologies in fuel cells (SOFC and PEM types); gas turbines, engines and heat pumps; capabilities for different fuels; overall systems; specialised direct combustion processes and environmental performance. This involves selection and capture of international technologies and niche innovation.

7. Energy storage
Outcomes: Industry demonstrations and commercial acceptance of energy storage technologies that assist towards:

- implementation of renewable energy in remote area and grid-connected applications
- cost savings and load levelling in mainstream power generation
- applications in telecommunications and information technology
- power quality for end-users
- drive trains for hybrid electric vehicles.

Outputs: State-of-the-art electrical, mechanical, thermal and chemical storage technologies. These include lead-acid and novel battery systems, super-capacitors, hybrid systems and carbon nanotechnology. This involves selection and capture of international technologies and niche innovation.

8. Renewable energy
Outcomes: Accelerated implementation of renewable energy technologies and increased utilisation of solar, wind, biomass, waste and other green energy resources.

Outputs: Resources mapping, cost-effective technology matching, demonstrations where appropriate within the areas of biomass and waste utilisation, solar thermal and wind energy.

9. Direct greenhouse gas mitigation
Outcomes: Enhanced capability for industry and government to undertake direct (end of pipe) reductions of greenhouse gas emissions from large stationary sources, with quantification of the economic and environmental consequences. Actual implementation may be required to start in the next triennium, leading into the first Kyoto commitment (2008–12) period.

Outputs: Analyses, tools and techniques plus selected demonstrations, including increased participation in international programs, for capture and sequestration of carbon dioxide and methane from coal mines and power stations.

10. Energy end-use efficiency
Outcomes: Enhanced ability for industry and government to undertake greenhouse gas reduction with net economic benefits, from energy end-use efficiency, especially new and future process practices across industry, plus transport and buildings.

Outputs: Establishment of this area as a significant cross-sector business opportunity in CSIRO. Enhanced collaboration with Manufacturing and Built Environment Sectors. Input to the new CSIRO Sustainable Energy Building and Headquarters in Newcastle, which will serve as a showcase for selected national and international technologies.

Development of R&D Capacity

Half of the above components represent major variations or extensions of established activities, and some are completely new initiatives to be developed over time to position CSIRO and the Energy Sector for the longer term future.

An international business development leader will be appointed for Component 6—Distributed Energy (Gas Utilisation), and a CRC is being proposed. Another business development manager is expected for Component 8—Renewable Energy (Biomass), while a joint appointment is already in place between the Division of Energy Technology and the Division of Atmospheric Research in respect to Component 9—Direct Greenhouse Gas Mitigation. Other new staff are being sought, for example in Component 1 for economic and technological modelling. These appointments are complemented by significant redeployment of established staff to the new components, mainly within the lead Division, plus enhanced external interactions with market consultants to the power industry, and with the CRC for Renewable Energy.

In respect of the new Component 10—Enhanced Energy End-Use Efficiency, initial leadership will be sought, jointly with other sectors, to define the program and the external and internal stakeholders. This small but critical commitment reflects that the

major output here is to build CSIRO R&D capacity. Concrete outputs, and implementation outcomes by industry and government, thereby become prospective in the following triennium that leads into the first Kyoto (2008–12) commitment period.

Equipment and facilities will be enhanced particularly for the new components. In this respect, a major contribution to R&D capacity will be the relocation of the lead Division, Energy Technology, to a new world-class, sustainable energy complex at Newcastle.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Energy modelling	1 186	311	1 492
2. Coal mining	8 611	7 858	16 439
3. Coal preparation	4 512	3 118	7 424
4. Coal safety, health & environment	4 434	3 692	8 105
5. Clean coal power	12 992	9 851	21 318
6. Distributed energy (gas)	6 853	1 956	8 726
7. Energy storage	6 104	3 931	10 031
8. Renewable energy	6 837	2 608	9 364
9. Direct greenhouse gas mitigation	2 861	1 382	4 193
10. Energy end-use efficiency	348	0	350
Grand total	**54 739**	**34 707**	**87 443**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Atmospheric Research	460	120	581
Energy Technology	31 442	16 037	47 207
Exploration & Mining	10 269	10 122	20 371
Forestry & Forest Products	1 123	510	1 634
Land & Water	1 687	869	2 605
Manufacturing Science & Technology	4 406	1 901	6 314
Minerals	2 977	3 690	4 945
Petroleum Resources	991	642	1 635
Telecommunications & Industrial Physics	1 054	650	1 681
Wildlife & Ecology	329	166	469
Grand total	**54 739**	**34 707**	**87 443**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

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MINERAL EXPLORATION AND MINING

The goal of the Mineral Exploration and Mining Sector is to locate and exploit the next generation of giant ore deposits in Australia. This goal was encapsulated in the 'Glass Earth' and 'Accessible Earth' concepts presented to the CSIRO Executive Committee in May 1999 in the sector's investment portfolio, and is the focus of the key issues and priorities set out in the Sector Plan for the 2000–03 triennium. The Sector Advisory Committee was closely involved in the development of both the investment portfolio and the plan, and endorsed the latter at its meeting in Melbourne on 11 November 1999.

At that meeting, the committee discussed a range of matters associated with the sector planning process, three of which I would like to mention.

- As the incoming Chairman, it is clear to me that a strong relationship has developed between the CSIRO Divisions involved in the sector and the committee. The committee and selected key industry advisers worked closely with CSIRO staff to develop the investment portfolio and review the plan. Committee meetings are always well attended. Members feel their views are listened to and the meetings are always productive.
- The committee feels strongly that the exploration, mining, processing, marketing and environmental streams of the Australian minerals industry should be more closely linked than they have been in the past. As outlined in Component 9 of the plan, which was included at the suggestion of the committee, Australian mining companies must be able to maximise the economic recovery of the mineral resource and optimise their operations with respect to changes in ore types, market requirements and community expectations. To help bring this together it is pleasing to note that the chairmen of two closely related Sector Advisory Committees—the Mineral Production and Metal Processing Sector and the Built Environment Sector—are also members of our committee. In future, I believe it would be helpful if the chairman of the Energy Sector's committee also participated in our meetings and I have asked the sector coordinator, Dr John Read, to see if this can be arranged.
- One session of the meeting was devoted to exploring alternative commercialisation vehicles for CSIRO technologies. To this end, Dr Bruce Hobbs outlined a proposal that CSIRO establish a company aimed at providing the next generation of technology and services to the global exploration and mining industry. The proposed company would be independent from CSIRO, although the organisation would have an equity holding and its aim would be to commercialise CSIRO technologies. The committee liked the suggestion and supported the concept of a company that was commercially driven with the objective of delivering a return on investment. From comments made at the meeting by Dr Colin Adam, the committee understood that there were no particular impediments from CSIRO's point of view and agreed that a small subcommittee be formed to work with Dr Read to help develop the concept.

In closing, I would like to add my support to that of my predecessor, Mr Dick Carter, who was the inaugural chairman of the committee and who actively backed the efforts of CSIRO to build a strong relationship with the Australian minerals industry through the adoption of the sector planning process. The activities of the committee show that the process has industry's support, and my committee colleagues and I look forward to helping CSIRO determine its research directions beyond the 2000–03 triennium.

Andrew Michelmore
Chair, Mineral Exploration and Mining
Sector Advisory Committee

Mineral Exploration and Mining Sector Advisory Committee:
Andrew Michelmore, (Chair) WMC Resources Ltd; Alan Broome, AMP Control Pty Ltd; Alan Castleman, Western Metals Limited, Australian Unity Limited; Mark Cutifani, Sons of Gwalia; Dick Davies, Australian Mineral Industries Research Association; Geoff Dickie, Department of Mines & Energy, Queensland; Phillip Harman, BHP Minerals Discovery; Jeff Harris, Department of Industry Science & Resources; Neil Phillips, Great Central Mines Ltd; Jim Torlach, Department of Minerals & Energy, Western Australia; Mark Woffenden, KPMG

MINERAL EXPLORATION AND MINING

The Mineral Exploration and Mining Sector is specifically concerned with the exploration for, and mining of, economically viable, inorganic solid mineral deposits. Environmental impacts of mining, mine site rehabilitation and occupational health and safety considerations are included within the sector's scope of activities.

Sector Context, Dynamics and Outlook

Australia is among the world's major suppliers of bauxite, iron ore, gold, coal, diamonds, mineral sands, lead and nickel, and exports substantial quantities of other metals including zinc, uranium and silver. The industry is highly productive, technology-intensive and focused on its global markets, international opportunities, capital and cost-competitiveness, safety, environmental management and sustaining its licence-to-operate.

The discovery, mining and processing of inorganic minerals to the basic mineral commodity stage underpins the other parts of the industry and, as Australia increases its mineral processing, the value of that sector will grow and the exports ascribed to the Mineral Exploration and Mining Sector will decrease. The net trade for the sector in 1996–97 was $2481 million; this does not include gold and bauxite (Mineral Processing and Metal Production Sector) or coal (Energy Sector). There is strong potential for development of a $1 billion export industry in related equipment, technology and services.

R&D investment: The sector enters the triennium near the low point of an unusually deep cyclical low in minerals prices, intensifying the industry's focus on cost reduction and market diversification. Mergers and acquisitions have resulted in increased concentration of production. Spending for future growth has been severely curtailed, with particular impact on exploration and R&D. Real prices are not expected to increase sufficiently over the triennium to reverse the decline in exploration and new capital expenditure.

When cyclical prices recover, the sector will rebound, but the structural changes and focus on cost-efficiency are unlikely to be reversed. The longer-term challenge is the underlying 50-year trend of declining real prices.

Uptake of R&D: Exploration and mining companies, their suppliers and consultants will increasingly seek R&D internationally, making it essential for CSIRO to maintain its demonstrable world-class capability. Increasingly, R&D providers must provide packaged or turn-key solutions to ensure adoption of advanced technologies. Nevertheless, surveys by the Australian Bureau of Statistics confirm an impressive record of technology uptake in the sector and, as the level of local ownership remains high, the returns to Australia are strong.

Other drivers: Unrelenting public pressure for safer and more acceptable mining practices accompanies increasing community concern over the environmental impacts of mining and the value of other land uses. The emergence of major new mining economies overseas presents an opportunity for CSIRO to support Australian companies in their efforts to pursue new areas.

Diminution of Australia's more easily accessible deposits is forcing exploration and mining activities into deeper, more remote and difficult environments, with higher operating costs. The most likely areas for new exploration success now lie in the 70% of the continent that is covered by a deep layer of highly weathered regolith, in which conventional exploration techniques are largely ineffective. Competitor nations are less affected by this distinct feature of Australia's geological evolution.

R&D providers: CSIRO is the largest coherent minerals mining research body in Australia, with a portfolio of strategic, collaborative and contract research aimed at enhancing the competitive advantage of the sector in the global market place. Private sector R&D is dominated by the major mining houses which undertake applied research specifically tailored to the needs of their parent companies. CSIRO supplements these in-house capabilities and meets the applied research needs of smaller mining companies.

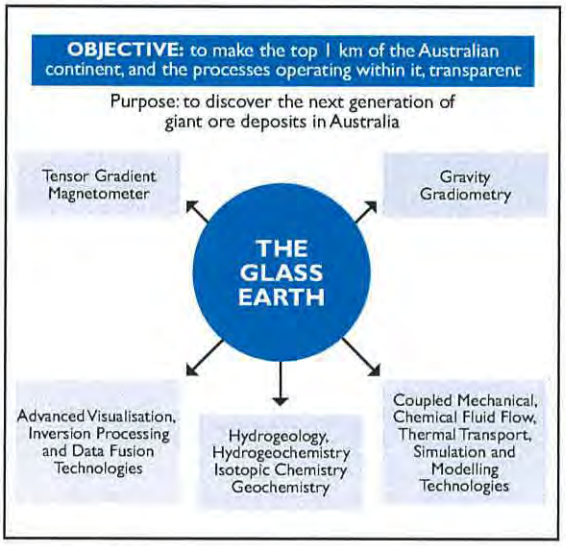
Collaborative projects facilitate technology transfer and provide a cost-effective mechanism for companies to access CSIRO's unique capabilities. There is also increasing emphasis on addressing the research needs of service providers, exploration consultants and equipment manufacturers. Appropriation funds support pre-competitive research aimed at delivering sector-wide benefits and national wealth creation.

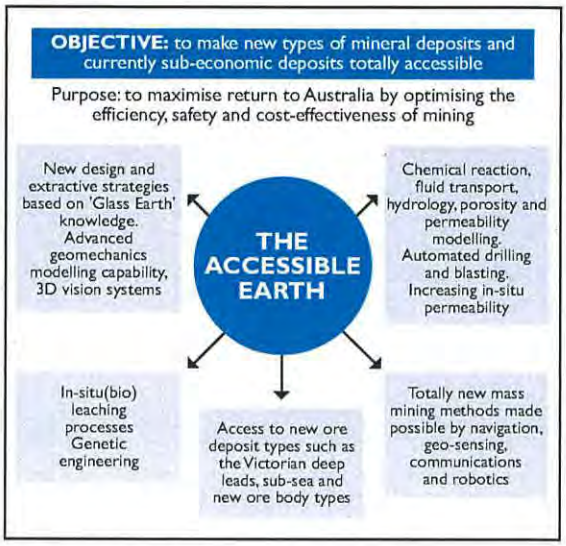
Planned Achievements

The sector plan consists of nine research components that address the key strategic issues facing exploration and mining companies, namely:

- Why do quality ore bodies exist and what causes them?
- How do companies reduce the time and expense involved in finding such an ore body?
- Once found, how do companies delineate the resource accurately?
- How do companies safely and efficiently extract the resource while minimising dilution and environmental impacts?

The objectives are encapsulated in the 'Glass Earth' and 'Accessible Earth' concepts illustrated below.





1. Area selection criteria

Outcomes: Improved probability of selecting, for exploration, areas that host large mineral resources.

Outputs: Understanding of the geological processes responsible for the formation of quality ore deposits. Definitions of diagnostic properties of selected ore deposit styles. Terrain specific exploration strategies.

Development of R&D capacity: Increased emphasis on interaction between modelling work and exploration practice.

2. Recognise ore-bearing systems

Outcomes: Improved precision in appropriate siting of drill holes.

Outputs: Technologies for detecting the imprint of hidden ore systems. 3D geological images of the earth's upper kilometre.

Development of R&D capacity: Increased emphasis on advanced visualisation and data fusion technologies. New airborne capabilities including an earth sensing satellite (as part of the ARIES consortium).

3. Exploration through regolith

Outcomes: Removal of the greatest physical impediment to continued exploration success in Australia.

Outputs: Characterisation of the properties and distribution of the regolith. Technologies for detecting ore systems under 100–200 metres of highly weathered material. Procedures for exploration within and beneath sediment cover.

Development of R&D capacity: Increased emphasis on hydrogeology and hydrogeochemistry.

4. Mine design

Outcomes: Improved mine safety, lower pit costs, better reserve estimation, increased recovery, reduced geotechnical risk, improved control of downstream costs, quality and production.

Outputs: New visual and infrared spectrometric sensors for mining applications. Improved geophysical characterisation and delineation of ore or waste. Improved geological and geotechnical models. Procedures to reduce geotechnical hazards.

Development of R&D capacity: Greater emphasis on geophysics and engineering geology.

5. Mine operations

Outcomes: Reduced geotechnical hazards and risks. Reduced dilution of ore, improved product quality and reduced processing costs. Automated/robotic mining equipment manufactured in Australia.

Outputs: Technologies incorporating real-time integration of geotechnical assessments in mine operations for the management of hazards/risks, machine dynamics and human–machine interface.

Development of R&D capacity: Current skills and infrastructure are sufficient for this objective.

6. Innovative mining systems

Outcomes: Reduction in unit and up-front capital costs. Extraction of previously sub-economic or inaccessible deposits. Fewer people exposed to hazards in the mining zone.

Outputs: New mass mining methods. New in-situ leaching systems. A mole miner, Sord and Shield. Access to undersea deposits in the longer term. Non-explosive hard-rock cutting methods.

Development of R&D capacity: Increase skills base in mechatronics, mining engineering, hydrology and modelling.

7. Health and safety technologies
Outcomes: Safer operation of mines, improved information on the location and status of people in underground mines. Reduced costs due to personal injury, lost production and plant damage

Outputs: Monitoring and control technologies for risk/hazard assessment and management, people tracking, communications and environmental sensing.

Development of R&D capacity: No change.

8. Environment technologies
Outcomes: Reduced whole-of-life adverse effects of mining on the environment.

Outputs: Ground-based and airborne sensors and systems that measure and monitor rock, soil and water, and vegetation changes due to mining operations. Whole-of-life planning tools that schedule and cost final rehabilitation. Methods for tailings treatment and disposal, waste disposal and control of emissions and impact assessment. Design criteria for constructed landforms at mine sites.

Development of R&D capacity: Increase skills in hydrology and plant ecology.

9. Exploration to market systems
Outcomes: Operational and capital cost reduction by optimising whole production systems from ore deposit delineation, through mine design to product specification and delivery.

Outputs: Measurements of the effect of dilution on processing performance. Definition of the economic and other consequences of process variability. Technical and economic models of the mine-to-mill processes.

Development of R&D capacity: Acquire skills in mining engineering and economic geology.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Area selection criteria	10 068	7 646	17 715
2. Recognise ore-bearing systems	16 325	12 858	26 771
3. Exploration through regolith	11 012	8 914	19 943
4. Mine design	5 175	3 753	8 953
5. Mine operations	3 025	1 298	4 332
6. Innovative mining systems	3 693	2 389	6 097
7. Health & safety technologies	793	559	1 352
8. Environment technologies	5 785	3 305	9 314
9. Exploration to market systems	513	0	516
Grand total	**56 389**	**40 721**	**94 994**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Energy Technology	107	87	194
Exploration & Mining	44 786	34 584	76 858
Land & Water	4 112	2 118	6 348
Manufacturing Science & Technology	1 240	952	2 190
Maths & Information Sciences	2 268	1 027	3 652
Telecommunications & Industrial Physics	3 413	1 650	5 004
Wildlife & Ecology	462	303	748
Grand total	**56 389**	**40 721**	**94 994**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

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MINERAL PROCESSING AND METAL PRODUCTION

It is my pleasure, on behalf of the Mineral Processing and Metal Production Sector Advisory Committee, to present the Sector's Plan for the 2000–03 triennium.

CSIRO has become increasingly responsive to the needs of the Australian industry over recent years. There has been considerable success in the sector in developing and improving customer relations. The minerals industry has undergone radical changes during the last five years, as a result of the need to increase shareholder value, through mergers and acquisitions, downsizing and re-focusing on core businesses. This has resulted in a reduced emphasis on R&D by the industry, relative to other concerns, and the adoption of shorter time scales for returns on R&D expenditure.

CSIRO must continue to anticipate and respond to these changes in providing cost-effective solutions to industry problems.

At the same time, CSIRO must not lose sight of the need to continue to develop its expertise base and the technologies for the future even though there may not be financial support from industry for many of these until they are closer to the technology transfer and implementation stage. Accordingly, the external earnings target for the minerals sector has been set to be challenging, but achievable, without sacrificing the strategic capabilities of the organisation.

Through extensive consultation over a period of more than 12 months, the Sector Plan was developed to identify the key issues facing the minerals industry which may be addressed, at least in part, by technical innovation. There has been careful analysis of the issues to determine CSIRO's contribution to their resolution and the interface between CSIRO, other public sector research institutions and the private sector. I believe the plan strikes an appropriate balance between the development of enabling technologies (such as flotation chemistry, melt chemistry, computational fluid dynamics), and the development of radically new processing and extraction technologies (such as in-situ mining, biomineral processing and titanium metal production). The enabling technologies will be applied and strengthened through contract and collaborative work with appropriate companies.

Finally, I commend the sector for its efforts in aligning its work with important sectors of the Australian economy.

Dick Davies
Chair, Mineral Processing and Metal Production
Sector Advisory Committee

Mineral Processing and Metal Production Sector Advisory Committee:
Dick Davies, (Chair) Australian Mineral Industries Research Association; Richard Aldous, Iluka Resources Limited; Roy Ames, Consultant; Deanna Aubrey, Department of Mines & Energy Queensland; Stephen Barnett, QNI Pty Ltd; David Coutts, Australian Aluminium Council; John den Dryver, Normandy Mining Limited; Ian Lawrence, Lawrence Consultants Pty Ltd; Elizabeth Lewis-Gray, Gekko Systems Pty Ltd; Malcolm Richmond, Curtin University; Ray Shaw, Rio Tinto; Don Smale, Department of Industry Science & Resources; David Sutherland, Nabalco Pty Ltd; Bob Watts, BHP

MINERAL PROCESSING AND METAL PRODUCTION

The Mineral Processing and Metal Production Sector relates to activities which transform as-mined mineral ores to:

- *mineral products, often mineral concentrates, to be used in this form or processed to metal (such as copper concentrate, clays, silica, beneficiated iron ore, ilmenite)*
- *chemically processed minerals in a relatively pure state, sold for their intrinsic chemical value as feedstock to a manufacturing process (such as titania for incorporation into paints or plastics and magnesia for refractories, flame retardants or effluent treatment) or for further processing to metal (such as alumina, synthetic rutile, directly reduced iron)*
- *refined and unrefined metal in relatively undifferentiated forms such as ingot, sheet or rod for sale as feedstock to metal fabricators and manufactures (such as aluminium ingot, anode copper, steel billets, lead bullion, zinc ingot, nickel powder).*

The sector bridges the gap between mining (part of the Mineral Exploration and Mining Sector) and the Integrated Manufactured Products Sector. However, the boundaries are becoming blurred due to increasing integration of processing steps.

Sector Context, Dynamics and Outlook

The sector is Australia's largest exporter, and is by far the largest net exporter. Iron ore makes up 4% of total merchandise exports, copper 1%, zinc concentrates 1% and uranium just less than 1%. Exports of basic manufactured products of mineral origin (such as alumina, aluminium, synthetic rutile, pigments, steel, copper, nickel, lead, zinc etc.) were $17 600 million in 1995–96 and when combined with the exports of mining products accounted for 45% of total merchandise exports.

While the sector is a low direct employer, the multiplier factor on employment in other sectors (particularly the Services and Integrated Manufactured Products Sectors) is about eight.

R&D investment: The industry is world class in its technology and this has been a key factor in winning market share. The R&D intensity by value-added is relatively high but is low by turnover, 3.6% and 1.4%, respectively according to Australia New Zealand Standard Industry Classification, or 6.8% and 2.6%, according to socioeconomic objective. Expenditure by most companies on medium and long-term R&D has declined significantly in recent years.

Sector dynamics: The industry operates against a backdrop of widespread change, reorganisation and uncertainty. The rapidly changing environment is characterised by increasing globalisation, erosion of technical capability, and the need to process ever more complex and often lower grade ore bodies in the face of declining commodity prices and lower profitability. At the same time, there is increasing public scrutiny of the environmental and social impact of mining and minerals processing and of the life cycle of metal-containing products.

Commodity prices are at their lowest for a decade, in part due to the Asian economic crisis, and this is placing pressure on companies to reduce operating costs and to maximise return on assets in the short to medium term. Recent trends in the industry can be characterised as follows:

- Amalgamations and take-overs have produced a small number of large trans-nationals although there is a large number of medium-sized companies that are poised to play an increasing role in the future.
- New resources in the emerging economies are being acquired for competitive advantage.
- Companies have retreated to their core businesses (mining, mineral processing and metal production), with few involved in vertical integration through to manufacturing.
- Cost reductions are being achieved through staff reductions, re-focusing of R&D on core issues (with short time frames), and outsourcing of non-core functions (exploration, human resources, information technology, maintenance etc.); the emphasis in technology is on fast-following—companies prefer to acquire or adapt proven technology rather than develop new technology.

The key companies and agencies are companies with in-house R&D, usually large with international operations, (which value CSIRO for its people and specialist facilities); companies with limited in-house R&D (which value CSIRO's ability to provide a range of expertise); equipment and consumables suppliers (mainly manufacturing and chemical companies, including small to medium-sized enterprises and multinationals and their agents); engineering companies (which provide turn-key plants and offer an increasingly important commercialisation path for CSIRO technology); consultants (with little scope for interaction with CSIRO); and industry bodies (such as the Minerals Council of Australia, the Australian Mineral Industries Research Association and the Australian Minerals and Energy Environment Foundation).

Uptake of R&D: Many of the outcomes of CSIRO's R&D are appropriated by companies and deliver benefits in the form of lower costs, increased profit, compliance with regulations, increased reserves etc., but most also provide significant benefits to the

government and nation (increased taxes, royalties, improved balance of trade) and/or the community (increased employment, particularly through the multiplier effect, better environment, safer working conditions, sustainable communities).

5–10 year outlook: The trend in commodity prices will continue downwards, but demand will begin to pick up as the global economy improves. There is opportunity for a market share increase for Australia. Pressure for sustainable processing will continue to grow—with implications for greenhouse-gas reduction, light metal production, biomineral processing, recycling and zero waste processes and the social impacts of mining and processing. Further growth in productivity will be achieved through acquisitions, increase in the scale of operations and through introducing innovations that reduce costs. Step-changes in technology, producing industry-changing gains in processing type or efficiency (such as past successes using carbon-in-pulp for gold and high pressure leaching for nickel) will be rare, but will play an important part in the long-term viability of the industry.

Planned Achievements

The sector plan consists of eight research components that address the two key strategic issues facing the industry: sustainability and profitability. Sustainability must be addressed to ensure the industry has a long-term future: the licence-to-operate conferred ultimately by society and the use of technologies that maximise the life/value of resources 'in the ground'. Profitability must be addressed to ensure that the industry has a short-term future: costs must be driven downwards so companies remain competitive.

1. Sustainability

Outcomes: Applications of life-cycle analysis by the minerals industry to quantify environmental impacts, identify strategies and reduce impact. More environmentally robust mineral-processing operations. Sustainable management of water and waste products. More effective involvement of stakeholders in strategic decision making. Improved performance, monitoring and reporting of environmental and social impacts of mining and processing.

Outputs: Improved understanding of the issues of sustainability and strategies to address them. Life-cycle analysis tools. Technologies for minimising the impact of processing. Protocols for studying sustainability issues.

Development of R&D capacity: Links will be developed with the Land and Water Sector through CSIRO Mining Environmental Research and the Environmental Projects Office in the Division of Land and Water. Capabilities in stakeholder a nalysis methodologies and their application will be strengthened through collaboration with university groups.

2. Process improvement

Outcomes: Improved mineral and metal recoveries. Higher grade concentrates. Better use of reagents. Lower energy consumption. More selective recovery. More intense processing. Smaller, less expensive reactors. Optimum unit operation configurations for mineral processing operations.

Outputs: Improved understanding of the chemistry of flotation and metal production. Improved design of reactors. Mathematical models for predicting slag properties, thickener performance, flow, heat transfer and reactions in multi-phase reactors, and comminution/liberation.

Development of R&D capacity: Present areas of expertise—computational fluid dynamics, fluid bed processing, computer simulation, melt chemistry, flotation chemistry and process mineralogy—will be enhanced and comminution and flowsheet modelling capabilities will be further developed.

3. Increased asset utilisation

Outcomes: Improved on-line monitoring and control of processes. A stronger Australian on-line analyser manufacturing industry. Better scheduling of assets and of their maintenance. Adoption by industry of tools for optimising planning and scheduling.

Outputs: New on-line analysis instruments. Techniques to integrate on-line sensing and analysis technologies with expert systems, adaptive control, fuzzy logic and neural nets in 'smart sensors'. Models to simulate the effect of process variables on materials performance. Multi-agent maintenance-scheduling protocols for mineral-processing applications.

Development of R&D capacity: Expertise will be enhanced in advanced concepts and technologies that will form the basis of future on-line analysis systems (particularly artificial intelligence, advanced signal processing and advanced digital processing). Development of expert systems and generic techniques for experimental design and other minerals applications. Integration of experimental and environmental variables into predictive models for improving materials performance and selection.

4. Difficult-to-treat deposits

Outcomes: Processing of ores that were previously unprofitable. Increased reserves of economically treatable ore. New or expanded processing industries for Australia.

Outputs: Improved understanding of the relationship between ore characteristics and metallurgical performance. More reliable assessment of downstream processing performance. Novel processing technologies and novel adaptations of existing technologies for treating low-grade, fine-grained, complex or impure ores.

Development of R&D capacity: Capacity will be enhanced in fine particle flotation, comminution using high pressure grinding rolls and in high pressure leaching, particularly of laterite.

5. Processing in 2010

Outcomes: Integrated mining and metal-extraction operations. Seamless mine-to-mill processing. In-situ mining operations. Smaller mine footprint. Lower environmental impact of mining and mineral processing.

Outputs: Validated computational simulators for in-situ solution mining for investigating options and designing mines of the future; processes using natural organisms to revolutionise metal extraction and waste remediation. Understanding how to link multi-sensor data on ore characterisation with key control parameters for mining, ore sorting, comminution and flotation.

Development of R&D capacity: Establishment of a centre of excellence in modelling in situ solution mining operations, involving collaboration between the Divisions for minerals, and exploration and mining. Establishment of a multi-disciplinary biomineral processing team. Development and linking of capabilities for integrating mining and mineral-processing operations through use of intelligent multi-sensor systems.

6. Differentiating commodities

Outcomes: Better consistency, quality and suitability of raw materials for processing (for example, iron ore, coke, alumina). New value-added products (such as magnesia-based products, higher grade synthetic rutile). Export levels/values maintained or enhanced in the face of increased competition.

Outputs: Improved sampling, blending and stockpiling techniques to improve product consistency and meet customer specifications. Technologies for better control of particle properties through crystallisation, agglomeration, size reduction etc. to enhance product quality and downstream performance. New and enhanced products and processing routes for Australian mineral commodities.

Development of R&D capacity: Enhanced capabilities will be developed in briquetting technology and population balance modelling, particularly in precipitation processes. Better sampling methods.

7. Light metal production

Outcomes: Consolidation of the Australian aluminium metal industry through introduction of greenhouse-efficient technology. Establishment of a magnesium metal smelting and die-casting industry. Progress in the establishment of a titanium metal industry in Australia.

Outputs: Identification of market leverage points for titanium metal. New improved technologies to produce titanium metal. Next-generation magnesium smelting and casting technologies. Technologies for recycling aluminium (and magnesium) drosses and spent pot liners from aluminium cells. A new carbothermic reduction technology for aluminium smelting.

Development of R&D capacity: Enhanced scientific and technology skills in high temperature chemistry and metallurgy, molten salt electrowinning, plasma science and technology, casting, chlorine utilisation and recovery, anhydrous feedstocks, metal purification, and process development and modelling.

8. Enabling science and technology

Outcomes: The outcomes of this component will be realised through the other seven components.

Outputs: Micro-characterisation service provided through telepresence. Pilot plant for bioleaching of metals. Next-generation intelligent sensors for process control. Processes for production of nanostructured materials. Node in a global network of micro-characterisation centres. Biomineral processing coordinating committee. Enhanced knowledge management processes. Enhanced links with industry through targeted extranets.

Development of R&D capacity: Increased understanding of materials and processes at the molecular level. Genetic characterisation of micro-organisms relevant to biomineral processing. Enhanced capabilities and infrastructure in parallel computing. A senior scientist group within the Minerals Division to benchmark capabilities in core disciplines. Knowledge assets manager to establish equipment and expertise databases, enhanced intranet and targeted extranets, and supervise and integrate knowledge-management functions. Establishment of a visiting scholar program. Joint CSIRO–Curtin University chair in process engineering installed. Pro-active involvement in post-graduate and post-doctoral education, including through CRCs.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Sustainability	5 256	2 605	8 754
2. Process improvement	23 788	19 300	39 092
3. Increased asset utilisation	6 617	3 770	10 527
4. Difficult-to-treat deposits	4 799	3 027	7 964
5. Processing in 2010	9 594	3 974	14 941
6. Differentiating commodities	11 732	7 714	19 410
7. Light metal production	8 745	3 122	13 137
8. Enabling science & technology	7 753	2 924	12 740
Grand total	**78 283**	**46 435**	**126 566**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Building Construction & Engineering	6 377	3 757	10 131
Energy Technology	1 523	1 120	2 640
Land & Water	1 417	730	2 188
Manufacturing Science & Technology	4 823	1 972	6 804
Marine Research	498	218	717
Maths & Information Sciences	1 631	803	2 514
Minerals	59 995	37 835	99 555
Molecular Science	1 080	0	1 086
Telecommunications & Industrial Physics	940	0	933
Grand total	**78 283**	**46 435**	**126 566**

**External revenue for research and services.*
***Includes other external revenue and retained earnings applied to the sector*

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PETROLEUM

The petroleum industry already supplies more than half of Australia's energy needs, and it is set to play an increasing role in Australia's economic development. This will be driven especially by our significant endowment of natural gas with its outlook for growth, both as liquid natural gas exports and, domestically, as an increasing proportion of Australia's energy mix. The forecast is that domestic demand for gas will increase from a current 18% to about 28% of Australia's total energy needs by 2010. The outlook for oil, however, is not as strong as that for gas, and Australia faces a significant challenge to maintain the 80% oil self-sufficiency that it has enjoyed for the past few decades.

Because most of our gas lies offshore, remote from markets and increasingly further from shore and in deeper waters, we are being challenged to stretch the boundaries of technology in areas such as the ability to drill horizontal reaches of over 11 kilometres and finding the means by which we can add value to gas offshore. It is obvious that technology is one of the keys to meeting these challenges and to realising the opportunity that oil and gas have to underpin economic growth in Australia through the supply of internationally competitive energy. The research plans have been developed by CSIRO, in conjunction with the oil and gas industry and government, to help address these national challenges.

The Australian oil and gas industry is part of a global business that develops its technology around the world. Australia's oil and gas provinces, however, have geological, geographic and environmental peculiarities, which give rise to special challenges. It is important, therefore, for CSIRO to develop strategies that recognise these challenges as well as issues of national interest, and to work in a way whereby its activities complement and are integrated with the global research and technology development effort.

Australia has limited R&D funding, and I am concerned that we get maximum value from both company and government investment through increasingly efficient relationships. We need to work at the relationships between the producing companies, the service companies and Australia's R&D and educational institutions (CSIRO, the Australian Geological Survey Organisation, AIMS and the universities) as well as the cross-divisional and cross-organisational synergies that I am sure exist within CSIRO itself. In this context, the industry has decided to support the creation of Petroleum Research and Technology Ltd to facilitate these relationships and R&D activity. The development of the Australian Resources Research Centre in Perth as a venture between CSIRO, the Western Australian Government and Curtin University will provide a focus for petroleum R&D and is a significant step in the right direction.

Finally, but most importantly, the industry is well aware of its responsibilities to the environment, with particular emphasis on the marine environment and the challenge of reduced greenhouse gas emissions. The latter is of fundamental importance if Australia is to achieve its potential of being an internationally competitive provider of 'clean' energy, with the greenhouse credits rightfully attached thereto.

On behalf of the committee, I look forward to supporting the implementation of this plan.

Agu J Kantsler
Chair, Petroleum Sector Advisory Committee

Petroleum Sector Advisory Committee:
Agu Kantsler, (Chair) West Australian Petroleum Pty Ltd; Dave Agostini, Agostini Consulting Pty Ltd; Charles Balnaves, BHP Petroleum Pty Ltd; Michael Frost, Santos Ltd; Rodney Halyburton, BHP Petroleum Pty Ltd; John Hartwell, Department of Industry Science & Resources; John Hebberger, West Australian Petroleum Pty Ltd; Doug Hodson, Woodside Energy Ltd; Leif Larsen, Schlumberger Oilfield Australia Pty Ltd; Rob Male, Woodside Energy Ltd; Kees Van Gelder, Woodside Offshore Petroleum Pty Ltd; Robert Willink, Boral Energy Resources Ltd

PETROLEUM

The Petroleum Sector comprises the companies, associations and government entities that are concerned with the exploration and production of oil and gas through to the generation and distribution of oil and gas products to the consumer.

Critical interfaces are at the end of this chain concerning utilisation (Energy Sector), along the chain concerning operations in the marine environment (Marine Sector) and greenhouse gas emissions (Climate and Atmosphere Sector), and with the coal mining industry concerning the production of methane from coal seams (Energy Sector).

Sector Context, Dynamics and Outlook

National significance: The oil and gas industry delivers to Australia a competitive and secure supply of oil and gas and growing revenue from gas exports. It satisfies most of Australia's energy needs—currently 54%, including 80% of oil and 100% of gas needs. Gas is forecast to increase its share of Australia's energy mix to 28% by 2010, largely at the expense of coal for electricity generation.

The value added to Australia's GDP is $8.7 billion (1.7%). A 20% increase in production increases GDP by 0.4–0.5%. The flow-on multiplier to the rest of the economy is a high 1.8–2.4. Liquid natural gas exports earn $5.7 billion, with growth potential. Australian content of projects now exceeds 70% with growing service companies. The industry is a major source of government revenue—$3 billion in production taxes plus $1.1 billion in fuel other taxes, excluding excise.

Outlook: Australia's demand for energy is increasing at 3.5% per annum. The outlook for oil in Australia suggests a declining self-sufficiency from a traditional 80% to about 52% by 2005, with an increased import requirement equating to $4.1 billion per annum. This is driving an increased focus on oil exploration, especially in the north-west. The Australian Geological Survey Organisation is currently appraising the prospectivity along Australia's southern margin. The outlook for gas supply is strong, based on major developments like the North-west Shelf and Gorgon projects with an estimated resource equating to about 100 years at current consumption rates. The major challenges concern market development and the remoteness of the gas from market and shore.

The petroleum industry is conscious of its environmental responsibilities with a focus on the marine environment and greenhouse gas emissions.

Industry dynamics: The increasingly challenging operating environment and the declining prospectivity for oil indicate an increasing cost outlook. At the same time, the price outlook is flat. Margins are thus likely to become tighter while technical challenges increase. This is expected to maintain or increase the current trends for mergers, outsourcing and collaboration.

Operating companies are decreasing their technology development role, while that of service companies is increasing. Service companies are turning increasingly to major laboratories such as CSIRO for R&D that enable them to cut their time to market.

The industry is currently feeling the consequence of the significant price drop during 1998–99, despite the recent price recovery. The focus is on rationalisation and cost cutting, which is having a short-term adverse impact on R&D investment. The Australian Petroleum CRC will evolve over the next 2–3 years into Petroleum Research and Technology Ltd, which will be owned mainly by the industry and will focus on the strategic and operational relationship between the industry and research providers.

CSIRO's role: The Australian petroleum industry is part of a well-structured global industry. In this context, CSIRO has established itself as the major Australian R&D provider addressing Australian priorities, but operating on a global stage.

CSIRO's emphasis must be on the challenges and opportunities that are special to Australia. These concern our particular geological environment, our abundance of remote gas, but declining supply outlook for oil, the concentration of the industry's activities in the marine environment and its response to greenhouse gas emission targets.

In this context, CSIRO values its relationship with its industry customer base and with its global R&D network—including the Australian Geological Survey Organisation, the Australian Petroleum Production and Exploration Association and government departments, especially the Department of Science, Industry and Resources.

Planned Achievements

The research components address four over-arching objectives of the Petroleum Sector:

- Competitive prospectivity and exploration performance—Competitive finding costs and the addition/replacement of reserves are pre-requisites for the long-term performance of the industry (Component 1).
- Competitive financial performance of the industry through technology. With a flat price outlook, there is a focus on the cost side, especially increasing returns from drilling and offshore facilities (Components 2, 3, 4 and 9).
- The sustainability of the environment. The emphasis is on the marine environment and greenhouse gas emissions (Components 7 and 8).
- Maximum value to Australia from its oil and gas

resources. The emphasis is on increasing the fraction of total oil in place that can be economically recovered and on capturing greater value from Australia's large gas resources (Components 2, 5 and 6).

1. Increasing exploration success
Outcomes: Increased reserves and exploration success rate, above the present one well in six, leading to increased national oil self-sufficiency.

Outputs: Technologies for industry that: enable better quantification of Australia's petroleum systems (source, generation, charge dynamics and migration); predict sand-body (reservoir) distribution and reservoir properties for Australian depositional systems; overcome the scattering of seismic energy by thick carbonates; and improve ability to appraise the integrity of fault seals

2. Field appraisal and development
Outcomes: Increased efficiency of field development. Increased resource recovery. Reduced time from discovery to production, especially oil.

Outputs: Improved knowledge of reservoir geology in the Australian context and new technologies that: model reservoir facies to predict reservoir production parameters from pore to sand body scale; integrate different sources and scales of data (geology, seismic and well-log data) to build a more coherent picture of reservoirs; and provide more accurate estimates of relative permeability and residual saturation.

3. Drilling performance
Outcomes: Reduction in costs of drilling, especially of long-reach wells, enabling the development of otherwise marginal fields and the increased recovery of resources.

Outputs: A suite of technologies that enable optimal management of drilling fluids, with an emphasis on technologies for extending reach drilling beyond 10 kilometres. A software platform to capture drilling data and experience and to enable fast learning and decision making. Technology that improves the capacity to look ahead of the bit, especially to recognise abnormal fluid pressures.

4. Risk and uncertainty
Outcome: Reduced technical economic and environmental risks and uncertainty in petroleum exploration and recovery operations, in complex project environments, based on improved decision-making processes.

Outputs: A generic strategic decision-making software package for petroleum sector applications. Advanced mathematical tools/theories that underpin decision-making processes. Decision-making frameworks to support. Appraisal of seal integrity and pore pressure.

5. Adding value to gas resources
Outcomes: A significant increase in the assessed value of large static gas reserves in the offshore north-west, and low-permeability eastern basins.

Outputs: Technology strategy for the development of Australian gas processing, targeted especially at the gas that is remote from market and in increasingly deeper water further from shore. Technologies for small-scale liquid natural gas production and gas processing. Technologies that enable economic production rates from low permeability sandstone and coal reservoirs.

6. CO_2 sequestration
Outcomes: Increased sequestration of CO_2 thereby reducing national greenhouse gas emissions

Outputs: Technologies that support the sequestration of CO_2 into depleted reservoirs and aquifers. Technologies to support the sequestration of CO_2 into unmineable coal seams (with the Energy Sector). A technology appraisal of the potential for sequestration into the ocean (with the Marine Sector)

7. Disposal of wastes
Outcome: Adoption by the industry of methods and technologies to assess and manage environmental impacts, thereby enabling sustainable petroleum operations in the marine environment.

Outputs: Quantification of environmental risks, establishment of acceptance criteria and monitoring frameworks (with the Marine Sector). Strategies to reduce or remediate marine environmental impact at vacated sites. New water-based drilling fluids that satisfy the criteria for marine disposal of drill cuttings. Improved technology to clean drill cuttings to within the criteria required for marine disposal.

8. Met-ocean conditions
Outcomes: Improved engineering design of offshore structures, including pipelines, based on improved predictive capability for met-ocean conditions.

Outputs: Models which improve prediction of North-west Shelf ocean currents, sediment transport and their coupling with winds. Understanding of factors affecting deep-water oceanographic currents.

9. Business development
Outcomes: Strategic alliances with the sector's major industry players and increased technology transfer.

Outputs: Structured account relationships with new key or major accounts. Increased use of CSIRO capability to support sector industries. Additional significant projects. Increased capture of R&D value through improved commercial arrangements.

Development of R&D Capacity

Development of capability in previously identified disciplines will be continued, viz commercial and business development, geophysics, mathematical modelling of geo-processes, decision making, fast learning and gas processing. CSIRO's core capability will continue to be strengthened through further development of its business and global R&D network. A major part of the strategy to build the focus of Australia's petroleum R&D capacity in Perth through CSIRO, in conjunction with universities, will be realised during the triennium with the completion of new laboratories adjacent to Curtin University.

RESOURCE SUMMARY ($'000 OVER THE TRIENNIUM)

Component	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
1. Increasing exploration success	10 227	7 368	17 878
2. Field appraisal & development	3 814	3 420	7 352
3. Drilling performance	8 841	7 977	17 141
4. Risk & uncertainty	1 691	1 076	2 832
5. Adding value to gas resources	3 001	2 346	5 414
6. CO_2 sequestration	782	579	1 383
7. Disposal of wastes	2 551	1 770	4 562
8. Met-ocean conditions	407	57	466
9. Business development	1 500	0	1 538
Grand total	**32 813**	**24 593**	**58 566**

Division	Income		Planned Expenditure**
	Direct Appropriation	R&S Revenue*	
Building Construction & Engineering	707	303	1 007
Exploration & Mining	797	570	1 367
Land & Water	536	276	827
Marine Research	577	81	661
Maths & Information Sciences	2 184	1 076	3 368
Minerals	268	272	445
Molecular Science	644	375	1 344
Petroleum Resources	27 101	21 640	49 546
Grand total	**32 813**	**24 593**	**58 566**

**External revenue for research and services.*

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SECTION THREE
The Decision Process

THE TRIENNIAL PLANNING PROCESS AND ASSESSMENT FRAMEWORK

The sector planning process was designed as a strategic dialogue involving staff, the Sector Advisory Committees and the CSIRO Executive. It was designed to encourage both a strong focus on outcomes and to foster a preparedness to think outside the box—to see where particular skills might best be deployed.

The process involved:

- a mid-term review of progress against the 1997–98 to 1999–2000 triennium plan to reflect on achievements and to see where improvements, refocusing and re-directions were required
- preparation of sector outlooks to provide the context and drivers for the new plans
- preparation of sector investment portfolios against three budget scenarios—plus 20%, steady and minus 20%—to draw out clear statements of priorities and provide options for decision by the Executive.

The sector investment portfolios together with the sector outlooks and mid-term reviews then formed the basis of discussions between the CSIRO Executive and teams representing each of the sectors and their advisory committees. These took place during the first two weeks of May 1999.

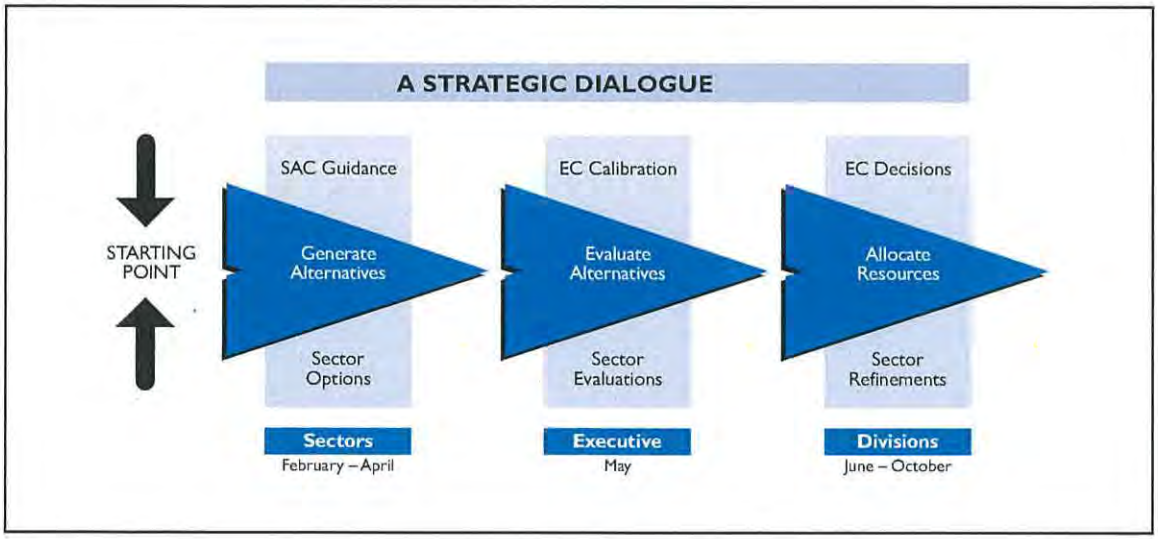
These meetings were followed by an Executive Workshop at which indicative decisions for the sector investments and external earnings targets, and consequent Divisional appropriation allocations, were made. These decisions were accompanied by a series of messages and challenges which were addressed in the final planning phase by Divisions in consultation with the Sector Advisory Committees.

Key considerations included:

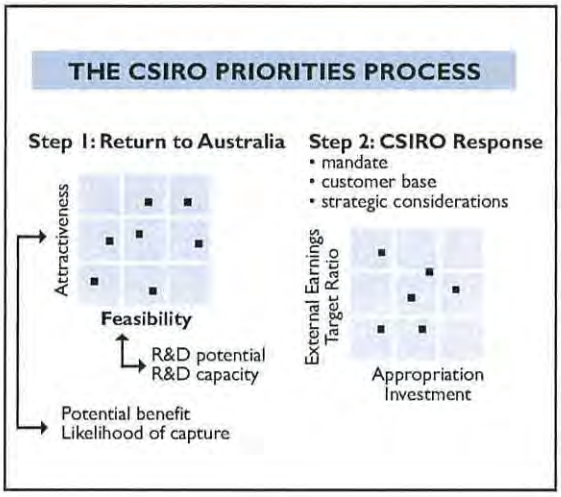
- clear definition of the industry–community–environmental issues to be addressed
- identification of strategies to ensure that scientific outputs will be adopted and their impact maximised to achieve the desired outcomes (the route-to-market adoption strategies)
- evidence of capacity to assemble the right mix of skills from within, and where appropriate from outside CSIRO, to do the science and ensure its uptake
- portfolios with a balanced mix of activities—some close to market and some far from market activities—some risky but possible high return projects as well as some where success is more assured but perhaps with a lesser return.

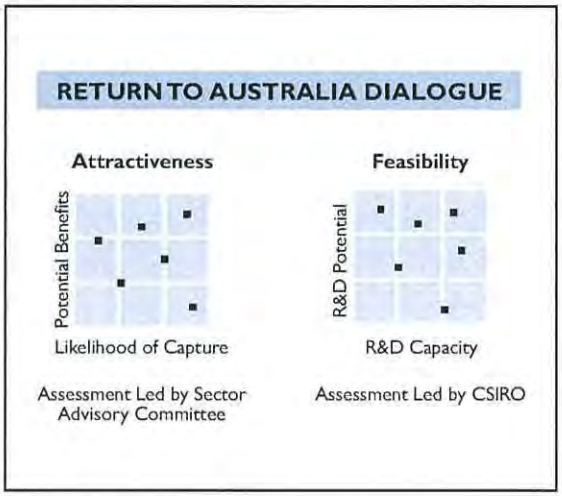
The output from this process is an overarching statement of strategic directions and major initiatives and a set of sector plans, each consisting of an executive summary and a number of component research plans, each of which addresses a key strategic issue or objective for the sector. The executive summary of each sector plan is included in section two of this CSIRO Strategic Plan.

CSIRO's investment decisions are based on a two-step process involving an assessment of the 'Return to Australia' from R&D based on attractiveness and feasibility criteria, followed by a determination of 'CSIRO's Role and Investment Strategy'. Application of the assessment criteria is neither an end in itself nor



a way of automatically deriving 'correct' resourcing for sectors. It is only a means for identifying and discussing relevant data and information in a structured and comprehensive way.





Return to Australia

'Return to Australia' reflects the relative *attractiveness* and *feasibility* of R&D for each of the strategic issues within sectors and for the sectors as a whole. Assessment is based on relative values, not absolute ones. Each sub-criterion is assessed independently; taken in any order.

Attractiveness

How and to what extent does Australia, in general, and do CSIRO's customers, in particular, benefit from relevant scientific and technical advances? This assessment is based on two sub-criteria—potential benefit and ability to (or likelihood of) capture. The second criterion is a probability function of the first so that, taken together, the two criteria provide an assessment of 'attractiveness'.

Potential benefits

What and how large are the potential economic, social and environmental benefits from successful research conducted for the sector? The size of these benefits is calculated from the estimated marginal impact of R&D, by comparing the 'with research' situation for the sector (research successfully completed and adopted) and the 'without research' prognosis.

CSIRO needs to consider:

- all possible research opportunities, not only CSIRO's traditional research activities
- that Australia conducts only 2% of global R&D and that access to, and benefits from, the remaining 98% are highly important
- the competitive impact of technology on an industry
- that reduced or avoided costs are a form of benefits.

Factors to bear in mind include:

- Size and growth of target sector: The size of potential benefits is determined significantly by the size of the target market. Benefits flow in the future, so potential benefits are influenced by future size, which can be estimated from growth trends.
- Productivity increases: R&D frequently leads to productivity increases—reduced cost of production and/or increase in quantity produced.
- Increase in exports/reduction in imports.
- Global R&D intensity: This is a pointer to the benefits of R&D for a sector, as perceived by other nations and firms.
- State of environment: This indicates benefits that could accrue from restoring degraded natural resources or protecting them from degradation.
- Impact on other sectors: Any spillover benefits or costs (such as pollution) should be added to (or subtracted from) the potential benefits for the sector.

Australia's ability to capture

What is the likelihood of Australia capturing the potential benefits? The likelihood is determined by factors such as industry structure and global competitiveness and the willingness of firms, resource agencies or individuals to take up the R&D. An understanding of the industry structure, say by vendor pyramid analysis, may be used to determine where the maximum benefits to Australia may be generated.

CSIRO needs to consider:

- who the potential research users are and how they will capture benefits (by what mechanisms?)
- local versus overseas adoption of the technology

- factors (other than R&D) necessary to realise the benefits from successful R&D, for example distribution networks and marketing skills
- public acceptance and legislative issues.

Factors to bear in mind include:

- Competitive technological position: For a particular industry this is reflected by its:
  - market share—more competitive firms have greater ability to capture benefits (one indicator is share of target markets relative to competitors)
  - industry structure—in industries with many small firms each may be less able to capture R&D benefits compared to industries with more concentrated ownership
  - level of innovation in the recipient firm or area—data are available from the Australian Bureau of Statistics on levels of innovative activities in various sectors of the economy
  - Australia's R&D effort—R&D intensity (the ratio of gross R&D expenditure to the value of production or sales) indicates receptiveness to R&D; size of R&D effort by firms indicates the degree of technical competence.
- Customer type: Different customers, for example public (government, agencies), private (small to medium enterprises, large enterprises), and rural industry corporations, have different sorts of scientific and technological requirements.
- Export or import intensity: High ratios of exports to production or low ratios of imports to production help indicate competitiveness (but may reflect high levels of protection or assistance).
- Uniqueness of problem to Australia: This is attributable, most often, to environmental or natural resource problems.
- Existence of supporting government policy for the sector: The ability to capture may be higher in sectors which have targeted support.
- Public good research: Spillover of benefits to overseas users doesn't reduce benefits to Australian users, so ability to capture is high.

Feasibility

How feasible is it for CSIRO and its partners to achieve the scientific and technical progress that the sector requires? This assessment is also based on two sub-criteria—R&D potential and R&D capacity. The second criterion is again a probability function of the first, so that the two criteria, taken together, provide an assessment of 'feasibility'.

R&D potential

What overall rate of progress in scientific understanding and technologies is likely for the research considered in identifying the potential benefits? Where is current technology on the S-curve the 'technological maturity'? Is technical progress rapid, moderate or slow?

Factors to bear in mind include:

- Excitement and enthusiasm in the research community: The appearance of new, international conferences in particular fields is one sign.
- Patents and publications: The numbers and trends in relevant fields of science and technology.

R&D capacity

How strong is the existing capacity of CSIRO and existing, or likely, collaborators to perform the required R&D and achieve the R&D potential in a timely and competitive fashion?

Capacity should be judged relative to other research performers anywhere in the world. What is CSIRO's competitive position globally?

CSIRO needs to consider:

- what particular skills and experiences are needed
- whether nationally or internationally competitive research teams be assembled
- whether the necessary research infrastructure (that is, the equipment, buildings and other facilities) is in place
- whether CSIRO has developed a strong intellectual property position.

Factors to bear in mind include:

- Number of research groups with international standing and critical mass: This may be judged by factors including patents and publications, invitations to international conferences, invitations to participate in international research consortia etc.
- R&D expenditure: Overall magnitude of the R&D effort can be important.

CSIRO's Role and Investment Strategy

Having determined the relative attractiveness and feasibility of research for each of the strategic issues within sectors, decisions are then required on the role that CSIRO should play, in the context of other public and private sector research agencies. Account must be taken of strategic factors judged to be important for CSIRO to realise its overall mission.

Thus, an assessment is made of:

- the overall level of effort CSIRO should devote to each sector in the national context
- the desired mix of appropriation funds and external income for the sector.

This assessment is based on consideration of:

Questions of mandate

- Does CSIRO have any specific responsibilities or restrictions?
  Examples of responsibilities are measurement standards (legislated) and national facilities, while some restrictions apply to defence and clinical medical research.
- What other public sector research agencies operate in the sector? In terms of Cooperative Research Centres operating in the sector, what should CSIRO contribute?
- Are there general government policies or obligations bearing upon the level or kind of effort in CSIRO?

Customer base

- What does the nature of the customer base (that is, the users or potential users of CSIRO's research results) imply for the role of public sector R&D? Within this, what does it imply for CSIRO's role? (CSIRO must also take account of the role of other public sector research agencies.)
- The target balance between contract research (with transfer of intellectual property) and collaborative research (with shared costs and risks and shared intellectual property). This discussion point may have particular implications for the target ratios of external funds/total funding.

Strategic considerations

CSIRO needs to consider:

- the balance between delivery to customers in the short-term and maintaining and developing expertise and the disciplinary skills base
- the balance of R&D effort between sectors required to satisfy skills base
- political and other considerations not specified above.

Indicator Data

Data on a selected set of indicators (listed below) are used to inform deliberations on the relative attractiveness of the production-based sectors. These data must be supplemented by judgments and other available indicators for the non-production-based sectors.

Potential benefits

- value added (GDP)
- value of world trade
- global R&D intensity (by turnover)
- diffusion of technical progress.

Likelihood of capture

- value of exports
- growth in exports
- Australian business R&D intensity (by value added)
- level of technological innovation in business (Australian Bureau of Statistics survey).

These and related data have been sourced from the Australian Bureau of Statistics and mapped to the CSIRO sectoral definitions. An overview of the data is shown in the preceding two tables.

ALL VALUES CONVERTED TO CURRENT YEAR PRICES, USING AN ECONOMY-WIDE DEFLATOR—$ MILLION

	Sector	Value Added		Turnover		Business Expenditure on R&D (BERD) (ANZSIC)		BERD (SEO) (Socioeconomic objective)		CSIRO R&D		Gross Expenditure on R&D (GERD)		Exports (SITC)		Imports (SITC)		Net Trade (Exports - Imports)		Employment in ,000	
		1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97
AGRIBUSINESS	Field Crops	4 871	7 333	8 709	13 191	0.2	0.2	15.7	18.6	55.3	59.5	240.3	256.1	4 929	8 699	463	367	4465	8333	129	136
	Food Processing	12 934	13 847	47 069	50 446	149.4	239.3	119.0	224.0	19.2	21.9	155.9	263.4	3 222	3 837	2 445	2 645	777	1192	175	172
	Forestry, Wood & Paper Industries	3 682	3 906	8 965	9 517	71.0	180.4	74.2	171.6	33.8	33.2	145.0	256.7	1 026	1 109	2 908	2 617	-1882	-1508	66	59
	Horticulture	3 026	4 088	5 809	7 558	8.4	10.9	12.7	11.0	19.0	15.1	107.7	119.9	1008	1 537	286	328	722	1209	78	85
	Meat, Dairy & Aquaculture	5 035	6 824	10 385	14 067	6.3	6.9	41.5	31.4	72.9	70.3	253.4	265.2	5 328	4 840	863	932	4466	3908	148	159
	Textiles, Clothing & Footwear	3 828	4 749	10 523	12 617	22.2	19.9	38.2	36.0	61.1	55.8	158.0	150.4	5 724	5 475	4 473	4 663	1252	812	140	145
IT IS	Built Environment	77 274	84 719	148 270	162 830	265.1	210.2	113.3	245.0	45.6	42.3	249.3	388.0	6 690	7 408	8 961	9 133	-2271	-1725	1210	1206
	IT & Telecommunications	36 706	43 716	65 328	76 617	786.8	904.8	915.6	951.8	43.1	35.6	1142.5	1188.7	3 723	4 369	12 226	12 802	-8503	-8434	452	490
	Services	212 070	235 427	388 457	429 339	429.5	388.8	68.3	117.8	2.9	3.0	411.8	538.6	13 082	16 097	11 384	12 954	1698	3143	5058	5288
MANUF	Chemicals & Plastics	4 563	5 002	13 709	15 019	180.1	168.8	143.8	143.8	14.8	17.3	178.5	175.3	2 093	2 276	8 249	8 741	-6156	-6464	89	90
	Integrated Manufactured Products	23 621	25 854	64 553	70 245	953.5	1 093.9	814.9	859.6	64.5	65.5	1012.9	1091.1	10 226	13 101	37 646	39 134	-27420	-26033	420	433
	Pharmaceuticals & Human Health	786	886	2 471	2 784	184.2	202.0	186.8	242.4	33.0	31.4	810.8	950.0	725	915	827	903	-103	12	14	14
M&E	Energy	9 131	10 303	12 999	14 779	92.3	125.3	163.4	181.4	17.0	24.7	205.6	234.1	6 927	8 009	253	282	6675	7727	44	39
	Mineral Exploration & Mining	4 195	4 887	8 686	10 295	118.3	259.9	110.9	255.1	39.8	35.8	192.2	348.6	2 286	2 621	145	140	2141	2481	33	34
	Mineral Processing & Metal Production	5 787	6 686	15 392	17 308	179.1	242.8	348.6	451.3	35.4	38.0	395.3	506.9	14 880	15 937	1 423	1 236	13457	14701	45	46
	Petroleum	8 122	8 662	16 335	17 386	50.9	55.7	59.3	85.9	8.8	12.2	100.5	171.0	4 308	5 707	3 635	5 146	673	561	16	17
	Marine Fishing	525	481	1 288	1 237															9	8
	Excluded Trade Items													886	1 134	59	80	827	1055		
	Other	45 617	50 439	61 809	68 342			156.9	97.3	116.5	131.2	1561.3	1789.0								
	Total	**461 774**	**517 810**	**890 758**	**993 574**	**3 497**	**4 110**	**3 226**	**4 027**	**683**	**693**	**7 321**	**8 693**	**87 063**	**103 071**	**96 246**	**102 102**	**-9 183**	**969**	**8 127**	**8 420**

For Value Added and Turnover, 'Other' refers to ownership of dwellings.

For R&D 'Other' refers to the non-production based sectors such as the environment ones and advancement of knowledge.

Note that trade data is by SITC (Standard International Trade Classification), a commodity-based classification, and not by ANZSIC (Australia New Zealand Standard Industry Classification—as commonly used by industry) which is an establishment-based classification.

	Sector	BERD (ANZSIC) Intensity by Value Added		BERD (ANZSIC) Intensity by Turnover		BERD (SEO) Intensity by Value Added		BERD (SEO) Intensity by Turnover		CSIRO R&D Intensity (Value Added)		GERD Intensity (Value Added)		Export Propensity (Exports (SITC)/ Turnover)		Import Penetration (Imports (SITC) Turnover)		Turnover ($ million)/ Thousand Employees	
		1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97	1994-95	1996-97
AGRIBUSINESS	Field Crops	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.2%	0.1%	1.1%	0.8%	4.9%	3.5%	57%	66%	5%	3%	68	97
	Food Processing	1.2%	1.7%	0.3%	0.5%	0.9%	1.6%	0.3%	0.4%	0.1%	0.2%	1.2%	1.9%	7%	8%	5%	5%	269	294
	Forestry, Wood & Paper Industries	1.9%	4.6%	0.8%	1.9%	2.0%	4.4%	0.8%	1.8%	0.9%	0.8%	3.9%	6.6%	11%	12%	32%	28%	135	162
	Horticulture	0.3%	0.3%	0.1%	0.1%	0.4%	0.3%	0.2%	0.1%	0.6%	0.4%	3.6%	2.9%	17%	20%	5%	4%	74	89
	Meat, Dairy & Aquaculture	0.1%	0.1%	0.1%	0.0%	0.8%	0.5%	0.4%	0.2%	1.4%	1.0%	5.0%	3.9%	51%	34%	8%	7%	70	89
	Textiles, Clothing & Footwear	0.6%	0.4%	0.2%	0.2%	1.0%	0.8%	0.4%	0.3%	1.6%	1.2%	4.1%	3.2%	54%	43%	43%	37%	75	87
IT IS	Built Environment	0.3%	0.2%	0.2%	0.1%	0.1%	0.3%	0.1%	0.2%	0.1%	0.0%	0.3%	0.5%	5%	5%	6%	6%	123	135
	IT & Telecommunications	2.1%	2.1%	1.2%	1.2%	2.5%	2.2%	1.4%	1.2%	0.1%	0.1%	3.1%	2.7%	6%	6%	19%	17%	145	156
	Services	0.2%	0.2%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%	3%	4%	3%	3%	77	81
MANUF	Chemicals & Plastics	3.9%	3.4%	1.3%	1.1%	3.2%	2.9%	1.0%	1.0%	0.3%	0.3%	3.9%	3.5%	15%	15%	60%	58%	154	168
	Integrated Manufactured Products	4.0%	4.2%	1.5%	1.6%	3.4%	3.3%	1.3%	1.2%	0.3%	0.3%	4.3%	4.2%	16%	19%	58%	56%	154	162
	Pharmaceuticals & Human Health	23.4%	22.8%	7.5%	7.3%	23.8%	27.4%	7.6%	8.7%	4.2%	3.5%	103%	107%	29%	33%	33%	32%	174	194
M&E	Energy	1.0%	1.2%	0.7%	0.8%	1.8%	1.8%	1.3%	1.2%	0.2%	0.2%	2.3%	2.3%	53%	54%	2%	2%	297	380
	Mineral Exploration & Mining	2.8%	5.3%	1.4%	2.5%	2.6%	5.2%	1.3%	2.5%	0.9%	0.7%	4.6%	7.1%	26%	25%	2%	1%	265	305
	Mineral Processing & Metal Production	3.1%	3.6%	1.2%	1.4%	6.0%	6.8%	2.3%	2.6%	0.6%	0.6%	6.8%	7.6%	97%	92%	9%	7%	343	373
	Petroleum	0.6%	0.6%	0.3%	0.3%	0.7%	1.0%	0.4%	0.5%	0.1%	0.1%	1.2%	2.0%	26%	33%	22%	30%	1005	1025

Note that for the Pharmaceuticals and Human Health Sector, only the production of pharmaceuticals and some devices are concorded (hospitals and medical services etc are concorded to the Service Sector), while the R&D data for the Pharmaceuticals and Human Health Sector includes all medical R&D except Health and Support Services. Hence the GERD Intensity ratio is large because GERD includes medical R&D carried out in hospitals.

Most other publications calculate these ratios using trade data by ANZSIC rather than by SITC. ANZSIC-based trade yields higher values for manufacturing sectors. For example, the corresponding ratio for food processing by ANZSIC is 24% in 1994–95.

CSIRO OPERATIONS AND REPORTING Acting Chief Executive – Dr Colin Adam

CSIRO

Deputy Chief Executives / DIVISIONS	ALLIANCES and SECTORS: Agribusiness						Environment & Natural Resources				Information, Manufacturing & Service Industries								Minerals & Energy			
	Field Crops	Food Processing	Forestry, Wood & Paper Industries	Horticulture	Meat, Dairy & Aquaculture	Textiles, Clothing & Footwear	Biodiversity	Climate & Atmosphere	Land & Water	Marine	Built Environment	Chemicals & Plastics	Information Technology & Telecommunications	Integrated Manufactured Products	Measurement Standards	Pharmaceuticals & Human Health	Radio Astronomy	Services	Energy	Mineral Exploration & Mining	Mineral Processing & Metal Production	Petroleum
Dr Chris Mallett																						
Animal Health		●			●	●																
Animal Production					●	●	○	●		○						○						
Food Science Australia	●	●		●	●							●										
Plant Industry	●	●	●	●	●	●	●	●														
Textile & Fibre Technology						●																
Tropical Agriculture	●				●		●	●	●	●												
Dr Paul Wellings																						
Atmospheric Research								●											○			
Entomology	●		●	●	●	●	●	●	○		●	●				●						
Forestry & Forest Products		●					●	●	●		●								●			
Land & Water	●			●	●		●	●	●		●								●	●	●	○
Marine Research					●		●	●		●						●					○	○
Wildlife & Ecology	●		●		●	●	●	●	●	○								○	○	○		
Dr Ron Sandland																						
Australia Telescope National Facility																	●					
Health Sciences and Nutrition	●	●			●											●						
Manufacturing Science & Technology											●	●		●				●	●	●	●	
Mathematical & Information Sciences	○	●	●	○	●	○	●	●	●	●	●		●	●			○	●		●	●	●
Molecular Science											●	●				●					●	●
Telecommunications & Industrial Physics								●			●		●	●	●			●	●	●	●	
Dr Bruce Hobbs																						
Building Construction & Engineering							○	●	○		●	●	●								●	●
Energy Technology								●	●	●									●	○	●	
Exploration & Mining																			●	●		●
Minerals																			●		●	○
Petroleum Resources																			●			●

• *and* ○ *indicate sectors to which a Division plans to contribute during the triennium. An open circle indicates a contribution of less than $300 000 per annum.*

SOME SPECIAL ACHIEVEMENTS

In the 1997–2000 triennium, CSIRO invested $23 million of corporate funds, supplemented by Divisional and external support, in eight special projects selected by the Chief Executive to showcase CSIRO's impressive scientific and technological skills. The ability to create excitement, impact and profile were key criteria in the selection process.

The results from this initiative have been impressive, both in overall terms and from the specific project outcomes.

- The substantive funding has resulted in focused effort with excellent progress being made on many fronts and footholds gained in several 'big' science areas.
- Several new networks have been developed which operate well across Divisions and sectors and which have assisted other projects.
- The projects have generated excitement within the teams and this excitement has diffused to other parts of the Divisions involved.

The projects, their overall aims and a selection of achievements were:

Towards sustainable energy—to demonstrate a solar thermal-fossil energy hybrid concept for generating electricity with high efficiency and with potential for greatly reduced CO_2 emissions.

- A facility, designed to generate 10-30 kW of electricity, has been constructed and will be operated in 2000–01 to demonstrate 'proof-of-concept' of all key steps of the technology.

The CSIRO low-emission vehicle project—a demonstration of CSIRO technological capability that is relevant to the future automobile industry, and can help Australia address the issues of greenhouse gas emissions.

- With the assistance of Holden and 80 component manufacturers, two hybrid petrol-electric vehicles (the Holden ECOmmodore and the aXcess II) have been built and are being showcased in Australia and overseas.

Advanced millimetre-wave integrated circuits—CSIRO has developed world-class Indium Phosphide millimetre-wave integrated circuits. Amplifiers at 100 and 200 GHz have exhibited the best combination of gain, noise figure and bandwidth ever reported. The world's first 100 GHz bi-directional amplifier and IC voltage controlled oscillator have been demonstrated.

- These chips will revolutionise the design of millimetre-wave radio astronomy receivers and will also enable industry to develop better imaging sensors for security, improved collision detection systems for intelligent transport networks, and new ultra-wide-band systems for delivery of wide-band telecommunications services.

Functional genomics—to maintain Australia's front-running position in providing high quality agricultural products by developing our capabilities in the science of genomics and to participate in international genome projects in plants and animals in order to gain access to data generated by overseas laboratories.

- International positioning of each of the participating groups in the fast evolving area of genomics was achieved through the establishment of EST sequence databases (6 000–12 000 sequences) from tissues that are central to quality traits, and the design of new DNA vectors for creating mutations using transposable elements. Well-defined intellectual property positions for genes that determine key features of product quality and productivity of agronomically important plants and animals have been established.

Bioactive molecules—an initiative to combine new chemistry with new biology with CSIRO's diverse biota collections for the discovery, design and development of biologically active compounds for the pharmaceutical, agrichemical and food industries.

- The initiative established a network across six Divisions that generated intellectual property in the fields of cardiovascular disease, new antibiotics and control agents for crop pests. Integration with the Bioinformatics Initiative enabled the mining of the 'big science' international genomics databases. This,

combined with in-house pharmacology and molecular biology, has enabled the discovery of a class of ligand-gated ion-channels, whose presence in invertebrates had previously been discounted, and the identification of novel molecular target sites in bacteria. These present commercial opportunities in anthelminthic, insecticidal and antibiotic development. As a result CSIRO has developed early leads in drug and agrochemical discovery. CSIRO's future in discovery research depends on the marriage of bench and *in silico* science.

Bioinformatics—to provide access to databases of genomic and biodiversity information allowing rapid integration of information at many levels of biological organisation as well as improved data analysis and visualisation tools. This will improve the efficiency of the discovery process by enhancing software performance and tools for cross-organisational collaboration. This innovation in informatics will develop specific applications in partnership with biotechnology, biomedical and environmental sectors.

- Biodiversity Information Management System, BioLink®, developed and adopted internationally. A national network of informatics consortia created, leading to development of a seventh round CRC for Bioinformatics proposal.

Novel technologies for preventing the establishment of feral populations of exotic animals—to develop new methods that allow animals to be bred in captivity, but renders them infertile in the wild, by allowing reversible control over fertility and reproduction. The technology aims to provide a containment mechanism for genetically modified or exotic organisms and thus prevent genetic pollution and the establishment of new feral populations. It could also provide protection for investments in breeding stocks.

- Patent application has been lodged and further ideas have been developed that may lead to similar technology for the management of some pest populations.

Urban water program—leading to opportunities to improve the sustainability of urban water systems and to reduce their costs.

- The feasibility stage of this program has revealed means by which system costs can be reduced by as much as 50% and environmental impact of system operation significantly reduced. Investment in these concepts is now being contemplated by Australian and international organisations.

The heartlands project—to work with communities in the Murray-Darling Basin to design landscape reconstruction, implement it experimentally, and manage adaptively on the basis of the effects during the subsequent decades. This will allow for emergent policy options to be analysed; and will provide land managers and policy makers with strategies to address land and water degradation, loss of biodiversity, and a declining production base in the basin based on re-vegetation and land management.

- A consortium of key agencies has been formed and two-thirds of the financial commitments required have been confirmed.

OUR PURPOSE

We serve the Australian community through outcomes which provide:

Benefit to Australia's industry and economy

Environmental benefit to Australia

Social benefit to Australians

Support to Australia's national and international objectives

Through excellence in science and technology, and in the provision of advice and services.