STIMBR

Stakeholders in Methyl Bromide Reduction Incorporated Primary Growth Partnership Programme

Final Report June 2014

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1. Executive summary

With the good work undertaken in this programme STIMBR is on track to prevent the release of methyl bromide to the atmosphere by 2020 enabling the continued export of logs, timber and horticultural products. STIMBR is now much better placed to meet this challenge now than it was when it started the PGP programme. As well as the research outputs produced within this programme it has grown its relationships and connections with industry, researchers and government agencies that will support the delivery of the tools required by Industry.

This programme was designed as a stone turning exercise to allow STIMBR and its stakeholders to identify which of the many possible tools and alternative fumigants could viably deliver solutions for the forestry and horticultural industries. Scientific research comes with no guarantees and in many instances the work undertaken within this programme has resulted in STIMBR gaining an understanding of what will not provide a solution to the challenge of preventing methyl bromide emissions. This has had the positive effect of narrowing the field and ensuring future funds will be invested to best effect.

Two things became apparent early in the programme. Firstly that there would be no single solution and secondly that a lot more work would be involved in finding solutions than was first envisaged. This resulted in two significant changes. Firstly on the back of early discoveries within the PGP programme, SCION, supported by STIMBR, was successful in securing MBIE funding to progress some of the research. Secondly the PGP programme of activity was sped up resulting in the programme being foreshortened from 5 to 2 ¾ years.

As a result, new outputs were agreed between STIMBR and MPI and achieved within the life of the programme. The STIMBR PGP programme has produced a wealth of data and a number of tools for research and industry use. The contracted achievement measures remain unchanged and so will not be achieved until after the end of the programme. STIMBR's Executive team however is confident that many will be delivered by the target date of 2016 and all will be delivered by 2020.

STIMBR recognises that while it will continue to be instrumental in outcome delivery it will not be able to deliver any of the outcomes on its own. It must do so by communicating with stakeholders. Outcome delivery will need to be undertaken by the forestry and horticulture sectors and in some instances will require the involvement of regulatory organisations to facilitate their delivery. STIMBR is aware that considerable continued effort will be required to deliver the short, medium and long term outcomes agreed with MPI and that it and researchers have a leadership and facilatory role in delivering these outcomes.

STIMBR is fully aware it must actively drive research so that the tools and technologies required by industry are delivered before the 2020 deadline. This will take a coordinated and sustained effort. STIMBR has recently developed a comprehensive five year research strategy to progress the outputs from the STIMBR PGP programme. Knowing funds will be limited STIMBR has undertaken a process to prioritise the research to ensure promising tools, that are most time constrained, are progressed first. It will work with its partners and stakeholders to identify funding sources and deliver the research.

STIMBR will make every effort to progress research in as many lines of research as possible since favourable results cannot be guaranteed. STIMBR will also continue to scan domestic and international forums for completed technologies that could be picked up by local industries to enable them to adjust to the EPA's 2020 deadline

STIMBR has identified that there are a number of risks that could prevent delivery and uptake of the necessary tools and technologies by the 2020 deadline. These risks have been mapped and will be proactively managed to ensure that New Zealand's forestry and horticultural exporters can profitably export and grow markets post 2020. When this is achieved the programmes long term goal of protecting and growing New Zealand primary produce export sector will have been delivered.

2. Overview of the PGP programme

2.1. Background

In 2010 the New Zealand EPA[1] completed a reassessment of methyl bromide approving the continued use of methyl bromide while imposing a new overall management regime which includes strengthening the tolerable exposure limits, requiring air quality monitoring and reporting, and imposing minimum buffer zones. The Authority also requires all methyl bromide fumigations to be subject to recapture by 2020.

Methyl bromide is a broad spectrum highly effective fumigant that has been used to control insect pests, nematodes and pathogens since the 1930s. It is a highly toxic, odourless gas which has ozone-depleting properties. In 2010 methyl bromide was the only proven fumigant accepted by a number of New Zealand's overseas markets for the treatment of quarantine pests on forest and horticultural products. Forestry and Horticultural exports contributed $7 billion in 2010 to the New Zealand economy and both industries had ambitious strategies to increase exports by 2020.

STIMBR[2] was formed in 2008 by stakeholders that had an interest in methyl bromide. The group provided a united voice on issues associated with methyl bromide, supported initiatives to reduce its release to the atmosphere and undertook activities to encourage a reduction in its use. On the back of limited earlier work STIMBR commissioned some research ($150,000 per annum) between 2008 and 2010 to rationalise methyl bromide use and to look for methyl bromide replacements. STIMBR funds its activity through a voluntary levy that is set annually, based on methyl bromide and phosphine use.

On the release of the EPA decision users predicted that if alternative treatments were not found, the 2020 requirement to recapture methyl bromide would have a hugely negative effect on New Zealand exports and would increase the biosecurity risks associated with a number of New Zealand's imports.

The EPA reassessment identified there were a number of potential technologies and treatments[3] that could replace methyl bromide. It was also noted that 10 years would be sufficient time for industry to identify either a replacement fumigant or develop a technology to prevent the post fumigation release of methyl bromide to the atmosphere.

STIMBR considered the EPA's reassessment document, undertook a scan of international work and identified that while there were a large number of potential solutions there were no economically viable solutions that could be guaranteed to safely and reliably replace methyl bromide or prevent its release to the atmosphere. The alternatives/ tools that did exist varied widely and STIMBR realised that simply identifying those which warranted serious development would require significant funding. Funding for such a 'stone turning' programme within the tight time frames required to deliver a solution by 2020 would be a challenge since industry already had other significant research requirements and established commitments.

A successful application to PGP in 2010 for a programme totalling $2.4 million ($1.2 million industry contribution) to undertake this exploration provided the boost required to get the work underway. It required industry to increase its levy by 40% and resulted in STIMBR employing a Research director to drive the research in a coordinated and cohesive approach.

The STIMBR-PGP programme sought to identify tools and techniques which with further development would prevent the potential negative effects of the EPA's requirements. The programme was designed to identify cost efficient solutions to:

- Enable the ongoing export of the rapidly increasing log crop to New Zealand's main log markets; China and India (total log harvest expected to rise from 29.5 million m^3 in 2009 to 35 million m^3 in 2025)

[1] EPA The Environmental Protection Authority
[2] STIMBR The stakeholders in Methyl Bromide reduction incorporated
[3] Based on information from the Methyl Bromide technical working committee which advises the ozone secretariat of the UN

- Minimise the phytosanitary risks associated with the export of produce and provide a tool that could enable export when cold disinfestation is not practicable ,
- Prevent methyl bromide emissions to the atmosphere, and
- Provide importers and MPI with tools to protect New Zealand from quarantine pests on imported products.

The research programme spread its net wide in an attempt to review areas identified by the EPA and to identify any other new areas that could provide solutions. In doing so the programme worked across five key areas:

- Maximising the efficacy and safe use of phosphine
- Assessing other alternative fumigants
- Improving fumigation safety through monitoring and modelling
- Assessing ways to reduce methyl bromide emissions
- Assessing non fumigant pathway risk management strategies.

2.2. Contracted programme

The STIMBR – PGP programme was seen as key to progress STIMBR's vision of "*enhancing market access and biosecurity clearances for goods and products while reducing the release of methyl bromide into the atmosphere and seeking the long term reduction in its use."*

In 2011 the joint research programme was contracted with an end date of 2016. Early in the programme discussion between the regulatory arm of MPI, scientists and STIMBR's newly appointed Director of research identified that a 2016 delivery would not provide sufficient time to either develop:

- Fumigant efficacy data to support any new phytosanitary treatments for renegotiation with key markets (data required by 2018), or,
- Methyl bromide recycling and / or destruction equipment to a point where it could be commercially available to fumigators.

Rescheduling of some items of research and the support of key researchers allowed the programmes completion date to be brought forward to June 2014 reducing the 5 year contract to 2¾ years. The complexity of the programme's outcomes and the early foreshortening of the programme by two years has meant that while all milestones were delivered some of the contracted achievement measures will not be delivered during the life of the contract. STIMBR's Executive team is confident that these will be delivered by 2020 and many of them will be delivered by the target date of 2016. The actual contract outline is documented in sections 2.1.1 to 2.2.3 below.

2.2.1. Programme Vision

STIMBR's vision is to protect the value of New Zealand's primary produce export sector by facilitating the development of alternative options for negotiating and meeting overseas countries' phytosanitary requirements with respect to exports of logs, sawn timber and other wood products (the sector with the highest use of methyl bromide) without reliance on methyl bromide (in full or in part). This vision will be achieved by developing new alternative options to the currently required official methyl bromide based phytosanitary treatments. This will bring benefits to all stakeholders through addressing perceived public health risks, the environmental concerns, and the economic costs currently associated with methyl bromide.

2.2.2. Outcomes

The Programme was contracted to support the achievement of the following outcomes;

- Protection of market access for existing forest produce
- Potential to grow forestry exports in situations where methyl bromide sensitivities are important
- Provision of alternative treatments for forestry and horticultural produce
- Access to a wider range of treatments to protect New Zealand's border
- Increased profitability through reduced costs of treatment

- Environmental benefits and enhanced environmental management
- Increased accountability to communities and hence lower business risk
- Provide evidence of New Zealand's commitments to following and developing best practices and to minimising environmental impact.

2.2.3. Contracted achievement measures

To support the delivery of these outcomes the programme was contracted to deliver on a number of specific and measureable outputs. These were documented as:

- By 2016 efficacy data for at least one alternative to methyl bromide will be available for MAF[4] to use in market access negotiations.
- By 2016 at least one alternative treatment to methyl bromide will be available for forestry and horticultural produce.
- By 2016 at least one alternative treatment to protect New Zealand's border will be available to treat imported products.
- By 2016 efficacy data supporting a rationalization of the treatment requirements for methyl bromide will have been made available to MAF to use in trade negotiations.
- By 2016 new tools to apply to components of the product pathway will be available to increase the pathway security for use in one forest and one horticultural product.
- By 2016 a dispersion model, revised monitoring protocols and national monitoring recording data base will be in use.

Photo 1 Counting insects to inform pathway security studies

2.3. Development of an Outcome Logic Model

Once the STIMBR PGP programme was contracted, STIMBR and MPI developed and agreed an Outcome Logic Model (OLM) for the programme (see Diagram 1). The OLM is effectively the map for outcome delivery.

The OLM was based on the programme's contract and was developed to provide a schematic representation of the activity areas that will be required to progress the findings of this programme through to beneficial outcomes for the industry and the country. All contracted work was included in the OLM but work areas were more clearly differentiated into logical activity areas. In developing the OLM, STIMBR and MPI retained the intent of the programme and its vision but agreed to change some of the wording to accommodate changes that had occurred over the life of the contract. Table 1 shows how the contracted objectives were translated to the activities and outputs documented in the OLM.

[4] Ministry of Agriculture and Forestry, now part of the Ministry for Primary Industries

Table 1 Contacted work areas relationship with OLM activities and outputs.

Contracted objectives	Work emphasis	OLM Activities and outputs
Maximising the efficacy and safe use of phosphine	Phosphine monitoring	Fumigant monitoring and modelling
	Phosphine efficacy	Phosphine and alternative fumigants
Assessing other alternative fumigants	Assessing alternative fumigants	Phosphine and alternative fumigants
Improving fumigation safety through monitoring and modelling	Methyl bromide modelling	Fumigant monitoring and modelling
	Methyl bromide use monitoring	Fumigant monitoring and modelling
Assessing ways to reduce methyl bromide emissions	Methyl bromide destruction Methyl bromide recycling	Reduce methyl bromide emissions
Assessing non fumigant pathway risk management strategies	Pathway strategies	Non fumigant risk management
	Joule heating	Non fumigant risk management
Intellectual support	Intellectual support	Intellectual support

Building on the programmes activities and outputs the OLM clearly documents the necessary relationships that must be developed between resources, activities, outputs and outcomes of the programme. It provides a common language for all those involved in progressing the programmes outcomes. As such the OLM will act as the basis for post programme evaluation and monitoring of outcome delivery.

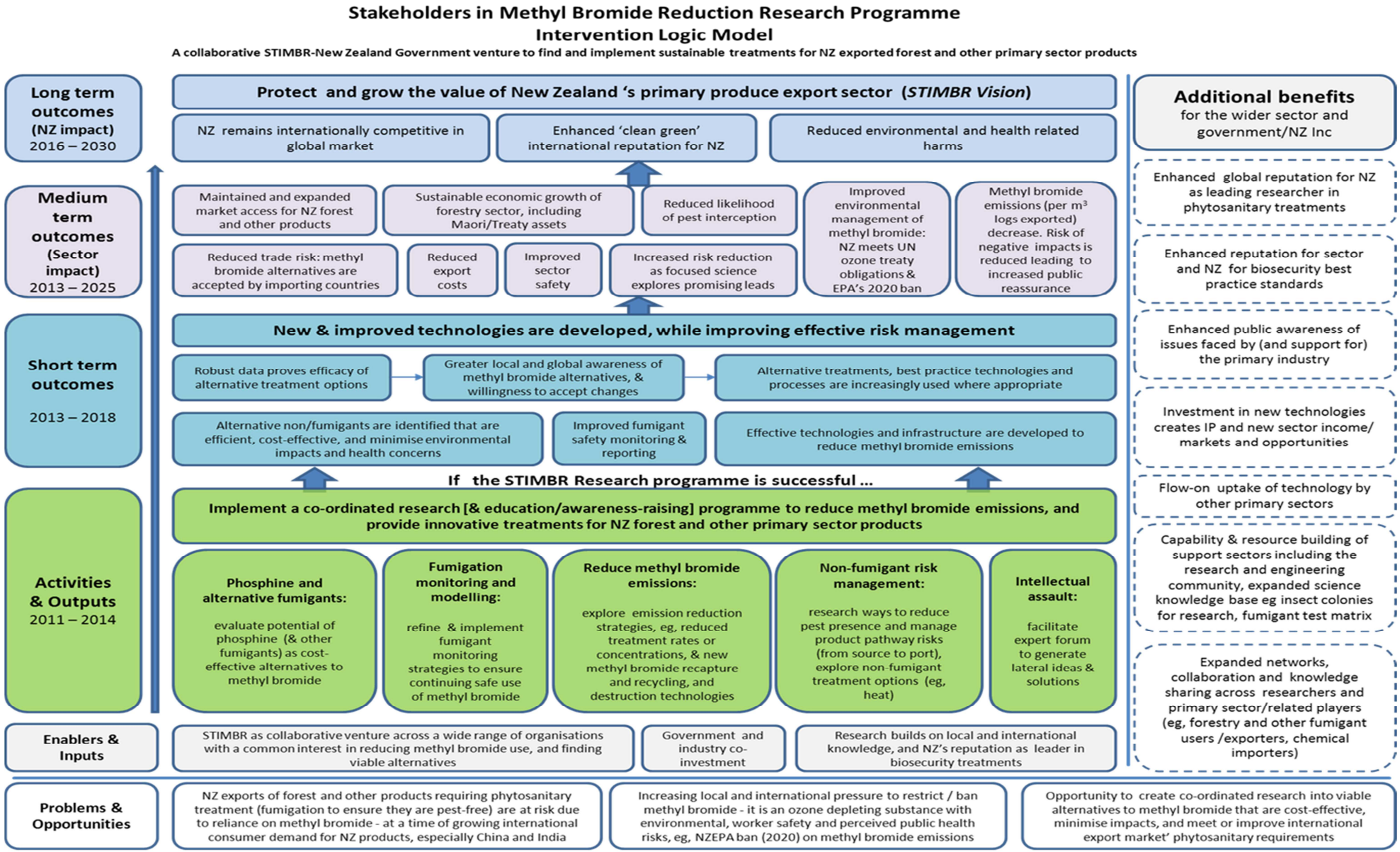
Practically the OLM will assist STIMBR to drive work post the PGP contract to deliver not only the contracted achievement measures but also its longer term outcomes and vision. The OLM has already been used to shape the development of STIMBR's five-year research strategy which will continue outcome delivery beyond 30 June 2014 when the STIMBR PGP contract was completed.

In addition to the agreed changes in wording the research has already produced a number of unanticipated results which have provided both different opportunities (for example a potential methyl bromide recycling technology) and ruled out a number of potential solutions (for example four of the seven fumigants identified by the EPA's in the reassessment as possible replacements for methyl bromide have proved to be unsuitable). While the removal of a potential solution can be disappointing such results narrow the field allowing funding to be placed in areas of greatest potential and informing discussions with regulators and society.

Scientific research increases our knowledge of a subject and allows stakeholders to more accurately to describe what exists and how is behaves. The STIMBR PGP programme has produced a wealth of data that will inform future discussion and a number of tools useful to both researchers and industry (these are identified in section 3 of this report). STIMBR is confident that on the basis of the results of this programme's outputs solutions will be found which enable horticulture and forestry exporters beyond 2020 and deliver the majority of the medium and long term outcomes described in the OLM.

Photo 2 Logs ready for export

Diagram 1


Stakeholders in Methyl Bromide Reduction Research Programme
Intervention Logic Model
A collaborative STIMBR-New Zealand Government venture to find and implement sustainable treatments for NZ exported forest and other primary sector products
Long term outcomes (NZ impact) 2016 – 2030
Protect and grow the value of New Zealand 's primary produce export sector (STIMBR Vision)
NZ remains internationally competitive in global market
Enhanced 'clean green' international reputation for NZ
Reduced environmental and health related harms
Medium term outcomes (Sector impact) 2013 – 2025
Maintained and expanded market access for NZ forest and other products
Sustainable economic growth of forestry sector, including Maori/Treaty assets
Reduced likelihood of pest interception
Improved environmental management of methyl bromide: NZ meets UN ozone treaty obligations & EPA's 2020 ban
Methyl bromide emissions (per m3 logs exported) decrease. Risk of negative impacts is reduced leading to increased public reassurance
Reduced trade risk: methyl bromide alternatives are accepted by importing countries
Reduced export costs
Improved sector safety
Increased risk reduction as focused science explores promising leads
Short term outcomes 2013 – 2018
New & improved technologies are developed, while improving effective risk management
Robust data proves efficacy of alternative treatment options
Greater local and global awareness of methyl bromide alternatives, & willingness to accept changes
Alternative treatments, best practice technologies and processes are increasingly used where appropriate
Alternative non/fumigants are identified that are efficient, cost-effective, and minimise environmental impacts and health concerns
Improved fumigant safety monitoring & reporting
Effective technologies and infrastructure are developed to reduce methyl bromide emissions
If the STIMBR Research programme is successful ...
Activities & Outputs 2011 – 2014
Implement a co-ordinated research [& education/awareness-raising] programme to reduce methyl bromide emissions, and provide innovative treatments for NZ forest and other primary sector products
Phosphine and alternative fumigants: evaluate potential of phosphine (& other fumigants) as cost-effective alternatives to methyl bromide
Fumigation monitoring and modelling: refine & implement fumigant monitoring strategies to ensure continuing safe use of methyl bromide
Reduce methyl bromide emissions: explore emission reduction strategies, eg, reduced treatment rates or concentrations, & new methyl bromide recapture and recycling, and destruction technologies
Non-fumigant risk management: research ways to reduce pest presence and manage product pathway risks (from source to port), explore non-fumigant treatment options (eg, heat)
Intellectual assault: facilitate expert forum to generate lateral ideas & solutions
Enablers & Inputs
STIMBR as collaborative venture across a wide range of organisations with a common interest in reducing methyl bromide use, and finding viable alternatives
Government and industry co-investment
Research builds on local and international knowledge, and NZ's reputation as leader in biosecurity treatments
Problems & Opportunities
NZ exports of forest and other products requiring phytosanitary treatment (fumigation to ensure they are pest-free) are at risk due to reliance on methyl bromide - at a time of growing international consumer demand for NZ products, especially China and India
Increasing local and international pressure to restrict / ban methyl bromide - it is an ozone depleting substance with environmental, worker safety and perceived public health risks, eg, NZEPA ban (2020) on methyl bromide emissions
Opportunity to create co-ordinated research into viable alternatives to methyl bromide that are cost-effective, minimise impacts, and meet or improve international export market' phytosanitary requirements
Additional benefits for the wider sector and government/NZ Inc
Enhanced global reputation for NZ as leading researcher in phytosanitary treatments
Enhanced reputation for sector and NZ for biosecurity best practice standards
Enhanced public awareness of issues faced by (and support for) the primary industry
Investment in new technologies creates IP and new sector income/ markets and opportunities
Flow-on uptake of technology by other primary sectors
Capability & resource building of support sectors including the research and engineering community, expanded science knowledge base eg insect colonies for research, fumigant test matrix
Expanded networks, collaboration and knowledge sharing across researchers and primary sector/related players (eg, forestry and other fumigant users /exporters, chemical importers)

3. Delivery of outputs from the STIMBR PGP programme

The OLM (Diagram 1 above) describes how the activities and outputs produced within the STIMBR Programme contribute to a number of short, medium and long term outcomes. The OLM also identifies a number of additional (spillover) benefits that will provide benefit for New Zealand but will not be included as part of the solution. This section looks in some detail at activities within and outputs from this programme, identifies what additional work is required to deliver on the intended outcomes and lists the additional benefits that have arisen as a consequence of the work.

3.1. Programme Activities and Outputs

The OLM identifies five work areas. Each work area is reviewed identifying:

- What has been achieved,
- Whether the contracted work was completed; and,
- The next steps that STIMBR will undertake as its resources allow.

3.1.1. Intellectual assault

An Intellectual assault (think tank) was organised early in the programme which brought together a range of subject-matter experts. This group was asked to reconfirm that the proposed work was being undertaken in those areas that provided the greatest chance of success in a way that would best facilitate commercialisation once proof of concept had been achieved and to identify possible solutions not previously identified.

Intellectual assault- progress summary	**Completed**
Outputs	• Programme approach endorsed. • Provided recommendations to strengthen the programme. • Identified two potential avenues for future research. • Contributed to the successful MBIE research bid to progress outputs of this programme. • Identified two left-field solutions (zeolite and cold radiation[5]) that it was agreed had a high risk profile and should not be included in the programme.
Status	• Fully completed
Conclusion	Provided several important recommendations which have had a significant effect. These are: a) Only one of the methyl bromide destruction technologies being investigated at that time should be progressed. It was agreed that any investigation of the other four alternative destruction or recapture technologies should be stopped until the potential of the promising pathway was proven or otherwise. This work has resulted in the development of a destruction substrate by Scion. b) The need for a gold standard approach to fumigant research resulting in the work on fumigants being restructured to provide more robust data. c) The realisation that a significant amount of additional work would be required on alternatives fumigants and non- fumigant management.
Next steps	• Possible research into left field solutions if medium term outcomes cannot be delivered from existing research.

[5] Cold radiation is to be explored in the MBIE research programme

Photo3 Test Fumigation Chambers

3.1.2. Phosphine and alternative fumigants

One way to decrease the use methyl bromide is to identify one or more alternative fumigants which can be used in its place. Seven fumigants were identified by the EPA in its reassessment as possible alternatives to methyl bromide. Work in this area was designed to identify which fumigants could be used as efficient cost effective alternatives to methyl bromide. Phosphine was particularly promising since it had been used for over 10 years as a phytosanitary treatment for logs in transit to China.

***Phosphine and alternative fumigants* – progress summary**	**Completed**
Outputs	• Ethyl formate identified as promising kiwifruit fumigant that does not affect fruit quality. • EDN identified as possible fumigant that requires a detailed techno economic assessment before undertaking further research. • Discounted four fumigants identified as possible alternatives in the 2010 EPA reassessment (Carbonyl sulphide, methyl iodide, methyl isocycnate and sulphyl fluoride). • Partial data on phosphine efficacy produced for MPI's consideration.
Status	• Contracted outputs delivered but substantial amount of additional work is required to provide alternative fumigants to industry.
Conclusion	• Significant progress has been made within this work area to distinguish potential methyl bromide replacements from those which cannot be cost effectively employed. Four of the seven fumigants tested have been shown to be of no use in replacing methyl bromide, either because of lack of efficacy or because of their effect on human health or the environment. At the end of the programme work on EDN, ethyl formate and phosphine can still be regarded as works in progress each requiring further funding to complete the science needed to de-risk their status as potential alternatives.
Next steps	• The promising ethyl formate results will inform the development of an efficacy set for kiwifruit. • A techno-economic report will be prepared to identify whether EDN has sufficient promise to warrant the development of a full efficacy set (estimated cost $1.8 million). • An extensive international literature review is underway outside of this programme to see if any other chemical alternatives to methyl bromide exist. • Additional work on the use of phosphine on logs required. A full efficacy data set may be developed.

3.1.3. Fumigation monitoring and modelling

Use of any fumigant is made safer and more reliable if its use can be monitored and its post-fumigation dispersion modelled. Work in this programme sought to identify an in-hold monitor for phosphine and to develop a dispersion model and reporting system for methyl bromide.

Fumigation monitoring and modelling – progress summary	**Completed**
Outputs	• Identified a monitor capable of monitoring in-hold phosphine levels for the time periods required to deliver phosphine as a phytosanitary treatment. • Developed and agreed (with the EPA and industry) a methyl bromide reporting system that has been implemented nationally. • Developed a Good Practise Guide for Ambient Air Monitoring and Fumigation Sites. • Developed a methyl bromide plume dispersion model (as required by the EPA) that can be used to predict and calculate off site post fumigation methyl bromide levels to plan for safe fumigations.
Status	• Contracted outputs delivered but additional work will be needed to improve usability of the tools produced beyond the scope required in this programme.
Conclusion	• Models and monitors have improved the monitoring and safety of fumigant use in New Zealand.
Next steps	• Potential upgrade of initial dispersion model to allow greater granularity of plume dispersion on port to inform regional council monitoring of methyl bromide use. • Potential investigation of the optimal placement of in-hold phosphine probes.

3.1.4. Reduce methyl bromide emissions

While the primary intent of this research programme was to identify replacements for methyl bromide, it was considered important that efforts be made to reduce the effects of methyl bromide in case no suitable methyl bromide replacements are available by 2020. Two areas were investigated:

- Rationalising methyl bromide rates of use. In the past methyl bromide rates were agreed with target markets without good scientific support (efficacy data). It was hypothesised that it may be possible to reduce usage rates
- The EPA 2010 decision allowed for the use of methyl bromide beyond 2020 if it can either be recaptured or destroyed.

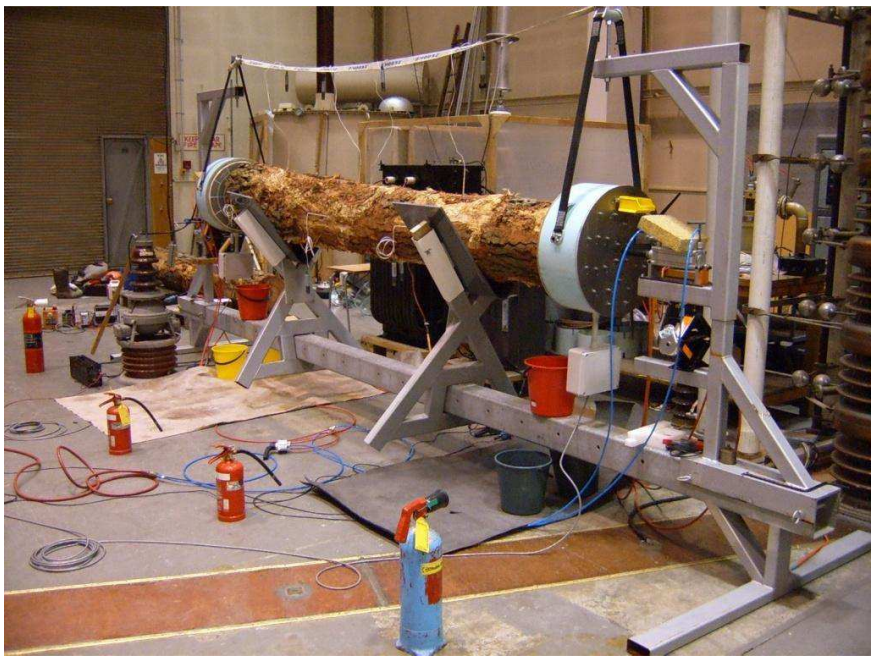
Early in this programme a capture technology using carbon to remove the remaining methyl bromide from the fumigation space after treatment was explored. Methyl bromide capture with carbon technically worked well but required four to five times the quantity of carbon to recapture a unit of methyl bromide. Landfill operators in New Zealand will not accept the potentially large volumes of used carbon (an estimated 3,000 tonnes of carbon could be produced per annum) and shipping carbon off-shore was not cost effective. As a consequence the technology was dismissed as a viable treatment for large quantities of logs limiting it to very niche applications.

Later in the programme a potential recycling technology was identified which could be used to support the recapture system. This New Zealand developed recycling technology will remove methyl bromide from the carbon substrate and re-pressurises it for reuse. This would allow the economic capture of methyl bromide and reduce New Zealand's overall use of methyl bromide, since the recycled portion could be reused. A review undertaken within this programme has confirmed the validity of the process.

Several new potential destruction technologies were also developed or identified in this programme or in work occurring parallel to the programme. All of them have shown proof of concept but require additional work before the technologies can be commercialised.

Reduce methyl bromide emissions – progress summary	***Proof of concept work ongoing***
Outputs	• Work started within this programme has confirmed that a reduction in methyl bromide rates by up to 40% is possible. The output from this programme provided the proof required to initiate the development of an efficacy data set. • One unique destruction substrate has been developed from first principles by Scion. • Two potential destruction technologies developed in New Zealand outside of the programme have been identified as potentially worth progressing. • A method to recycle methyl bromide captured on carbon has been confirmed.
Status	• Contracted outputs delivered but a significant amount of work is required to deliver tools.
Conclusion	• Good progress has been made in an area where a number of diverse leads were followed. If an alternative fumigant is not identified before 2020 the development of one or more of these potential tools will be critical to support exports beyond 2020.
Next steps	• Complete efficacy data for methyl bromide to support a 40% reduction in treatment rates. • MPI to re-negotiate methyl bromide rates for log trade with key markets. • Identify and further develop two of the methyl bromide destruction/recycling technologies for commercial use by 2020.

Photo 4 Joule heating rig



3.1.5. Non-fumigant risk management

While the majority of this research programme concentrated on identifying replacements for methyl bromide it was considered important efforts also be made to assess non-fumigant strategies and tools in case no suitable chemical replacement were available before 2020. Two quite different areas were investigated:

- Joule heating of logs which used electricity to increase the internal temperature of a log to a point where insects will be killed.

- The non-chemical management of pests focussing on the modification of large-scale site lighting, UV light traps and the application of physical barriers to minimise pest infestations.

Non Fumigant research – progress summary	***Completed***
Outputs	• Joule heating proven as a possible phytosanitary treatment. • Confirmed UV lights attractive to insect pests and may be modified for pest control. • Sodium lights are now recommended for use in timber yards to minimise pest problems. • Insecticide impregnated mesh nets shown to be effective for excluding hitchhiking insects. • The programme collated biological and ecological risk factors relevant to each key pest, and mapped infestation risk points along the major forest industry supply chain. This supported the successful MBIE programme to develop a treatment free winter period for log exports. • Data from this programme allowed MPI to increase the Maximum Post Fumigation Exposure Period (MPFEP) in winter from 72 hours to 21 days significantly reducing costs and increasing flexibility. This will save the forestry industry both money ($70,000 per annum) and time.
Status	• Contracted outputs delivered from many of these areas are being continued in the MBIE programme.
Conclusion	• Fundamental work completed in both investigation areas. Work from this area laid the ground work for the development of the MBIE research programme for fumigant free log exports. While it is likely that these approaches will never completely replace the need for a fumigant they will potentially reduce New Zealand's year round reliance on chemical fumigants.
Next steps	• Joule heating is being progressed for potential use as a niche phytosanitary treatment. • Lighting and its role in repelling/ attracting pests being progressed. • Further refining of the MPFEP to allow greater use of off port treatments. • Detection methods for pest infestations within logs being considered to support assurance requirements for a future treatment free winter period.

3.2. Additional benefits

The OLM identifies a number of additional benefits that will occur as a consequence of this programme. These are benefits that would not have occurred if this programme had not been undertaken. These benefits have been integral to the success of the research, may be required to undertake research but will not be involved directly in the delivery of the contracted outcomes. There are several types of additional benefits identified in the OLM that have arisen from this programme. These are:

1. Enhancing New Zealand's global reputation as leading researchers of phytosanitary treatment.
2. Flow on uptake of technology by other primary sectors.
3. Capability and resource build of support sectors including research and engineering community, expanded science knowledge base.
4. Expanded network, collaboration and knowledge sharing across researchers and primary sector related players.
5. Reliable information available for society and regulators to minimise concerns and inform debate.

3.2.1. Enhanced global reputation

To enable work on this research programme to be undertaken efficiently and robustly, three areas of development were required to enable data collection. These three areas represent significant developments

and will enhance New Zealand's reputation as leading phytosanitary researchers while providing ongoing benefit to research in New Zealand.

a) ***Development of a research matrix*** for efficacy data sets development. Prior to the STIMBR-PGP programme commencing, all previous fumigation research on logs in New Zealand was undertaken as discrete projects with little recognition of conditions used in previous research and little or no comparability between trials. Populations of all four insect life stages (eggs, larvae, pupae and adult) of unknown ages were used and results were often unexpected and at times contradictory. The need for a more systematic approach was identified as a necessary input during the intellectual assault. As a result a 'gold standard' matrix was documented to guide the research through a systematic and consistent approach that will provide comparable, defensible and enduring data sets.

b) ***Insect breeding to support the development of efficacy data sets.*** Efficacy data set development needs large numbers of each life stage of each target insect pest to provide mortality data. For the development of one efficacy data set for one fumigant, substantial numbers of each insect species is generally required (i.e. >1000).

   Insects associated with bark and logs have historically proven difficult to breed in captivity and any fumigant research was undertaken using wild-caught insects. This restricted fumigant research to times of the year when insects were naturally available and limited the amount of research that could be completed to the insect supply. In years when inclement weather depressed insect numbers research was disrupted and delayed. Results in such circumstances often had high mortality rates in the controls and higher margins of error.

   Within this programme two laboratories[6] have had considerable success in developing the understanding of insect requirements that will lead to 'captive' self-sustaining colonies of key insect pests associated with logs and timber products. Laboratory culture supplemented by wild collected individuals has resulted in a more reliable and consistent supply of insects allowing greater amounts of research to be undertaken throughout most of the year.

c) ***Effect of logs on in-hold environment.*** Prior to this programme the effect of logs on the in-hold environment was largely unstudied. Data collected in this programme has identified the effect of fresh logs on the temperature and atmospheric composition of a closed space. This information can be used to tailor fumigant research so that it takes into account changes in the in-hold environment improving the validity of the research results.

3.2.2. Flow on uptake of technology

The development of technologies from this programme will take place after the next phase of research. However the exploration of potential solutions within this programme lead to the arable sector commissioning research on one fumigant rejected by this programme. Ozone was considered as a potential fumigant for kiwifruit but was abandoned because of quality effects on the ripening fruit. Scientist involved in its initial trial have recently reported that on the basis of its use in this programme the arable industry is now considering it as a fumigant for seeds.

Photo 4 Kiwifruit quality was affected by ozone

[6] P&F funded through this programme and Scion funded through the STIMBR-MBIE programme

3.2.3. *Capability and resource build*

Private industry in New Zealand does not readily invest in research. This programme has required industry to provide $1.2 million in research funding over three years and has built capability and understanding both within industry and research organisations. STIMBR (i.e. industry) has also provided $250,000 above the contracted sum to enable work to occur within this STIMBR PGP programme. These benefits will have an ongoing effect. Three benefits in particular have been identified:

a) ***Capability building in the CRIs.*** Fumigant facilities, team capability and capacity have been increased at Plant and Food Research (P&F) as a consequence of work undertaken in this programme. This work has specifically
   - Contributed to P&F's decision to make a capital investment to support fumigant research by upgrading research facilities. The resulting laboratories will significantly improve P&F's ability to undertake future fumigation research safely and efficiently.
   - Lead to P&F employing additional younger staff (two scientists) in this area so that they can build capability and have a succession plan in place to provide on-going resourcing.
   - Scion has increased its modelling capability by employing a specialist modeller for particle dispersion in the atmosphere. This provides Scion with new skills that will be available for future fumigant modelling and potentially research into atmospheric pollutants.

b) ***Additional research and funding in this area.*** A successful bid by Scion to MBIE for funding of a six-year programme drew heavily on early research from this programme and will take some promising areas to completion. This MBIE programme is continuing work on several of the outputs from the PGP programme namely an efficacy data set for a 40% reduction in the use of methyl bromide, fumigant periods that may allow export during specific time periods(i.e. winter) each year and prototype development for joule heating. A literature review considering alternative fumigants completed in the STIMBR-MBIE programme has confirmed that many of the alternative fumigants identified in the 2010 ERMA reassessment are not likely to be suitable as replacements for methyl bromide. It is also notable that industry is providing co-funding ($3 million) for this programme.

c) ***STIMBR capability build*** before this programme STIMBR employed a coordinator for approximately 100 hours per year and held general meetings annually or biannually. With the need to manage a larger programme a Research director was employed and the STIMBR constitution was revised to include a formal Board, strategic science advisory forum and independent Chair. This has resulted in a more formal structure where the Board meets at least quarterly. The STIMBR Executive team recognises that these changes represent a significant increase in its own capability which will directly contribute to post PGP outcome delivery.

3.2.4. Collaboration and knowledge sharing

The PGP programme has not only increased capability within STIMBR and the science institutions it has also indirectly contributed to capability within industry through the knowledge sharing that has occurred between industry and science

a) ***Improved relationships.*** Improved relationships, partnership and cooperation between Scion, the forestry industry, P&F and other key stakeholders. This programme required these bodies to work closely together throughout the contract at all levels from management to technical staff. STIMBR required that the staff from the two CRIs meet at least quarterly to exchange results and discuss challenges. As a result this programme has resulted in improved relationships and higher levels of cooperation between the teams and the different organisations.

b) ***Research appreciation.*** This programme has seen increased appreciation by log exporters of the importance and nature of research. Regular reporting on this programme to the forestry industry has increased log exporters knowledge about research and the challenges that are faced in producing robust results. Key players now understand that it will take time and sustained funding to produce the tools required. It is notable that by 2014 the Forest industry had increased the levy on methyl bromide and phosphine use by 40 % above[7] what it was before the PGP and MBIE programmes were contracted.

3.2.5. Reliable information available

The EPA reassessment of methyl bromide was in part an official response to societal concern about the use of methyl bromide and its impacts on human health and the environment. At the time of the reassessment few alternatives fumigants had been seriously considered to replace methyl bromide and even less New Zealand specific work had been undertaken. The information available to the EPA on credible alternatives was scarce. This programme has provided a wealth of data to inform concerns.

a) ***Reassurance to communities***
   i. Reporting methyl bromide use as part of this programme STIMBR developed and agreed (with the EPA and industry) a methyl bromide reporting system that has been implemented nationally. Annual reporting via this system provides a granularity of information that has previously being lacking and can only lead to more informed discussion about methyl bromide its use and distribution.
   ii. The second EPA requirement that will provide assurance and has been developed within this programme is the development is a Best practice monitoring protocol for fumigants
   iii. This programme has also developed a model that demonstrates methyl bromide plume dispersion post fumigation. In the locality in which the model was developed this model has shown that methyl bromide levels in the dispersion plume will be below allowable levels when there is the slightest air movement. It is expected that this will result in some change to local regulations to prevent venting of treated stacks to periods of the day when air movement occurs and should allay any fears the local community has about log fumigations taking place within port boundaries. Widespread use of this model is expected to confirm similar conditions in other regions.

b) ***Credible alternatives*** this programme has demonstrated that of the alternative fumigants identified in the EPA methyl bromide reassessment none alone can completely replace methyl bromide. This information can be used in any future conversation between regulators, industry and society.

[7] Per unit of methyl bromide and phosphine

4. Programme Outcome Delivery

4.1. Can the outcomes be delivered?

The OLM elegantly documents how the activities and outputs of this programme can be developed and coordinated to deliver the programme's long term outcome of protecting and growing the value of New Zealand primary export sectors". This longer term outcome will result from the delivery of the medium term outcomes which in turn will have resulted from the shorter term outcomes that will arise from the outputs of this programme.

Scientific research is an interesting process which, unlike manufacturing, does not always deliver pre-agreed results. Results may exceed expectations, be easier to obtain than expected, more often are difficult to obtain, and may at times produce unanticipated results. The delivery of outcomes is similarly uncertain. We can only talk with confidence about progress to date. STIMBR and its stakeholders however are confident that the outputs that have been produced provide a credible base on which to build and it will do its best to ensure all the outcomes documented in the OLM. The key questions then are

- How successful has the programme been in progressing towards delivery of the long term outcome?
- Has the programme delivered value for money? ; and;
- Can the long term outcomes be delivered?

Yes the programme has been successful. It has delivered a wealth of information which will enable STIMBR to fund research areas which may credibly provide the necessary solutions. Just as importantly the programme has delivered a number of tools and range of enablers (as described by the additional benefits) that will support outcome delivery. Whether the required solution is present in the current programmes outputs will only be known when solutions are available to industry for use. The STIMBR Executive can however say with certainty that without this programme, industry would be faced with too many uncertain leads to competently fund. Delivery of a beneficial result would become more a case of luck. The STIMBR Executive team is clear that this programme has provided a valuable step towards the delivery of the long turn outcome.

Regarding value for funds spent. STIMBR can say categorically the funds have delivered excellent value for the sum invested. STIMBR must thank the researchers involved for their determination and persistence in providing such world class science over such a wide range of areas. Generally, large topic specific research programmes will often have problems at the start of a programme identifying the right equipment, obtaining the necessary permissions etc that must be resolved.

This programme was made up of relatively high number of exploratory projects each with its own challenging set up phase. For example the programme tested five fumigants and each had specific challenges to solve before data could be collected. Of these EDN required trial use permission from the EPA for its use and needed to identify a specialised scrubber to allow even small quantities to be used. Similarly the ozone trials needed to identify and import specific equipment to apply the required ozone carbon dioxide mix. Nearly every area investigated in this programme had one or more challenges to overcome before actual research could start. This programme has delivered very good value for the funds invested.

Can the long term outcome be delivered? As mentioned above science does not always provide the desired results. Likewise people and organisations cannot be depended on to deliver the support required to translate science into a commercial reality. However STIMBR has a solid network of connections established over the length of the programme. It also has a clear delivery deadline and an urgent need to deliver solutions. STIMBR will do everything within in its power to make sure the outcomes are delivered.

4.2. Next steps

To progress outcome delivery STIMBR has undertaken a stock take (Table 2) of the outputs produced and identified how the outputs can be progressed toward the next step of delivering the short term outcomes.

Table 2: Delivering the principal short term outcomes of the STIMBR PGP programme

Programme Outputs	Next steps	Leading to
Outcome 1: Alternative fumigants identified that are efficient, cost effective and minimise environmental impacts and health concerns		
Data on phosphine efficacy produced	Continue work to enhance phosphine efficacy and production of an efficacy data set	MPI negotiation with overseas markets so that new treatments can be used to enable exports
Ethyl formate identified as promising kiwifruit fumigant	Develop efficacy set for use on kiwifruit	
EDN identified as possible fumigant	Prepare techno–economic report and if positive produce full efficacy set	
Joule heating proven as a possible phytosanitary treatment	Refine Joule heating processes and determine wood quality impacts to inform development of a commercial scale joule heater for use on exports logs	
Range of promising non-fumigant techniques identified that may allow fumigant free export during defined periods	Refine efforts to use lighting, MPFEP and detection of in-log pests to support assurance requirements for future treatment free periods	
Discounted use of remaining four fumigants to replace methyl bromide	Extensive international literature review to identify and test any other alternative fumigants	Develop efficacy set for new promising fumigant, or Use proven lack of alternatives in discussion with regulators to identify optimal regulatory environment
Improved fumigant safety monitoring and reporting		
Identified monitor for in-hold phosphine monitoring during phytosanitary treatments	Identify optimal placement of phosphine probes in hold	Reliable safe use of phosphine
Reporting system used nationally	None required	EPA's requirements satisfied
Methyl bromide dispersion model for off port monitoring completed	Improve granularity of dispersion model to allow on port prediction	Improve safety of fumigations and provide data to reduce any public concern
Confirmed possible 40% reduction in methyl bromide rates for log exports	Complete efficacy data	MPI negotiation with overseas markets to enable reduce rates on exports and improves New Zealand's environmental management and reputation
Effective technologies and infrastructure are developed to reduce methyl bromide emissions		
Scion's unique destruction substrate developed	Develop methyl bromide destruction/recycling technologies for commercial use by 2020	Effective tools available to allow emission free use of methyl bromide
Two potential destruction technologies identified		
Methyl bromide recapture from carbon confirmed		

STIMBR has also undertaken a process to prioritise the research to ensure promising tools that are most time constrained, are progressed first and has recently developed a comprehensive five year research strategy to progress the outputs from the STIMBR PGP programme. STIMBR is also aware it must progress research in as many lines of research as possible since favourable results cannot be guaranteed. In addition it will continue to scan domestic and international forums for completed technologies that could be picked up by local industries to enable them to adjust to the EPA's 2020 deadline.

STIMBR is working hard to identify the research funding to progress the required work and is:

- Talking with Industry about research priorities and funding needs,
- Identifying Government research funding that may be sought to fund individual projects,
- Discussing the proposed research with CRIs to identify whether it is possible to reduce the level of funds required by identifying synergies in the research, and
- Talking with businesses that may be prepared to further develop concepts proven in this programme.

Photo 5 On port log fumigation

4.3. Risks to outcome delivery

STIMBR is aware that considerable continued effort will be required to deliver the short, medium and long term outcomes.

STIMBR has identified that there are a number of risks that would prevent delivery and uptake of the necessary tools and technologies by 2020. Successful development and uptake of the required tools and technologies would be prevented by:

- Failure to secure adequate funding to complete all of the work required to deliver the programmes tools and technologies.
- An inability to provide commercially viable methyl bromide destruction or recycling solutions.
- Failure of the forestry and horticultural sectors to pick up or implement solutions before the 2020 deadline.

To manage these risks STIMBR will

- Actively seek funding from the industry and pursing potential research co-funding from government and commercial partners.
- Closely monitor the development of its destruction and/or recycling technologies and if necessary invest in alternative approaches.
- Encourage industry to adopt new technologies and tools by working with industry leaders, providing communication and leadership.

- Making a case to the EPA for having the 2020 deadline extended if needed.

STIMBR is also aware of external risks that may impact on its ability to deliver tools by the time they are required by sectors. Of most concern is the possibility that regional councils could change environmental regulations and create additional restrictions on fumigant activities prior to 2020 or overseas markets could make changes to their importing requirements. To manage such external risks STIMBR and the Forest Owners Association will monitor changes in the regulatory environment (domestically or offshore) and will contest those that are unreasonable or will impact on exporting activity.

4.4. Facilitating Outcome delivery

To deliver the OLM outcomes STIMBR and its partners recognise they will need to drive activity to facilitate outcome delivery by 2020 when the EPA emission requirements on methyl bromide release to the atmosphere comes into force. STIMBR recognises that while it will continue to be instrumental in outcome delivery it will not be able to deliver any of the outcomes on its own without industry and stakeholder support. Outcome delivery will need to be undertaken by the forestry and horticulture sectors and in some instances will require the involvement of regulatory organisations to facilitate their delivery. STIMBR is aware that considerable continued effort will be required to deliver the short, medium and long term outcomes and that it and researchers have a leadership and facilitation role respectively in delivering these outcomes.

The STIMBR PGP programme has made good progress towards developing the required solutions. Just as importantly, it has grown the relationships and connections between industry, researchers and government agencies to support success and so protect and grow New Zealand's primary produce exports. This work has significantly increased the chance that industry will be able to satisfy the 2020 change in use conditions for methyl bromide and support the continued growth of both Forestry and Horticultural exports.

Photo 6 Preparing logs for fumigation