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Committee Secretary
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Carbon Farming Initiative Amendment Bill 2014 (Provisions) Inquiry

As discussed with Dr Sue Brown on 26 June 2014 attached is a copy of the CSIRO submission to the Emissions Reduction Fund Green Paper process.

CSIRO is unable to provide a witness to give evidence to the Carbon Farming Initiative Amendment Bill 2014 (Provisions) Inquiry but the Emissions Reduction Fund submission does contain information relevant to your Inquiry and we hope it will be of assistance.

Yours sincerely

Tracey Cootes
Liaison Officer
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CSIRO Submission 14/493

Emissions Reduction Fund Green Paper

February 2014

Introduction

CSIRO welcomes the opportunity to contribute to the Government's processes for developing an efficient and effective Emissions Reduction Fund.

CSIRO's expertise leads us to provide comment in the following areas raised in the Green Paper:

- Opportunities for large-scale, low-cost emissions reductions
- Methods to ensure genuine and additional emissions reductions
- How to best operate an efficient auction process to secure lowest cost emissions reductions
- The potential effect of ongoing uncertainty on technology cost and uptake
- Options for streamlining the Carbon Farming Initiative

Key Points

The following statements are supported by the information provided in pages 6-19 of this submission, including supporting references and calculations.

1. Opportunities for large-scale, low-cost emissions reductions

- Significant opportunities for abatement exist in the land, energy and resources sectors, using both technologies available now and technologies currently under development.
- The abatement opportunities highlighted in this submission are those which have been identified by our modelling and research as having the potential to make a significant difference for Australia, having a lower cost, feasible pathway to large-scale implementation, and where CSIRO has an active research program and expertise.

Land abatement

- Land-based emissions abatement in Australia could be significant in the period 2030 to 2050. Due to the time lag for adoption of new technologies, logistics and the nature of carbon sequestration curves (for example, tree planting where growth is slow in initial years), the most significant contribution from the land sector is likely to be achieved after 2030.
- The major opportunities from the land sector exist in afforestation, avoided deforestation, livestock methane and increasing rangeland and savanna carbon stocks through changed fire regimes. Soil carbon in agricultural zones is likely to provide low levels of greenhouse gas abatement.
- Contributions from the land sector are likely to be small unless the carbon auction price is more than \$50/t CO_2-e. With a carbon auction price above this it is technically feasible to achieve >100 Mt CO_2-e per annum abatement in the period 2030-50 from reforestation and afforestation activities. At this price it may be possible with existing technology to achieve an additional 1-5 Mt CO_2-e from livestock management changes, and higher levels with technological development.
- Long term maintenance obligations (100 years) associated with carbon sequestration, while securing the best outcome for the environment, will also provide a barrier to participation. Soil carbon projects will require that management changes that have built soil carbon stocks be continued for the obligation period, and afforestation projects will have to maintain carbon stocks in the face of fire, pests, drought and forest aging.
- Saturation of carbon sinks (the maturation of forests and the restoration of soil carbon levels) means that per annum abatement from the land sector will decline in the decades after project establishment. If forests are harvested and converted to long lived products (such as biochar or building products) or used to substitute for greenhouse intensive products or energy sources, this effect can be reduced as long as the mature trees are replaced with young plants.
- Many land sector projects can contribute environmental and livelihood co-benefits (for example, improved biodiversity or livestock production efficiency) in addition to greenhouse gas abatement, which will be important for uptake of abatement technologies by landowners.
- Enabling activities that could help achieve land abatement are developing low cost methodologies to credit changes in vegetation and soil carbon, including further development of soil carbon models, and developing national carbon measurement programs to underpin verification.

- See pages 7-9 for evidence to support the above statements.

Energy and resources sectors abatement

Fugitive emissions from coal mines

- Fugitive emissions from coal mines are the single largest growing addition to Australia's emissions inventory out to 2020.
- For underground mines, with timely development and deployment of technologies, abatement of 24 Mt CO_2-e/year in 2020 is possible using currently emerging drainage technologies, and ventilation air methane (VAM) technologies that will be available in 3-5 years.
- Abatement costs vary significantly for individual underground mine sites and the specific abatement approach chosen. Cost estimates are $10-30 and $1.5-3/t$CO_2$-e for gas drainage and drainage gas flaring, respectively. The current generation of VAM mitigation technologies might require carbon auction prices of $11-18/t CO_2-e, while the next generation technologies may only require $1-6/t CO_2-e.
- For open cut mines, there are also opportunities for abatement of fugitives, although the risks and costs of abatement are higher than for underground coal mines. It has been shown that enhanced drainage could be a positive business case for 40% of eastern Australian coal mines at a carbon auction price of around $30/t.
- A potential co-benefit is the production of extra gas or electricity that could help ease domestic gas price pressures.
- Enabling activities include technology refinement for drainage systems and VAM abatement, method development for fugitive emission abatement quantification, especially for open cut mines, and accelerating the development and demonstration of activities that span from methane destruction for emission reduction to methane utilisation either directly or for power generation.
- See pages 9-11 for evidence to support the above statements.

Enhanced coal bed methane

- Deployment of enhanced coal bed methane (ECBM) technologies using either flue gas or pure CO_2 streams has the potential to cumulatively abate significantly more than 10 Mt CO_2-e in the period 2016-20.
- An initial analysis in Canada identified a potential positive business for flue gas ECBM, whereas CO_2-ECBM needed an incentive in relation to the stored CO_2. However, a detailed cost benefit analysis is required to establish the economics more broadly for Australian coal seam gas basins.
- Potential co-benefits are the production of extra gas to ease gas price pressures and provision of a lower cost option for the geological storage of CO_2.
- Enabling activities would include establishing accelerated demonstration and deployment of the technology as well as clarifying the regulatory framework and the social licence to operate.
- See pages 11-12 for evidence to support the above statements.

High efficiency power generation from coal

- Deployment of novel technologies currently under development, such as the direct injection carbon engine (DICE), has the potential to replace traditional coal generation technologies over time.
- DICE could be commercially available in 2018 and may achieve a 15% market share of Australian electricity generation in 2050 in a high gas price scenario, potentially contributing 10 Mt CO_2-e/year abatement when compared to conventional coal fired generation.
- Co-benefits could include facilitation of grid integration of intermittent renewables by providing a rapid response power technology, and potentially lower environmental risks in the event of a spill (compared to oil).
- See page 12 for evidence to support the above statements.

Commercial and residential building efficiency

- Energy efficiency technologies and tools, such as automated tools for improving building heating, ventilation and air conditioning (HVAC) system efficiency, and tools to determine the energy performance of residential buildings, provide near term, low cost options to create significant abatement.

- Tools for automated fault detection and diagnostics and ongoing commissioning to increase building and HVAC efficiency are available now for commercial-scale deployment and could create an estimated abatement of 4 Mt CO_2-e per annum (assuming implementation in 50% of Australia's commercial building stock).
- Potential co-benefits include avoided network costs due to reduced peak demand, improved building maintenance and commissioning processes, and improved equipment life and building occupant comfort.
- There is also an opportunity for significant abatement through the introduction of a voluntary or mandatory disclosure scheme in relation to the energy, water and greenhouse performance of residential buildings.
- A full thermal assessment tool for residential buildings has the potential to deliver 16Mt CO_2-e over a 10 year assessment period through a mandatory disclosure scheme. This abatement is predicted to be higher than would be achieved using simplified thermal assessment tools. Furthermore, CSIRO estimates that new tools under development have the potential to deliver a full thermal assessment for the same cost as methods currently used for simplified thermal assessments.
- See pages 13-14 for evidence to support the above statements.

2. Methods to ensure genuine and additional emissions reductions

- Realising the opportunities in the land-sector requires the development of low cost methodologies that retain environmental integrity: what is required is that methodologies deliver confidence in the credited level of abatement, not necessarily precision in the sequestered level of carbon.
- Measurement methods for fugitive methane capture and abatement from gas drainage of underground coal mines are reasonably robust, however, further work is needed for measuring abatement of VAM (improved measuring equipment for gas concentration and flow rates) and abatement from open cut mines (for example, development of inverse methods for emissions estimation).
- See pages 15-16 for evidence to support the above statements.

3. How to best operate an efficient auction process to secure lowest cost emissions reductions

- The best auction design depends on a number of factors including the number of participants, the number of rounds envisaged and, in environmental auctions, the extent to which it is intended to achieve multiple benefits (co-benefits).
- Economic theory, laboratory experiments and real-world experience indicate that the uniform-pricing format is, in the majority of circumstances, the most efficient mechanism, particularly for repeated auctions targeting well known commodities such as water and carbon.
- Efficiency is likely to be maximised by the inclusion of a confidential reserve price and having fewer rounds of auction with a large number of participants in each round.
- The utilisation of land-based Carbon Farming Initiative (CFI) projects has the potential to deliver a range of benefits in addition to greenhouse gas abatement and these can be sought alongside carbon in an auction through the establishment of project eligibility criteria or weighting projects based on their co-benefits.
- See page 17 for evidence to support the above statements.

4. The potential effect of ongoing uncertainty on technology cost and uptake

- Many land sector projects (afforestation, soil carbon, avoided deforestation, fire management in the rangelands) will only be viable if they can generate carbon credits over long periods of time and align with landholder motivations and capacity to engage in carbon farming activities. Uncertainty of payment beyond an initial 5 year crediting period may act as a significant barrier to participation for landowners.
- See page 18 for evidence to support the above statement.

5. Options for streamlining the Carbon Farming Initiative (CFI)

- For livestock emissions modelling it is possible and would be advantageous for the National Inventory livestock model to be stepped down to operate at a regional level, enabling livestock CFI projects based on improvements in productivity.
- For soil carbon, there is a need for further soil carbon model development to allow methodologies to be simplified over time. In the meantime it would be best for soil carbon CFI methodologies to use a measurement route and the application of classical statistics to the data generated to define critical soil carbon stocks and stock changes, with a defined probability of exceedance.
- The vertical and horizontal aggregation of activities that will be possible under the 'Facility' approach may be useful if extended to agriculture and if it allows supply chain aggregation, and single methodologies that include multiple abatements arising from the one activity.
- See page 19 for evidence to support the above statements.

CSIRO Expertise

CSIRO's has relevant expertise in the following specific areas:

- Understanding the sources and sinks of greenhouse gases in ecosystems and the economy
- Understanding options for land abatement, including soil carbon, biochar, livestock methane, nitrous oxide, and soil changes under afforestation
- Developing approaches and guidelines to increase participation in abatement activities by landowners, including indigenous Australians
- Developing scientific solutions to increase agricultural productivity while reducing carbon emissions and environmental impact per unit of agricultural production
- Understanding behavioural economics and its application to the design of both market and non-market based instruments for acquiring environmental outcomes
- Developing and demonstrating novel technologies for the energy and resources sector, including:
    - emerging renewable stationary and transport energy technology options such as solar, geothermal, smart grids, energy storage and biofuels
    - local energy solutions such as high-efficiency, low peak load solutions for buildings and grid integration of intermittent renewable energy sources
    - extraction, production and generation of electricity from fossil fuels (coal, oil, gas), including managing and measuring fugitive emissions
- Developing a national integrated assessment exploring the food-water-energy nexus, involving model-based projections of a number of variables to 2050, including a detailed assessment of the potential for land-sector carbon sequestration
- Undertaking integrated energy modelling work that examines the implications of pursing particular technology paths for the Australian energy sector over the next 20 to 50 years

Opportunities for large-scale, low-cost emissions reductions

Land abatement options

Australia's agriculture and forestry - land-based abatement - can make a valuable contribution to lowering Australia's greenhouse emissions. The scale of contribution has been widely discussed and in the short term land based contributions are likely to be modest (Department of Climate Change[1] and Treasury[2] both suggest ranges 5-15 Mt CO_2-e/yr by 2020, consistent with CSIRO estimates[3]). CSIRO study suggests that with concerted effort, and supporting policies, land-based sources further into the future could contribute tens or even hundreds of Mt of abatement per annum by 2050, and in doing so contribute to environmental and livelihood co-benefits. The extent to which the full potential is realised will depend on carbon and agricultural commodity prices, competing land use activities, the regulatory framework and policy settings, and the extent to which research and development and extension activities can reduce transaction costs and uncertainty.

Long term maintenance obligations (100 years) associated with carbon sequestration, while securing the best outcome for the environment, will also provide a barrier to participation. Soil carbon projects will require that management changes that have built soil carbon stocks be continued for the obligation period, and afforestation projects will have to maintain carbon stocks in the face of fire, pests, drought and forest aging.

While the land sector may contribute abatement in a range of ways, at the moment it seems that large-scale (tens of Mt CO_2-e per annum) abatement is most likely to be achieved with afforestation/reforestation activities, reductions in livestock methane, avoided deforestation or changed forest management and changes in emissions and carbon storage in Australia's rangelands. Other land sector abatement opportunities, such as soil carbon increases on managed agricultural land, although small in total contribution, may be locally important or achieve worthwhile co-benefits.

Marginal abatement cost curves for afforestation and livestock methane reduction suggest some abatement may be achieved at low cost, however, substantial abatement will only be achieved via either pathway if the carbon auction price exceeds $50/t of CO_2-e[4,5,6].

With regard to reforestation and afforestation, a forthcoming CSIRO Australian National Outlook report[6] finds that, with strong price incentives, non-harvest carbon plantations and native vegetation could greatly increase sequestration to 2050. CSIRO projects low volumes of sequestration before 2030, even with strong price incentives (>$50/t CO_2-e), due in part to probable slow uptake and the physical characteristics of carbon sequestration. From 2031 to 2050, CSIRO finds average annual emission reductions of more than 100 Mt CO_2-e would be economically and technically feasible if payments to landholders are broadly consistent with the carbon auction price trajectories in the medium and high scenarios modelled by Treasury (the high price scenario assumes a carbon auction price of around $300/t CO_2-e in 2010 terms). However, abatement from reforestation and afforestation is projected to decline in the decades after 2050 as plantings mature. If forests are harvested and converted to long lived products (such as biochar or

[1] *Carbon Farming Initiative Preliminary estimates of abatement Discussion Paper*. (2014, February 13). Retrieved from: http://climatechange.gov.au/sites/climatechange/files/documents/04_2013/CFI-Preliminary-estimates-of-abatement.pdf

[2] *Indicative estimates of abatement from the Carbon Farming Initiative, 2012-13 to 2049-50*. (2014, February 13). Retrieved from: http://archive.treasury.gov.au/carbonpricemodelling/content/consultants_reports/DCCEE_Indicative_estimates_of_abatement_from_the_Carbon_Farming_Initiative.pdf

[3] *How much carbon can trees absorb?* (2014, February 13). Retrieved from: http://theconversation.com/how-much-carbon-can-trees-absorb-5829

[4] *Costs and potential of agricultural emissions abatement in Australia: A quantitative assessment of livestock abatement under the CFI*. (2014, February 13). Retrieved from: http://data.daff.gov.au/data/warehouse/9aac/9aace/cpaead9abce003/costAgEmissionAbateAust_v1.0.0.pdf

[5] *Opportunities for carbon forestry in Australia: Economic assessment and constraints to implementation*. (2014, February 13). Retrieved from: http://www.csiro.au/Organisation-Structure/Divisions/Ecosystem-Sciences/Opportunities-Carbon-Forestry.aspx

[6] *Integrated carbon assessment to help plan a low-carbon future*. (2014, February 13). Retrieved from: http://www.csiro.au/en/Organisation-Structure/Flagships/Energy-Flagship/Integrated-Carbon-Pathways.aspx

building products)[7] or used to substitute for greenhouse intensive products or energy sources[8], this effect can be reduced as long as the mature trees are replaced with young plants.

CSIRO research suggests that if historical production gains in agriculture can be maintained, these high levels of land use change if well planned and located will have minimal impacts on food production, and if the offsets are tradeable may have a positive impact on farm incomes while carbon stores are increasing.

Through herd management and dietary supplementation, and genetic selection for low emission animals, low levels of abatement (1-5 Mt CO_2-e) may be possible from the current national livestock herd[4], though changes in the national herd size can result in increased absolute emissions from the livestock sector[9] even though emissions intensity per unit of live-weight produced is improved. Progress is being made by CSIRO, and partners, developing vaccines that may more cheaply reduce animal methane production and where success may substantially decrease the emissions intensity of livestock production. Simultaneous improvements in production efficiency and greenhouse gas emissions are possible with livestock (emissions are effectively lost production) and focusing on emissions per unit of product may be a way to meet the dual objectives of supporting Australia's food and agriculture production objectives and of minimising accountable greenhouse gas emissions.

CSIRO research does not support the proposition that for currently well managed rangelands the removal of grazing will detectably change carbon stocks in vegetation with the crediting life of CFI projects (99 years). Further research is being undertaken to explore if this is consistent in landscapes where there has been substantial over-grazing. Changes in fire regimes in rangelands and savanna, however, can both reduce emissions[10] and modelling suggests that it will increase carbon storage[11]. Where fire is currently used to manage woody shrubs, reducing fire frequency may adversely affect pasture and livestock production. Methodologies for emissions reduction for savanna fire management are well established and could be extended to other biogeographies, though logistics and capability will impose limits on the achievable abatement. Significant challenges exist however in developing low cost methodologies for crediting changes in vegetation and soil carbon changes in the rangelands due to challenges in spatial and temporal variability, and the need to assess low rates of change over large areas – the aggregate potential is large but the unit area change is small. Unlike avoided emissions from savanna burning, on-going management of fire will be required to maintain the carbon sequestered in rangelands and savannas. A cessation of management and a reversion to prior management regimes will see a loss of the carbon storage and an increase in greenhouse gas emissions during the period in which vegetation restores to its earlier state.

How to best encourage land sector activities

The timescale for which there is certainty of payment will have a major effect on the uptake of land sector abatement projects. Afforestation, avoided deforestation and changed forest management, rangelands carbon stocks and soil carbon projects all deliver carbon abatement over long periods, and require returns over long periods to be viable. Afforestation projects for example take a number of years to enter the steep part of the carbon accumulation curve in which they might stay for 20-30 years. Establishment costs accrue at the start of projects and take a number of years to generate a net positive return. Uncertainty about the mode of payments beyond an initial crediting period will act as a barrier to participation for such projects.

[7] *Harvested forests provide the greatest ongoing greenhouse gas benefits. Does current Australian policy support optimal greenhouse gas mitigation outcomes?* (2014, February 13). Retrieved from: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/434643/Harvested-forests-provide-the-greatest-ongoing-greenhouse-gas-benefits.pdf

[8] *LCI Forestry and Wood Products Project Report 4 for Forest and Wood Products Australia*. (2014, February 13). Retrieved from: http://www.fwpa.com.au/LCI_Forestry_and_Wood_Products_Project_4_for_Forest_and_Wood_Products_Australia

[9] *Australia's Emissions Projections 2012*. (2014, February 13). Retrieved from: http://www.climatechange.gov.au/sites/climatechange/files/files/climate-change/projections/aep-summary.pdf

[10] *WALFA-West Arnhem Land Fire Abatement project*. (2014, February 13). Retrieved from: http://www.nailsma.org.au/walfa-west-arnhem-land-fire-abatement-project

[11] *Tiwi Carbon Study: managing fire for Greenhouse gas abatement*. (2014, February 13). Retrieved from: http://www.csiro.au/Organisation-Structure/Divisions/Ecosystem-Sciences/Tiwi-carbon-study.aspx#savannaburning

The transaction costs of participating in a carbon offset scheme will determine the participation of the land sector in generating abatement.

Land-based activities may be adopted if co-benefits (production, livelihood or environmental) are generated by abatement projects even if returns from offset generation are low. If co-benefits are to encourage the uptake of land sector abatement activities, or if their generation from projects will be used as selection criteria, we need to be in the position of being able to define or negotiate among participants the production, environmental and social benefits.

Energy and resources sector

To achieve a secure, prosperous, lower emissions energy future in Australia and internationally, multiple technologies will be required, including a mix of existing and new technologies. CSIRO modelling and research has identified technology options that have a lower cost, feasible pathway to large-scale implementation and the potential to deliver significant carbon abatement for Australia in the following areas:

1. Fugitive emissions from coal mining – management and utilisation
2. CO_2 and flue gas enhanced coal bed methane
3. High efficiency power generation from coal – Direct Injection Carbon Engine
4. Commercial and residential building efficiency – commercial heating and cooling, residential building performance disclosure

More detail is provided below on each of these technology options.

1. Fugitive emissions from coal mining

In 2012, fugitive emissions were 48 Mt CO_2-e (representing 8% of Australia's total greenhouse gas emissions), of which 34 Mt CO_2-e were from coal mining[12]. Note that fugitive emissions are usually classified as those associated with the production, processing, transport, storage, transmission and distribution of fossil fuels such as coal, oil and natural gas.

Fugitive emissions are projected to reach 79 Mt CO_2-e in 2020 and 100 Mt CO_2-e in 2030[12]. This projected growth is driven by the increasing demand for Australia's energy and metallurgical coal exports.

The single largest part of these fugitive emissions is from coal, from both underground and open cut coal mines, projected to reach 57 Mt CO_2-e in 2020. The most significant source of coal fugitive emissions is gassy underground coal mines, representing 60% of all coal fugitive emissions[12].

Currently, ventilation air methane (VAM) emissions are about 80%[13] of the total fugitive emissions from underground coal mines. The remainder is largely from un-utilised or un-flared drainage gas.

CSIRO, in collaboration with government and industry, has carried out considerable work in developing methods to quantify fugitive emissions from coal mining, drainage gas capture maximisation and VAM abatement technologies to reduce emissions.

Most underground coal mine methane emissions are accessible for abatement, indicating that there is an opportunity to develop incentives that promote operation of "near zero fugitive emission" underground coal mines. With timely development and deployment of technologies, CSIRO calculates that it is possible to reduce the underground fugitive emissions by 70% in 2020. This will contribute a reduction of 24 Mt CO_2-e. Two major actions are recommended to deliver this underground coal mining emissions reduction:

- Maximise methane drainage to reduce VAM from 80% to 60% of underground mine fugitive emissions by enhanced drainage technologies and operations, and reduce drained gas fugitive emissions from 20% to 10% by increased flaring and utilisation; and
- Mitigate VAM by 50% through deployment of new technologies.

[12] Department of the Environment. *Australia's Abatement Task and 2013 Emissions Projections*, 2013.

[13] Moreby, R., Balusu, R., Yarlagadda, S., Ren, T., Su, S. *Strategic review of gas management options for reduced GHG emissions* (ACARP project C17057), 2010.

Beyond 2020, with further and wider adoption of new VAM and advanced drainage technologies, it is also possible that most of the underground coal mining fugitive emissions will be abated in 2030.

Methane drainage from underground coal mines

The Australian coal mining industry already has the expertise and technologies to design and operate mine gas drainage systems, including effectively managing safety risks associated with mine gas. A number of Australian companies have led the world in mine gas drainage. However, further work is needed to develop and implement drainage systems that increase the flow rate, quantity and quality of gases drained in difficult mining conditions (for example, deep, multiple seams, and coals with low permeability). In addition, there is a need for a fundamental shift across the industry from gas drainage that prevents the risk of outburst and controls gas concentrations in coal mine workings to gas capture and production that maximises the utilisation for power generation and flaring in order to minimise fugitive emissions. If mine gas is captured at greater than 25% methane concentration, it can be mitigated with existing power generation and flaring technologies at a relatively low cost.

CSIRO has carried out comprehensive research in gas emissions modelling and measurements, gas flow dynamics, drainage design and optimisation, and drainage operations. This has led to the development of new technologies that maximise mine gas capture and methane mitigation, and support industry in developing a holistic approach to mine gas management that delivers mine safety and emissions reduction benefits.

Costs for gas drainage and mitigation can vary significantly depending on individual site conditions. The most significant factors include in-situ seam gas content, composition, pressure and permeability, and mining layout and sequence. CSIRO estimates that the gas drainage unit cost is \$10-30/t CO_2-e. Based on preliminary analyses, the unit costs for drainage gas flaring or utilisation are \$1.5-3/t CO_2-e.

VAM mitigation technologies for underground coal mines

VAM presents a challenge to mitigate or use as an energy source because it represents the largest proportion of fugitive methane emissions from coal mines, the air volume flow rate is large and the methane resource is dilute and variable in concentration. A typical gassy mine in Australia produces ventilation air at a rate of approximately 150 to 600 m^3/s with a methane concentration of 0.2-1%. VAM concentration varies at different mines[14].

CSIRO has comprehensively studied VAM mitigation and utilisation from mine site sampling, from fundamental studies (theoretic analysis and laboratory scale experiments) to small pilot scale prototype unit development. To date, an exhaustive range of VAM mitigation and utilisation ideas and concepts, taking into account mine site VAM characteristics, have been developed and evaluated. Much of the work has focussed on the thermal or catalytic oxidation of very low concentration VAM. CSIRO has developed three VAM technologies that exhibit advantages over other technologies (VAMMIT, VAMCAT and VAMCAP). These technologies address technical and economic issues to allow cost-effective capturing, use and mitigation of VAM from various methane emission streams. Depending on specific mine site conditions, a combination of two or three VAM technologies could be configured for a VAM plant to maximise the amount of VAM mitigated and utilised, and to maximise its economic performance. In some cases, the use of just one technology at a mine site could be the most economical option. The three CSIRO technologies could be ready to be deployed within 3-5 years.

The estimated VAM abatement cost depends on electricity prices, VAM concentration, capital cost, operational and maintenance cost. Preliminary economic analyses by CSIRO show that for the VAMCAT units, the break-even carbon auction price would be in the range \$6 to \$1/tCO_2-e for 0.5-0.8% methane, respectively (assuming a mine site drainage gas price of \$2.6/GJ and electricity price of \$85/MWh). In comparison, thermal flow reverse reactor technology for VAM mitigation could require break-even carbon auction prices of \$18 to \$11/tCO_2-e for the same methane concentration.

[14] Su, S., Chen, H.W., Teakle, P., Xue, S. *Characteristics of mine ventilation air flows*. Journal of Environmental Management, 2008, 86: 44-62.

Emissions reduction from open cut coal mines

It is estimated that about 30% of total coal mining fugitive emissions are from open cut mines[15]. The quantity of gas present in several open cut mine areas was measured in order to estimate the emission factor per tonne of coal mined. This ranged from 16.3 m^3 CO_2-e/t of coal mined for one area to a low of 0.23 m^3 CO_2e/t for another mine site[16]. Using the higher emissions factor, fugitive emissions from a 10 Mt/year open cut mine could have approximately 0.3 Mt CO_2-e/year.

Improvements in coal price and mining technologies have allowed open cut mining operations to access deeper reserves. As open cut mines move deeper, the gas content of the coals being mined will increase significantly with associated increases in fugitive emissions of coal seam methane.

Gas drainage is not practiced in Australian open cut mines to date. Gas drainage could reduce fugitive emissions where conditions are suitable, using wells drilled into the gas bearing formations that will be disturbed by the mining process. In comparison, gas content and pressure are lower at open cut mines than that at underground mines, thus gas production rates would be low and consequently long periods of gas drainage would be required. In addition, factors affecting the gas flows are not well understood. Risks and costs of open cut mine gas capture will be higher than that of underground mines.

Enhanced coal seam methane drainage could provide a solution that involves injecting a contrasting gas into a coal seam. This injected gas acts to displace the coal seam methane from the coal, allowing it to be produced, see below. This strategy has received considerable attention for coal bed methane (CBM) production where several field trials have been performed. The attraction for coal seam methane is that a greater proportion of the original gas is recovered. For coal mining, it offers the potential of draining the gas associated with open cut mining more efficiently, allows the gas to be utilised, and significantly lowers the fugitive emissions associated with mining. Another benefit is that the rates of drainage are improved so that shorter lead times are required before mining.

Enhanced gas drainage to reduce the fugitive emissions for open cut mining was analysed based on combined experimental work with modelling of gas drainage and economics to investigate the overall feasibility. One analysis for nitrogen enhanced drainage of open cut mines to reduce fugitive emissions showed that, at a carbon auction price of $30/t, enhanced drainage would have a positive business case for 40% of the eastern Australian coal mines[17].

2. CO_2 and flue gas enhanced coal bed methane

Enhanced coal bed methane (ECBM) involves the injection of CO_2 or flue gas from a power station into a coal seam. The injected gas acts to increase the recovery of the methane within the coal compared with normal gas production and at the same time store the CO_2. This is a lower cost option for geological CO_2 storage due to being able to use existing wells and infrastructure and sell the additional produced methane.

For the eastern Australian coal seam gas producing fields it is possible to estimate the CO_2 storage capacity from the actual and forecast coal seam methane production up to 2020[18,19]. For CO_2-ECBM the CO_2 storage capacity is twice that of methane. For flue gas-ECBM the CO_2 storage capacity is estimated to be between 0.5 and 1 times that of methane. Based on these assumptions, and the cumulative gas production, 950–1,130 Mt of CO_2 could theoretically be stored when pure CO_2 is injected and 240–570 Mt of CO_2 could theoretically be stored when a flue gas stream is injected.

Typically an additional incremental recovery between 10 and 30% can be achieved as a result of CO_2 or flue gas injection. Based on the historic data and future production estimates this yields between 820 and 2,460

[15] Day, S., Saghafi, A., Carras, J., Fry, R. *Emissions roadmap resource manual: Report 1: Tier 2-Tier 3 reporting requirements for fugitive emissions from open cut coal mining* (ACARP project C15077), 2007.

[16] Saghafi, A., Roberts, D., Fry, R., Quintanar, A., Day, S., Lange, T., Hoarau, R., Dokumcu, C., Carras, J., *Evaluating a Tier 3 method for estimating fugitive emissions from open cut mining* (ACARP project C15076), 2008.

[17] Connell, L.D., Sander, R., Packham, R., Pan, Z., Camilleri, M., Heryanto, D., Lupton, N., *The feasibility of enhanced gas drainage for coal mine operation* (ACARP project C17055), 2010.

[18] EnergyQuest *EnergyQuarterly*, 2011.

[19] Former Queensland Department of Employment, Economic Development and Innovation, *2012 Gas Market Review and Update*, 2012.

PJ in additional methane recovered.

An initial analysis of flue gas ECBM in Canada[20] found that flue gas ECBM had a positive business case and that CO_2-ECBM needed an incentive in relation to the stored CO_2. A consideration is that there are CO_2 emissions associated with compressing gas for injection and for flue gas these may be significant relative to the quantity of CO_2 stored during ECBM. A detailed cost benefit is required to establish the economics of ECBM for Australian coal seam gas basins.

To assess the order of magnitude impact of a strategic ECBM roll out by 2020 it was assumed that 10-30% of the total CBM produced in the previous year can be recovered annually through the application of enhanced production strategies. Based on this and assuming ECBM commences in 2016 it can be estimated that 420-1,260 PJ of additional natural gas can be produced by 2020. The associated CO_2 storage potential over this period is estimated as 40-130 Mt for pure CO_2 injection and 10-70 Mt for flue gas injection. Note that this high-level analysis does not include a detailed assessment of the feasibility of this approach.

3. High efficiency power generation from coal (Direct Injection Carbon Engine)

The Direct Injection Carbon Engine (DICE) is a potentially game-changing power generation technology. The recent renewed interest and development of DICE is being driven by high oil prices and major advances in fuel preparation technologies. The modern version of the DICE engine uses an ultra-finely ground, low ash carbon based fuel mixed with water to create a liquid fuel, called micronised refined carbon slurry (MRC). The MRC is a liquid fuel, similar in consistency to wet paint, which can be used in highly efficient diesel engines with minor modifications.

A DICE provides highly efficient coal-based power generation with significantly less emissions than conventional coal-based generation technology and has the potential to provide a cost-competitive, lower emissions energy supply option in its own right. For example, CSIRO results have shown 20-50 per cent lower CO_2 emissions per unit of power when compared to existing black and brown coal fired generation technologies, respectively. This benefit can be doubled if bio-chars are used as fuel. It can contribute to further reductions in CO_2 emissions by providing back-up and load-following power to enable the cost-effective integration of intermittent renewables into the grid.

DICE also has the potential to lower power costs, enable more renewable energy penetration in the grid and potentially create a new export market for Australian black and brown coal. It is modular and requires smaller capital investment than conventional coal generation technology, which is well suited to Australia's current energy market environment.

CSIRO and industry partners have been involved in projects to assess MRC production and its use in a converted diesel engine. The partners are currently working towards a pre-commercial 1MW single cylinder engine trial in 2014/15 to demonstrate the full potential of the technology. Following a successful demonstration, the development of an engine for the commercial market is expected by 2018.

MRC fuel may be produced at significantly lower costs compared to conventional heavy fuel oil or even high cost unconventional gas and so could reduce power generation costs for remote or decentralised generators, as well as centralised base-load power.

CSIRO's energy modelling[21] shows significant growth potential for DICE technology, equivalent to the currently installed Victorian brown coal generation capacity in the scenario of a high gas cost future. In this scenario DICE could occupy a 15% market share in 2050, equivalent to emissions savings of approximately 10 Mt CO_2-e due to replacement of traditional coal fired generation technologies (assuming emissions from current coal generation technologies are approximately 1 tCO_2-e/MWh and that DICE produces 30% less emissions than these technologies).

[20] Wong, S., Gunter, W.D., Law, D., Mavor. M.J., *Economics of flue gas injection and CO_2 sequestration in coalbed methane reservoirs*. Greenhouse Gas Control Technologies: Proceedings of the 5th International Conference (GHGT-5), 2000.

[21] *CSIRO efuture, Explore scenarios of Australia's electricity future*. (2014, February 13). Retrieved from: http://efuture.csiro.au/

4. Commercial and residential building efficiency

Significant abatement opportunity exists through the large-scale deployment of tools which can improve the efficiency of both residential and commercial buildings. In particular, CSIRO would like to comment on opportunities in the following areas:

- Commercial heating, ventilation and air conditioning efficiency
- Residential building efficiency

Commercial heating, ventilation and air conditioning efficiency

Heating, ventilation and air conditioning (HVAC) systems typically account for approximately 43% of electricity consumption in commercial buildings in Australia, equivalent to emissions of 46 Mt CO_2-e per annum (2010 figures)[22,23]. This means there is a potentially significant opportunity for improved energy efficiency and emissions reductions in the existing building stock through better operations and maintenance practices, recommissioning procedures and emerging automated fault detection tools. These opportunities can be classified under the 'Commercial retrofit energy waste reduction' and 'Commercial retrofit HVAC' opportunities (at negative cost) recently identified in the Low Carbon Growth Plan[22,24].

Historically, building case studies suggest that virtually all buildings have some sort of HVAC operational problem, and the vast majority of buildings are not carefully commissioned[25,26].

Re-commissioning procedures (analogous to performing a comprehensive tune-up on your car) offer energy efficiency opportunities in existing buildings. The experience from the NSW OEH Energy Saver program shows that by using building tuning and recommissioning practices, buildings can save 5-10% of their utility cost and simple payback is less than 2 years, some less than 1 year[27]. A building commissioning meta-analysis of 643 buildings across 27 US states representing 9.2 million square metres of floor space showed a 16% median whole-building energy savings in existing buildings, at a cost of AUD$3.60 per square meter[28]. However, the process is manual and highly labour intensive.

A significant opportunity thus exists for emerging automated fault detection and diagnostics (FDD) and ongoing commissioning software tools for HVAC systems that are poised to facilitate significant energy savings and emissions reductions from the built environment.

A rigorous and systematic evaluation of the potential costs and benefits of emerging automated FDD tools needs to be undertaken in an Australian context to determine their efficacy across a range of commercial building types. However, an order of magnitude estimate can be made based on American studies[28] and experiences from implementing similar building software tools. Assuming an automated FDD delivers the same impact as a manual re-commissioning procedure, whole building energy savings can be estimated at 17%[28]. Greenhouse gas abatement from the implementation of automated FDD software for HVAC systems in 50% of Australia's commercial building stock would then result in savings of 4 Mt CO_2-e per annum (based on emissions of 46 Mt CO_2-e/year). Based on information from CSIRO industry partners, the estimated cost of implementing automated FDD software is $0.90/square metre, resulting in a cost of the order of $60 million for this deployment.

Residential building efficiency

There is also a significant opportunity for abatement in the residential building sector through the introduction of a voluntary or mandatory disclosure scheme in relation to their energy, water and

[22] ClimateWorks, *Low Carbon Growth Plan for Australia*, 2010.

[23] Former Department of Climate Change and Energy Efficiency, *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia*, 2012.

[24] ClimateWorks, *Low Carbon Growth Plan for Australia – 2011 update*, 2011.

[25] Claridge, D., Haberl, J., Liu, M., Houcek, J., Athar, A., *Can You Achieve 150% of Predicted Retrofit Savings? Is It Time for Recommissioning?*, Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings, Volume 5, 1994.

[26] Piette, M.A., Nordman, B., *Costs and benefits from utility-funded commissioning of energy-efficiency measures in 16 Buildings*, ASHRAE Transactions, 1996, 102 (1): 482-491.

[27] NSW Office of Environment and Heritage, *NSW Energy Efficiency Plan*, 2013.

[28] Mills E., *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*, report prepared for California Energy Commission Public Interest Energy Research, 2009.

greenhouse performance. The current lack of house specific information and prompts for householder action make it difficult for consumers to make informed decisions to reduce their energy costs. This leads to inefficient investment in building energy and water performance. There is an opportunity to improve the quantity and quality of information available about building performance in order to assist market participants (including buyers, sellers, tenants and landlords) to compare, value and act upon cost effective energy and water efficiency performance in residential buildings. To effectively implement such a scheme requires the availability of validated and widely accepted information tools similar to the NatHERS tools used in the new home construction industry.

In the 2011 mandatory disclosure regulatory impact statement by Allens Consulting Group[29], several regulatory options were proposed. The study suggests that implementing a full thermal assessment tool could save 16Mt CO_2-e over a 10 year assessment period. The study assumes costs and complexity based on existing tools. CSIRO is currently developing a new simplified, cloud based tool that has potential to greatly accelerate data entry through tablet based geometric rendering and reduced data input requirements. Current analysis indicates that calculation rigour and application flexibility can be maintained in a tool that is consistent with existing regulations for new homes. This new tool will be available in around 18 months and could potentially deliver a full thermal assessment for the same cost as methods currently used for simplified thermal assessments (approximately $172.50 assessor and $25 householder waiting cost).

[29] Allen Consulting Group, *Mandatory disclosure of residential building energy, greenhouse and water performance, Consultation Regulation Impact Statement*, 2011.

Methods to ensure genuine and additional emissions reductions

CSIRO would like to comment on two specific aspects in relation to this question, the design of low-cost methodologies that retain environmental integrity, and the measurement of fugitive emissions associated with coal mining.

Low-cost methodologies that retain environmental integrity

CSIRO strongly endorses the principle of environmental integrity; abatement whether from the land sector or elsewhere must be real, additional and permanent. Realising the opportunities in the land-sector requires the development of low cost methodologies that retain environmental integrity: what is required is confidence in the credited level of abatement, not precision in the sequestered level of carbon. Generation of abatement from native forests and rangelands, for example, could be facilitated through conservative activity based emissions reduction factors (related to, for example, changed practice or changed ecological state) supported by on-going national programs of underpinning verification, examples of the latter being AusPlot[30] with supporting carbon measurements.

Measurement of fugitive emissions associated with coal mining

For underground coal mines, measurements of methane capture and abatement with gas drainage systems are usually reasonably robust. Most systems are set up so that the drained gas is piped through a reticulated network with gas flow and composition measured using conventional industrial instrumentation. Operational data of methane power generation equipment and flares can be used for abatement reconciliation.

For VAM from underground coal mines, current practices of abatement verification in Australia, China and the USA use the continuous monitoring of flow rates and gas compositions, and then net emissions reduction can be calculated for each VAM unit. Direct measurement of emissions requires information on the flow rate and composition of the ventilation air and, if present, the gas drainage system. Usually emissions associated with ventilation air can be calculated from the flow rates measured, and average methane and CO_2 concentrations determined with tube-bundle systems over a time frame such as hourly or daily. Improvements to concentration measuring instrumentation, and particularly flow rate measurement would substantially increase the accuracy of measuring the methane emissions through the ventilation air.

For open cut coal mines, accurate measurement and quantification systems provide not only a verification mechanism for emissions but also data and information that help in predicting the long term magnitude, quality and sources of methane emissions and developing potential abatement methods**.**

CSIRO has carried out considerable work which formed the basis of Methods 1, 2, 3 in the *National Greenhouse and Energy Reporting* (NGER) determination[31] for estimating emissions from open-cut coal mines.

Method 1 is based on the use of an emission factor derived from actual measurements of emissions in some mining regions in NSW and QLD. Under Method 1 for open cut coal mine emissions, the National Inventory default factors are applied at the state level to all mines in the state and provide the basis for a simple, low cost method of emission estimation. However, there is evidence to suggest that Australia's coal mines exhibit a wide variability in coal gas content, reflecting varying geological histories of each field.

The Australian Coal Association through ACARP has funded CSIRO research into alternative, more accurate methods. As a result of that work, a method was developed that relies on measuring in-situ gas content of coal and gas bearing strata ahead of mining. The method is mine-specific and much more accurate than the previous method and has been adopted as Methods 2 and 3 in the NGER Determination.

[30] *AusPlots Rangelands Survey Protocols Manual*. (2014, February 13). Retrieved from: http://tern.org.au/AusPlots-Rangelands-Survey-Protocols-Manual-pg23944.html

[31] Former Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, *National Greenhouse and Energy Reporting System Measurement. Technical guidelines for the estimation of greenhouse gas emissions by facilities in Australia*, 2013

While Methods 2 and 3 are substantial improvements over the state-based emission factor methodology, the dedicated coring required to collect the necessary data represents a significant cost to mine operators. Moreover, the methodology provides infrequent periodic measurements which may not adequately account for variations in mine emissions throughout the reporting year. There is a need for more accurate, efficient and cost effective fugitive emissions measurement methods.

Emission estimation methods that attempt to identify and characterise all the emissions sources (whether point, line or area) and then aggregate these to produce a total emission rate are commonly referred to as 'bottom up' methods. The 'bottom up' approach can further be improved with modelling of gas emissions using advanced coupled mechanical-fluid modelling codes such as CSIRO's COSFLOW, based on specific gas reservoir and mining condition. This also provides an insight into gas emissions mechanisms to support potential emission abatement of emissions at open cut mines.

An alternative approach is to use 'top down' methods. 'Top down' methods generally refer to techniques that provide integrated values of total emissions without necessarily apportioning emissions to individual sources.

The use of 'bottom up' and 'top down' methods in combination provides the greatest power in determining emissions and serves to provide a cross-check on each approach, identify gaps in the 'bottom up' approaches and improve the overall accuracy of emissions inventories. An inverse method developed in the atmospheric sciences could provide a new and better approach where elements of the 'bottom up' and 'top down' approaches are brought together to maximise the information obtained. The inverse method measures a concentration time series of a particular species (or number of species) and then uses a meteorological conditions and atmospheric transport model to back calculate emission strengths and locations.

How to best operate an efficient auction process to secure lowest cost emissions reductions

A recent CSIRO report (*Designing Auctions for Different Environmental Commodities*[32]) discusses various aspects of auction mechanism design. A key issue is the choice of pricing mechanism. Here, economic theory, laboratory experiments and real-world experience indicate that the uniform-pricing format is in the majority of circumstances the most efficient mechanism, particularly for repeated auctions targeting well known commodities such as water and carbon. The discriminatory price ('pay as bid') format is generally less effective at revealing true costs, resulting in higher prices being paid on average (or in a budget-constrained auction, a lower quantity being purchased). However, if an auction is likely to be dominated by a small number of sellers, offering supply schedules rather than single projects, the choice of auction format is less clear cut. And for auctions targeting less tangible commodities and public goods (for example, biodiversity), the discriminatory price format may sit better alongside other environmental policy tools such as awareness and extension campaigns.

The more bidders that participate in an auction, the greater the competition and the better the outcomes are likely to be for the buyer. Where multiple rounds are required (for example, due to the large scale of the program), increasing the length of time between auctions, and not guaranteeing that future rounds will go ahead, should enhance the level of competition in any given round. Fewer rounds, with more participants in each, will provide a more competitive market.

A reserve price is highly recommended in any auction, to reduce the risk of paying excessively high prices; it should be kept confidential to avoid providing an anchor for bid prices. A buyer should also retain some discretion as to the budget to be allocated in order to respond to greater or lesser numbers of competitive bids in any given auction round.

Environmental auctions often have the potential to deliver a range of benefits in addition to the targeted commodity. For example, some carbon projects offer substantial other environmental and social co-benefits such as biodiversity or Indigenous cultural values. These can be sought alongside carbon in an auction, through eligibility criteria or weighting projects based on their co-benefits, but this will inevitably come at a cost in terms of the price of quantity of carbon that can be purchased.

[32] *Designing Auctions for Different Environmental Commodities.* (2014, February 14). Retrieved from: http://www.csiro.au/Portals/Publications/Research--Reports/designing-auctions-environmental-commodities-report.aspx

The potential effect of ongoing uncertainty on technology cost and uptake

In the energy and resources sector, investments often involve construction of infrastructure that will only provide their full return to investors over a long time period (for example, 15-20 years). In planning such projects, investors will not only consider current market conditions and policy but also carefully consider the potential for change over time and its impact on the return on the investment. If uncertainty about future earnings is too high investment decisions will generally be delayed to allow some of the uncertainty to be resolved.

Similarly in the agricultural sector, afforestation, avoided deforestation and changed forest management, rangelands carbon stocks and soil carbon projects all deliver carbon abatement over long periods, and require returns over long periods to be viable. Afforestation projects, for example, take a number of years to enter the steep part of the carbon accumulation curve in which they might stay for 20-30 years. Establishment costs accrue at the start of projects and take a number of years to generate a net positive return. Uncertainty about further payments beyond an initial crediting period will act as a barrier to participation for such projects.

Options for streamlining the Carbon Farming Initiative

Simplifying methods and, where possible, incorporating models and processes used in the National Inventory has been identified in the Green Paper as a possible means of streamlining the CFI. CSIRO would like to make two points in relation to this suggestion, the first relating to livestock emissions modelling and the second to modelling of soil carbon.

To enable livestock CFI projects based on improvements in productivity, it would be advantageous for the National Inventory livestock model to be stepped down to operate at a regional level (it is currently state based). This could be done, within the same framework as the current national approach, by sourcing regional estimates for live weight, live weight gain and feed quality. Once this is implemented, greenhouse gas abatement at the CFI project level can be reflected as changes in the national accounts.

With regard to soil carbon modelling, without quantification of uncertainty in the models used, it may be highly misleading to use National Inventory approaches for CFI projects. This is because the national accounts for soil carbon are estimated for large areas where the various under and over estimates due to local variations in soil, climate and management tend to cancel each other out. This gives a robust estimate at the national level but is not good for paddock estimates. At the CFI project level the scale is much smaller and until models are appropriately scaled to deal with this, including the ability to define uncertainty and confidence intervals, our recommendation is that soil carbon CFI methodologies use a measurement route and the application of classical statistics to the data generated to define critical soil carbon stocks and stock changes, with a defined probability of exceedance. In the meantime, further soil carbon model development is highly recommended to allow methodologies to be simplified over time.

The proposal to include Facility as well as Activity methodologies is welcomed and may provide a means for reducing transaction costs in the land sector if it allows for vertical (through the supply chain in which processors may collect on behalf of suppliers) and horizontal (multiple but similar activities being collected and assigned average credits, or whole of farm greenhouse gas abatement approaches under the one methodology) aggregation.

The Green Paper proposes that under the Emissions Reduction Fund, consideration could be given to more frequent reporting and credit arrangements, for example, every six months. This unlikely to add value to land sector based projects. As already indicted, many projects will take extended reporting periods (>5 years) to allow improvements in carbon storage to be detectable against the background of seasonal variation or to recoup upfront costs of implementation through longer term sequestration. Hence, going to a shorter reporting period will not add utility and would significantly increase cost of land-based activities. Even with more certain sequestration projects, such as tree plantings, six monthly reporting is unlikely to add utility, as in most environments rainfall tends to be winter or summer dominant with the majority of growth occurring when moisture is available, and little in the drier period. Therefore, a six month period adds little to the ability to measure and credit carbon. However, with CFI projects based on avoided emissions such as methane captured from piggery ponds or avoided by feeding oils to dairy cattle, there may be cash flow advantages to project proponents of more regular payments.

The possibility of using a risk-based approach to auditing CFI projects is raised in the Green Paper. Self reporting with verification through random risk-based audits would simplify the scheme and lower transaction costs. There is a substantial game-theoretic literature around optimal fines and monitoring rates. However, it should also be noted that individual decision-makers are usually risk averse, tend to value doing the right thing and care about their reputations, so compliance often exceeds game theoretic predictions. The same applies to corporates, with reputation being particularly important. However, overly game-theoretic compliance mechanisms are more likely to engender game-theoretic responses, which could reduce compliance.

Maintaining uncertainty (i.e. unknown probability of audit), as opposed to known risk, is likely to enhance compliance and reduce the potential for gaming the system. Monitoring probabilities can be risk weighted, based on the scale of the project and the expected level of variability between different projects under a methodology. Modelling can be applied to design the optimal monitoring scheme, depending on project and methodology characteristics and overall policy objectives.