Questions for consideration

Introduction

CSIRO is pleased to provide the following submission to the Forest Industry Advisory Council's inquiry into strategic directions for the forest industry.

CSIRO supports one of the largest and broadest forestry research groups in Australia and is ranked highly for science and industrial impact internationally. In partnership with government, industry and communities, we apply skills in forestry, materials science and environmental management to address national challenges of sustainability and economic development. We also use our forest science skills to play a significant role in Australia's efforts to support development in countries in Asia, Pacifica and Africa.

This submission draws from CSIRO's expertise in forest science nationally and internationally, in:

- Productivity improvement
- Sustainable forest management and risk evaluation
- Fire behaviour and suppression science
- Landscape impacts (e.g water) and modelling
- Forest ecology
- Carbon flows and accounting
- Adaptation to climate change impacts
- Social and economic evaluation

In this submission, we provide a short commentary around quantifying and servicing future demand for forest resources; drivers and barriers to achieving this; and the role of and need for research and development to support the forest industry into the future (issues 1 – 4), and would welcome an opportunity to expand on any further matters if requested. We have not addressed questions outside CSIRO's remit as the independent National Science Agency.

Vision and objectives

1. What should the vision be for the forest products sector in the coming decades?

A contemporary vision for the Australian forest products sector could articulate values including:

- sustainability as an underpinning principle for forest management;
- the critical role of forests in providing forest products and environmental services;
- opportunities for the integration of multiple landscape functions (e.g. food and fibre production; climate change mitigation);
- proven opportunities for using forests for regional economic development and social well being and;
- the imperative of promoting competitiveness and profitability in a global market through continuous and judicious applications of advances in science, technologies and innovation.

2. What specific objectives should underpin this vision?

Nil response

Issue 1: Market trends and pressures

3. What forest products does Australia have a local and/or international competitive advantage in producing?

4. What is the potential demand for forest products in the coming decades?

Wood is renewable, recyclable and has a low carbon footprint. It can be grown in environmentally sustainable ways in managed forests. Thus it offers unique opportunities to mitigate greenhouse gas emission and underpin regional economic growth. Yet these values are often poorly articulated by the industry. Clearly establishing and communicating these links could contribute to increasing demand for forest products in Australia.

There is evidence that wood production, processing and marketing can help to alleviate poverty in rural areas in several developing countries (e.g. Bhaskar et. al. 2015). These nations also are aiming to increase per capita wood consumption. The scope is enormous for substantial increases in wood use (especially high quality new engineered wood products) for housing construction in countries such as India, China and emerging nations of Africa. Australia has large scale and expanding trade engagement with these and other countries, providing a vehicle to promote demand for Australia's wood products.

5. How can Australia best position itself for this demand, both nationally and internationally?

The last decade has been difficult for the Australian forestry sector, with many ownership changes and investment models, and some failures which adversely affected community perceptions and trust (Semple 2013). It could benefit the sector to move forward, refocus and embrace emerging opportunities at home and in the fast growing economies of the Asia-Pacific region. CSIRO suggests issues to consider include:

Re-focus on resource supply, resource security and efficiency. Growth in forest products places pressure on the forest sector to produce more from the current forest estate, despite increasing challenges from climate variability and change, and ongoing issues of maintaining long-term productivity. Ensuring resource supply and security is critical to meet increasing demand, and we are concerned that the sector may not be well prepared to address these challenges.

Build community support and confidence. Dialogue with the community about the environmental and societal values of wood products, and seeking to accommodate a range of values in its activities could assist the sector to establish a social licence to operate. Science can inform this dialogue through, for example, exploration of opportunities and impacts of different decisions such as intensification of management, land use change or the flow-ons from policy and regulatory change.

Research and development have a critical role to play. All the nations which are now in the forefront of the forestry and forest products sector (e.g. Chile, Finland, New Zealand) invest much more than Australia in forestry research and development, with a shift to low-risk short term applied research and development

rather than projects with potentially wider benefits but higher risk (Turner and Lambert 2011). Australian industry expenditure in business R&D declined from 1.6% to 0.8% of total business expenditure between 2005 – 2008 (Kile et al. 2014). Research and development could be front and centre for the Australian industry, creating opportunities for innovation and providing support for the development of new and emerging products, as well as ongoing support for management and expansion of the forestry estate in a sustainable way. An important role for R&D is to provide examples and scenarios to support an informed debate with society about the implications and consequences of changes and expansion of the forest industry.

What are the other drivers or disruptions that will potentially affect supply and/or demand?

Global population growth is driving demand for food and wood products. All indications are that the global population will continue to increase and in many parts of the world feeding that population will remain a political priority. Investment in increasing resource use efficiency, could achieve high production per unit area in a potentially shrinking land base. While it is certain that Australian and global population will increase in the following decades, no such certainties can be assumed for the rate of economic growth. This can be disruptive for a sector which needs to attract long term investment.

Maintaining a social licence to operate. The relatively low contribution of forestry to GDP (0.5%, ABARES 2014), the highly urbanised nature of our population (90% of Australians live in urban centres, ABS 2013), and real or perceived environmental impacts of forestry activities, may adversely affect the area over which forestry is accepted by the broader community. Additional community concerns about pollution have already galvanised strong community action against the development of processing plants, for example. Science cannot solve these problems, but can provide an independent assessment of impacts and trade-offs that can be used within the decision making process. For this to be credible, forestry science needs to be aligned to the broader public interest and not beholden to vested interests. .

Biophysical disruptions may have significant impacts on supply of wood and forest products. For example:

- *Climate variability* and change *will likely affect tree survival, productivity and the range and quality of wood products.* A recent analysis suggests that climate variability is likely to disrupt Australia's plantation forests through (1) rendering some areas of the current estate unsuitable for plantations because of the high probability of failure due to drought and high temperatures, meaning the current plantation estate is likely to contract; (2) reducing growth of other parts of the estate so that management adaptation may be required; and (3) increasing wood density associated with a drying environment (Pinkard et al. 2014). Much of Australia's resource already sits at the high end of densities acceptable for engineered wood products, so such changes may affect supply for some products.
- *Pests can impart major damage to our forests.* Pest outbreaks globally have caused major disruptions to native and planted forests. Historically in Australia, pests have reduced survival and production in the softwood estate, for example, Sirex wood wasp and Monterey pine beetle. Attempts to expand the eucalypt plantation estate into southern Queensland were largely abandoned due to difficulties in controlling pest outbreaks. While most pests can be managed to some degree and often quite successfully through control programs, such programs are expensive to administer, and the economic justification requires an effective monitoring program and ongoing research and development.
- *Increasing fire frequency will affect resource security and operational windows.* Large, devastating fires have become an increasing phenomenon in Australia over the past decade, with significant

environmental, economic and social impacts, including to native forests and plantations. Large catastrophic fires are expected to continue as a feature of the Australian landscape, as a result of changing climate, landuse and management practices (Cheney 2008; Matthews et al. 2012). Operational windows for prescribed burning are predicted to reduce in length as a result of climate change and community preference.

Our capacity to respond to biophysical threats has diminished drastically. Recent substantial declines due ti decreasing industry and government investment, in research, development and management capability in areas including forest health, fire behaviour and ecosystem management, are risks to our capacity to plan for and respond to pest outbreaks and biosecurity incursions; monitor and manage the impacts of climate variability on production; and manage fire hazard and impacts. For example, biosecurity measures have proven ineffective against potentially catastrophic (for the forest industry) recent pest incursions such as Myrtle rust.

Issue 2: Emerging uses and markets

6. Which emerging forest products have the greatest potential for Australia?

Research suggests there are a number of prospective forest products for Australia, many of which revolve around biomaterials. Many existing biomaterials are based on starch and/or sugar, often derived from corn, which creates potential impacts on food security and prices. There is significant potential for forest products to be used as biomaterial feedstocks, from plantations on land of low agricultural suitability, or from trees that are integrated into broader agricultural landscapes (e.g. Goss et al. 2014; Mendham et al. 2015). Examples include:

Bio-derived polyethylene terephthalate (PET). Rapidly growing interest in bio-derived PET has led to a global technology race to produce its precursors from renewable feedstocks. *Pinus* and *Eucalyptus* species contain target chemicals for PET production. There has been little study in Australia of the potential of our forests as a feedstock for PET. Issues of yield, economies of scale and sustainable production all need to be addressed in any assessment.

Jet fuels. The global aviation industry has in recent years agreed to ambitious goals for carbon emissions reduction and development of alternative, sustainable fuels generated from biomass. Recent studies have assessed the environmental, social and economic sustainability of conversion of mallee biomass to jet fuel. There is potential to produce high volumes of target chemicals from mallee feedstock, without detrimentally depleting surface or groundwater resources (Goss et al. 2014; Mendham et al. 2015). Chemical yield from mallee may be substantially increased through genetic improvement. In an alternative system, the cost of producing jet fuels from a mix of native grass, regenerating woody vegetation and short rotation plantations was found to be within the range of projected 2035 conventional jet fuel prices (Hayward et al. 2014).

Biochar. Biochar is the charred by-product of biomass pyrolysis. It is a highly stable form of carbon and as such can be applied to the soil to sequester atmospheric CO_2 (Singh et al. 2014). It may also have agronomic benefits, although studies show a range of responses from significant positive benefit to adverse effects, reflecting the complexity of biophysical interactions and processes that occur when biochar is applied to the soil. The chemical and physical properties of biochar are greatly affected by choice of feedstock, and this currently is poorly understood. Economically, the value of products such as biochar will be determined by carbon markets, availability of alternative low emission and carbon sequestration technologies, and global policy responses to climate change. The growing cost of waste disposal may make

biochar more economically feasible for energy production. The certification of biochar under the Clean Development mechanism of the Kyoto Protocol may improve economic viability.

Carbon. Whilst not strictly a product in the traditional sense, the management of forests to achieve greenhouse gas benefits is becoming increasingly important. The potential to generate carbon benefits from a subset of forest management activities is already embedded within the Australian Government's Emissions Reduction Fund (ERF) legislation, including the establishment of environmental plantings on cleared land, planting trees for farm forestry, and obtaining credits for avoided deforestation and avoided clearing. For example in the first ERF auction in April 2015 a total abatement of 47 million tonnes of CO_2-e was purchased by the government, of which over half (28 million tonnes) were awarded to forest management; primarily forest protection projects. At an average price of $13.95 per tonne this represents a significant investment.

There are additional forest management activities that could yield greenhouse gas benefits and thus could potentially be included in the ERF in the future. These include commercial plantation management, and improving the carbon balance of native forest harvesting activities. For both plantation and native forest management there is benefit in a more complete description of the system than is traditionally adopted, that includes not only the forest but also sequestration in the harvested wood products and landfill, any use of residues for bioenergy, and the substitution benefits of timber products over alternatives.

7. What are some of the barriers to the development and/or uptake of these emerging forest products in Australia?

Slow adoption of research. Australia has a track record of innovation in forestry research. However there is evidence that adoption rates are slow, meaning that the industry has not capitalised well on research and tools that are already available to it. One of the reasons for slow adoption may be lack of capability to take research results and apply them within the business (Kile et al. 2014). Current dependence of the industry on production of low value commodities may contribute to a reluctance to invest in the application of research outcomes. Slow adoption rates are likely to be a barrier to the development and uptake of emerging forest products.

Local capacity to adapt emerging technologies. Adapting new technologies to local conditions and markets requires in-country capacity to both assimilate and adapt knowledge and foster adoption of new technologies. Our long term experience with the sector clearly show that CSIRO's capacity and effectiveness in assisting the sector is greatly enhanced when our partners also have meaningful R&D skills that allow them to be creative and interactive partners.

Understanding the constraints in developing new products at scale. Experience in biofuels and biochemical products research within CSIRO has highlighted key questions around (1) the capacity of the current resource to service new products in terms of quantity and quality/properties, and the capacity of the sector to upscale the resource if required; (2) the scale of production required to make emerging industries viable and how this matches the potential resource supply; and (3) the scope to utilise mixed feedstocks to meet supply requirements. A recent workshop highlighted that assessment of the potential of the current resource to supply emerging industries in an environmentally sustainable way may contribute to overcoming this barrier to investment in emerging forest products (Hansen et al. 2015).

Long term sustainability requires a holistic and integrated approach. Post harvest forest residues (slash and litter) can be a source of biomass for energy production and a range of bioproducts. There is unequivocal evidence that depletion of such resources would lead to decline in productivity in plantations (e.g. Carlyle et al. 1998; Mendham et al 2014). One option might be to grow plantations dedicated to bioenergy where risks can be evaluated and remedied. Similarly, there are conflicting views about the desirability utilising wood residues from native forests where wood harvest is permitted, although it is likely that under certain ecological conditions removal of certain classes of wood reside for energy production may be environmentally feasible.

Loss of vertical integration. There has been near complete loss of vertical integration in the forestry sector in Australia, such that wood production and wood processing are not always run as complementary pursuits with regional or national goals (Kile et al. 2014).

8. What opportunities exist to better utilise wood resources?

Nil response

Issue 3: Forest resources

9. What is required to ensure the plantation estate is able to meet future demand for forest products?

Domestic wood supply in Australia is predominantly sourced from plantation forests. Future growth of the sector is likely to remain largely dependent on plantation-grown wood. Key issues revolve around the capacity of the current estate to supply and meet an increased demand for forest products, which we suggest is limited due to relatively low productivity rates, issues such as multi-rotation productivity decline, and the projected impacts of climate change and variability. We suggest that addressing the following issues could be advantageous.

Resource supply

Increase yield from the current plantation estate. A key issue to be addressed is the capacity to maintain or improve resource supply through increased production of the current estate. The area of land available for plantation forestry in Australia is limited by land competition, particularly in regions with >800 mm rainfall in southern Australia, where productivity is expected to be higher. Recent analysis of the impacts of climate change on the plantation estate suggests that the extent of the current estate suitable for growing plantations is likely to contract in the future (Pinkard et al. 2014), meaning that 'more from less' will be required to maintain or increase resource supply.

Benchmark our production against international competitors. The softwood industry in Australia has demonstrated how site selection, silviculture and genetic improvement can increase production, although productivity of these plantations is still well below the productivity of *P. radiata* plantations in New Zealand, for example (Palmer et al. 2010). Hardwood plantation production is very variable and rarely achieves more than 20 $m^3 ha^{-1} year^{-1}$ (Ferguson 2014) despite being planted primarily on highly fertile ex-pasture sites. International eucalypt growers achieve higher productivity in similar climate zones. Benchmarking against international growers would help us identify possible approaches to increase yield of Australian plantations.

Quantify the gap between potential and realized yield. Coordinated analysis of the gap between potential and realized yield, and opportunities for closing the yield gap, will help identify future issues of resource supply, and strategies for increasing yield of the current and future estate.

Address key supply issues such as multi-rotation decline. While issues of multi-rotation productivity decline in Australia have largely been solved for the pine estate, multi rotation decline is a serious issue for hardwood growers in SW Western Australia, resulting in as much as a 50% decline in productivity between first and second rotations (Battaglia et al. 2015). Thus multi-rotation decline is a significant threat to future resource supply. This is a complex problem, and will require further research to test the effectiveness of management responses.

Resource security

The challenges for achieving sustained resource security cannot be addressed by any single enterprise in isolation (unlike productivity improvements by better management) because the agents of risk (pests, fire, climate change) operate at large spatial scales. We provide the following examples of how resource security can be addressed more effectively at a range of scales.

Identify where, and to what degree, climate variability and change will affect productivity. Modelling suggests that the area of productive plantation will shrink in the future due to climate change, increasing the imperative for improving the productivity of the remaining estate. Recent research investment (Pinkard et al. 2014) has highlighted areas where plantations are unlikely to be viable in the future due to drought, fire and pest risk, and the degree to which changes in management or adaptation might modify vulnerability. Assessment of future productivity and risks requires regular review, as climate projections and understanding of key threats improve, to assist decision-making about where to invest and how to manage the estate to reduce plantation vulnerability.

Quantify pest risk through monitoring and modelling. The extent of current damage from pests, fire, drought, heatwaves and storms is poorly documented in Australia, meaning the economic impacts are difficult to quantify. There is currently no coordinated national system for monitoring the distribution and impact of key biophysical threats to resource security. There is in general poor coordination in the methods/ frequency of data collection at a regional scale, making it of limited value in addressing issues of resource security. The establishment of a national monitoring system would greatly assist in providing data for quantifying the extent of damage caused by threats, and improve our capacity to model risks and forest responses to threats.

Quantify fire risk and develop mitigation plans. With increased risk of wildfire as a result of global change (e.g. climate), quantification and mitigation of risk will be paramount to ensure economic viability of forestry activities. Because fires do not stop at ownership boundaries, and affect communities in terms of property damage, death and health issues, a landscape-level approach to risk mitigation and management would be beneficial. Research to quantify actual risks, identify cost effective mitigation options to reduce such risks to both the forest estate and its neighbours, and efficient application of such options is critical.

Minimising environmental impacts is an important element of resource security. The forestry sector would benefit from continually assessing the impacts of its operations on environmental values. This is increasingly important for gaining community support and promoting the market share of wood products.

10. What is required to ensure the native forest estate is able to meet future demand for forest products?

Many of the issues raised for plantation forests are also applicable to the native forest estate, particularly those issues involving resource security such as impacts of climate variability, pests and diseases, and the management of fire and other disturbances. There are some additional issues of particular relevance to native forestry activities.

Provision of a range of environmental services. While the net beneficiaries of plantation forestry activities are largely the owners, many of the benefits of native forests flow to those not involved in the production of forest products (e.g. water, amenity, biodiversity) for which the public is a major beneficiary. Hence there is a role for public sector support to ensure the management of native forests continues to provide this range of benefits into the future.

Integrated analysis of costs and benefits of forestry and other ecosystem services from native forests. In order for forestry activities in native forests to have a 'social licence to operate' they will have to be balanced against the need for broader ecosystem services provided by forests, such as water, biodiversity, carbon sequestration and recreational opportunities.

Research to support environmentally sustainable native forestry. The current debate surrounding native forest management in Australia has artificially polarised management for 'conservation' verses management for 'production'. Integrative analyses that simultaneously recognise the economic, social, and environmental benefits and disbenefits of the full suite of forest management options could help to de-polarise debate. This requires taking a spatially integrated view of the mix of conservation and harvesting across the total forest estate, and how forests interact with surrounding land uses such as agriculture, and surrounding communities.

11. What opportunities are there to increase wood supply from farm forestry, private native forestry and Indigenous owned and managed lands?

While there may be considerable opportunities to increase wood supply from other sources, analysis is required to match the potential for wood supply with cultural and social expectations. Monetary and non-monetary benefits and costs need to be better understood and quantified to help farmers and indigenous land managers develop a value proposition for investment.

Drivers and barriers for indigenous investment in forestry need to be assessed. While potential for broadacre commercial plantation forestry on Indigenous land may be limited due to its geographical distribution, there is considerable potential for indigenous communities to develop niche markets and products from native forests (e.g. carbon offsets, Robinson et al. 2014). Indigenous land managers already provide wood products for niche markets such as tonewood for musical instruments. There are opportunities to develop forest-based industries to build community self-reliance, such as plantations for local bioenergy production. A recent survey of opportunities for Indigenous participation in climate change mitigation strategies identified that obstacles for engagement revolve around land tenure arrangements, geographical and biophysical factors, low levels of requisite technical, human and financial resources, and appropriate recognition of indigenous knowledge and cultural responsibilities (Robinson et al. 2014). Similar barriers are likely to be relevant for indigenous engagement in forestry activities to increase wood supply.

Landscape-level analysis of the benefits and costs of farm forestry is required. While there is scope for increasing wood supply from farm forestry, there is potential conflict between food and fibre production. The capacity to resolve this conflict will be influenced by specific geography and production systems. There have been numerous studies of the potential benefits of trees on farms, in terms of improving stock survival and crop production, moderating the effects of climate change, and combating environmental degradation such as erosion and salinity. Many of these are small case studies or anecdotal, and a synthesis of benefits and costs of farm forestry could assist.

Targeting higher rainfall zones will provide greatest benefit for resource supply. Research by CSIRO suggests that:

- productivity is likely to be low in lower-rainfall (< 600 mm) zones, and properties such as density may not be ideal for current wood products (Bush et al. 2009), but may serve emerging bioproducts markets,.
- carbon farming is unlikely to be profitable until a carbon price of >$40/t CO_2-e is reached (Polglase et al. 2013). Regulations around permanence associated with carbon farming schemes currently limit flexibility in on-farm management, making them a potential barrier to broadscale adoption of carbon forestry.

Decision tools can help identify opportunities from other land bases. Existing modelling tools can help to assess the potential productivity of plantations, at either local or regional scales, irrespective of land-use or ownership. These tools can be used to identify areas where commercial forestry activities will be most profitable; potential yield and rotation lengths; harvest residues; carbon sequestration; and where trees will provide benefit in terms of improving farm productivity and sustainability. In general these models have been developed for the industrial plantation sector, and would require some modification for application for farm forestry applications. They include both more complex, research-focused models and decision support systems designed to aid land management decision-making.

Issue 4: Innovation, research and development

12. What are the future research and development needs for Australia's forest products sector, and which of these needs are specific to strengths and opportunities in the Australian context?

Innovative research and development underpins the success of the forest sector now and in the future. The Australian forest industry has benefitted from the long history of research collaboration and partnerships that underpins both plantation and native forest management. Research tailored for Australia's unique mix of old soils and large range of climates has helped provide the industry with customised management strategies. Sustaining the forest resource base and increasing production could be enhanced through, at the least, maintenance of local research capability both to provide innovative solutions and to act as a conduit for research findings from outside Australia. Assessment of key gaps in capability could form the basis of a framework to support strategically-focussed capability growth.

For the successful transfer of research findings, it is important that institutions and mechanisms allow dialogue and co-generation of research across the industry value chain and including policy, research, community and traditional or practical knowledge (e.g. from indigenous Australians, farmers and landowners). Through this collaborative generation of knowledge, innovation can occur. Excellent examples exist where such collaborations have generated significant results: the close partnership of

CSIRO and industry to address second rotation decline in the pine industry; partnerships between industry, universities and CSIRO to generate the germplasm to establish Australia's hardwood industry; partnerships between indigenous Australians, government and CSIRO to develop Indigenous Carbon Benefits criteria that are now allowing indigenous Australians to participate in carbon markets, in some cases involving afforestation.

Future research and development needs for resource supply and security include:

- Increasing productivity of the estate and reducing unit costs of production with multi-disciplinary research
- Maintaining productivity with more variable climate across both the productive and 'marginal' land base
- Further development of tools and methods for enabling decision-making to balance productivity gains, environmental outcomes and economics
- Detailed analysis of productivity trends and the development of an adaptive research platform in partnership with key stakeholders
- Capacity of the resource to support emerging products
- Development of new models of fire behaviour to enable fire prediction and management in our fast changing physical and climate environment and in response to peri-urban development and other social changes. More research is also required for developing methods for monitoring the impacts of fire management policies and strategies and effective use of technology.
- Local application of international technology for new and emerging products

13. What are the current inhibitors to private sector investment in research, development and extension and what role, if any, does the Australian Government potentially have in addressing these?

There is a poor culture of private R&D investment from the forest sector. Australia has a long history of government investment in forestry R&D. The current plantation estate was built on the back of largely government-funded research, a strategic decision by government to develop a viable domestic forest industry. Despite government incentives for R&D investment, there is not a culture of substantial private investment in forestry R&D, and this has been exacerbated by recent changes in plantation ownership and resultant changes in investment strategies. Businesses at one end of the value chain do not necessarily see the benefit of research at the other end, and there is little consultation about industry-wide R&D needs. CSIRO sees industry investment rates from forestry that are much lower than for agriculture.

The value of research is not well acknowledged by end users. The returns from research have not been well documented and promulgated, despite a number of studies showing favourable benefit/cost ratios of between 1.5 and 44 (Kile et al. 2014). This is in part a result of high industry turnover (e.g. ownership of hardwood forests in Australia turns over historically every 5 – 10 years despite a rotation being 10 –15 years), meaning that current value is based on the existing asset, land value and cost rather than future production potential. Changing national plantation ownership to one dominated by large international pension funds is unlikely to see a change in a conservative investment strategy.

14. How can the framework for coordinating Australian forestry research and development be strengthened?

We note the continual and substantial decline in research and development capability over past decades, which is likely to continue unless funding for forest research is increased. A crucial challenge is the viability

of research groups within private and public domains. We suggest some approaches for strengthening research and development capacity in the forest industry.

A coordinated national discussion of R&D needs is required. Currently there is little investment in forestry R&D, and this is a major threat to the long-term viability of Australian research capability. A coordinated participatory synthesis of R&D needs could identify priorities across the value chain and help research and development providers allocate their resources appropriately. Such a review could identify those components related to short term industry viability and benefit that would appropriately be funded largely by the private sector, and those parts that play to stewardship of national assets or help realise longer-term strategic objectives for regional development or creation of new markets, where a mixed funding model might be more appropriate.

Collaboration between research providers could be facilitated. Given the large reductions in forest R&D capability over the past 2 decades, frameworks that promote collaboration between capability providers could be considered. Forestry CRCs provided such a framework, but did not address the long-term issue of balanced research investment, and may in some instances carry substantial management overheads leading to inefficient research delivery. Alternatives to avoid the proliferation of research management infrastructure might include (1) a less engineered approach based on the existing RDC structure but with capacity to fund longer term targeted research; (2) funding of special purpose collaborations between research providers and industry beneficiaries to tackle specific issues. Research working groups have in the past provided a constructive framework, and were effective in promoting collective problem-solving and sharing of resources and data. There is currently no effective collaborative framework for coordinating R&D needs of the industry.

A national approach to R&D could be examined. There is merit in the proposal for the virtual aggregation of forestry research into a national centre.. The recently funded ARC Industrial Transformation Training Centre in Forest Value, located in Tasmania, is an excellent example, but does not address the full suite of issues necessary to sustain and drive the Australian forest products industry. To be effective, the centre would require a long term funding commitment, a national R&D focus, and research integrated across the value chain.

Foster international collaboration for national benefit. CSIRO's forest scientists have always maintained strong international collaborations to facilitate knowledge sharing and collective problem-solving. Research spill-ins from international research have always been a strong part of forestry innovation in Australia. FWPA's proposal for a more formal southern hemisphere research network may be a vehicle for coordinating international experiments of value to the Australian industry, particularly related to issues of climatic variability and environmental sustainability. .

Build pathways for research adoption. Historically most forestry companies had in-house research capability that played an essential role in the adoption of new research outcomes, but more recently this has declined considerably (Kile et al. 2014). Capacity to interpret and apply research outcomes should be included in forestry courses.

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