Australian Government

Department of Climate Change
and Energy Efficiency

CARBON FARMING INITIATIVE

Draft methodology for savanna burning

Disclaimer

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Interim assessment application template

Instructions for proponents

This template must be completed and used by proponents applying for assessment of a draft methodology by the DOIC. It incorporates:

1) details of a draft methodology, including detailed instructions to project proponents on how to implement and monitor a project for the specified eligible activity; and
2) supporting evidence to enable the DOIC to assess the draft methodology against the offsets integrity standards and other requirements specified in these guidelines.

The instructions on project implementation and monitoring will form the basis of the methodology determinations made by the Minister for Climate Change and Energy Efficiency. This information is to be provided in the blue boxes. If the methodology is assessed to meet CFI requirements, the information in the blue boxes would form the published approved methodology. As the published methodology will be used by project proponents to implement and monitor their projects, instructions should be clear and all technical terms should be defined.

Supporting evidence is to be provided in the green boxes. This information would not be contained in the published approved methodology, but will be made publicly available during the public comment period as part of the DOIC's assessment. Methodology proponents may submit a draft project plan as an example.

If a proponent wishes for any information provided as supporting evidence to be exempt from public disclosure, the information must be clearly marked 'CONFIDENTIAL'. An explanation of why this information should not be published during the public comment period should be provided in Section 14 of the template. Where the DOIC requires more information from a proponent on why the information should not be published, it may seek additional information from the proponent.

Draft methodologies that include confidential information in blue sections will not be considered by the DOIC and will be returned to the proponent.

Methodology proponents may wish to include the names and affiliations of technical experts consulted in the development of the methodology. The DOIC would seek permission from the expert to include their names in the draft methodology before it is released for public comment.

A general glossary of terms is provided at the back of the template. A glossary of terms specific to the methodology can be provided in Section 4 of the template. The definitions of terms in the methodology glossary should be consistent with definitions in the CFI legislation and the general glossary provided.

Methodology applications should be submitted to:
DOIC Secretariat
Department of Climate Change and Energy Efficiency
GPO Box 854
CANBERRA ACT 2601

Or DOIC@climatechange.gov.au

Section 1: Applicant details

Name:	Methodology Development Team
Company:	Department of Climate Change and Energy Efficiency
Position:	
Telephone:	
Email:	
Address:	PO Box 854, Canberra, 2600
Postal address (if different to above):	

Section 2: Expert consultation

Have you consulted technical experts in the development of this methodology? If yes, please provide names and affiliations.		
Name	*Affiliation*	*Does this expert endorse all or part of the draft methodology?*
Jeremy Russell-Smith	North Australian Indigenous land and Sea Management Alliance (NAILSMA) / Charles Darwin University (CDU)	All
Mick Meyer	CSIRO	All
Peter Whitehead	NAILSMA	All

Section 3: Existing methodologies

3.1 Has a similar methodology already been approved for use under the CFI? If yes, outline how the new methodology proposal is different.
No

3.2 Is the draft methodology an adaptation of an existing methodology that has been approved under an international offsets scheme or an offsets scheme in another Australian jurisdiction? If yes, provide a reference for the existing methodology and describe any major differences between the draft methodology and the existing methodology.
No

Section 4: Methodology glossary

Provide a glossary of terms that are specific to the draft methodology.

AVHRR – The Advanced Very High Resolution Radiometer (AVHRR) is a space-borne sensor with a pixel size of approximately 1 km^2.

Fire scar area – The area bound by the burn perimeter of a fire.

MODIS – Moderate Resolution Imaging Spectroradiometer (MODIS) is a space-borne sensor with a pixel size of approximately $250m^2$.

Pixel – A single point in a raster map.

Raster map – Raster maps are a type of Geographic Information System (GIS) map where each pixel is allocated a specific value.

Savannas – Tropical and sub-tropical formations with continuous grass cover occasionally interrupted by trees and shrubs (IPCC, 1997).

Strategic EDS burning – the planning and implementation of burning practices in the EDS that reduce fuels and create burnt fire breaks in the landscape.

Waypoint – A set of coordinates that identifies a point in physical space.

Section 5: Methodology (or activity) scope

5.1 Describe the specific abatement activities, technologies or management practices to which the methodology applies. Explain how the abatement activities, technologies or management practices will reduce or avoid emissions or remove and sequester greenhouse gases from the atmosphere.

Abatement activity

The abatement activity covered by this methodology is the use of controlled fire management across savannas in the fire prone tropical north of Australia to:

- reduce the area of a project that is burnt each year; and / or
- shift the seasonality of this burning from the late dry season (LDS) towards the early dry season (EDS).

EDS fires are characterised by low intensity, a high degree of patchiness, a greater propensity to extinguish spontaneously, and reduced total fuel consumption. LDS fires are characterised by high intensity, low levels of patchiness, a greater propensity to spread, and high total fuel consumption. The result of a shift from predominantly LDS to predominantly EDS fires is a net reduction in fuel consumed per unit area and area burnt. This generates a corresponding reduction in methane (CH_4) and nitrous oxide (N_2O) emissions released by fire per unit area.

This methodology applies only to methane and nitrous oxide emissions released by fire. The carbon dioxide released by fire is reabsorbed by the landscape in the next growing season (IPCC, 1996).

This abatement activity involves the application of a strategic EDS burning regime to reduce the risk and extent of LDS fires. Strategic EDS burning involves planning for, and implementation of, burning practices that reduce fuels and create more-or-less continuous burnt fire breaks in the landscape. For example, in the EDS fire breaks may be burnt alongside road or fence line corridors, or onto relatively moist fuels along water courses, to help reduce the risk of fire spreading in the LDS. At a landscape scale, an effective EDS fire break system consists of a network of inter-linking burnt patches and corridors. There is a number of ways to undertake strategic EDS burning, including igniting fires from aircraft, from vehicles along the sides of roads and tracks, from boats on waterways, or by walking across country. The specific location, timing and method of prescribed burning will depend on landscape features within the project areas and local weather conditions. The specific approach to strategic EDS burning is not prescribed in this methodology.

5.2 List the circumstances or conditions under which the activities, technologies or management practices are to be implemented. If they can be implemented under different circumstances or conditions (for example, climatic conditions, soil types and other regionally specific conditions), specify any differences in implementation for each of the different circumstances or conditions.

This methodology is applicable in project areas across high rainfall savannas in the fire-prone tropical north of Australia.

The abatement activity can only be implemented under specific circumstances. Projects must:

- be located in an area that receives an average of more than 1000 mm of annual rainfall. Figure 1 provides an indicative illustration of areas that receive more than 1000 mm of rainfall (areas in dark blue are eligible under this methodology). Section 11 sets out the reporting requirements for providing evidence of rainfall;
- be located in an area that is subject to an extended dry season during which the grass fuels cure annually and fires regularly occur; and
- contain only the vegetation classes as defined in Section 9.1 of this methodology. These vegetation classes are:
    - eucalypt open forest with tussock grass ground layer (EOF);
    - eucalypt woodland, with tussock grass ground layer (EW);
    - sandstone woodland with a mixed tussock and/or hummock (Spinifex) grass ground layer (SW); and
    - sandstone heath with a ground layer dominated by hummock grasses (Spinifex) (SH).

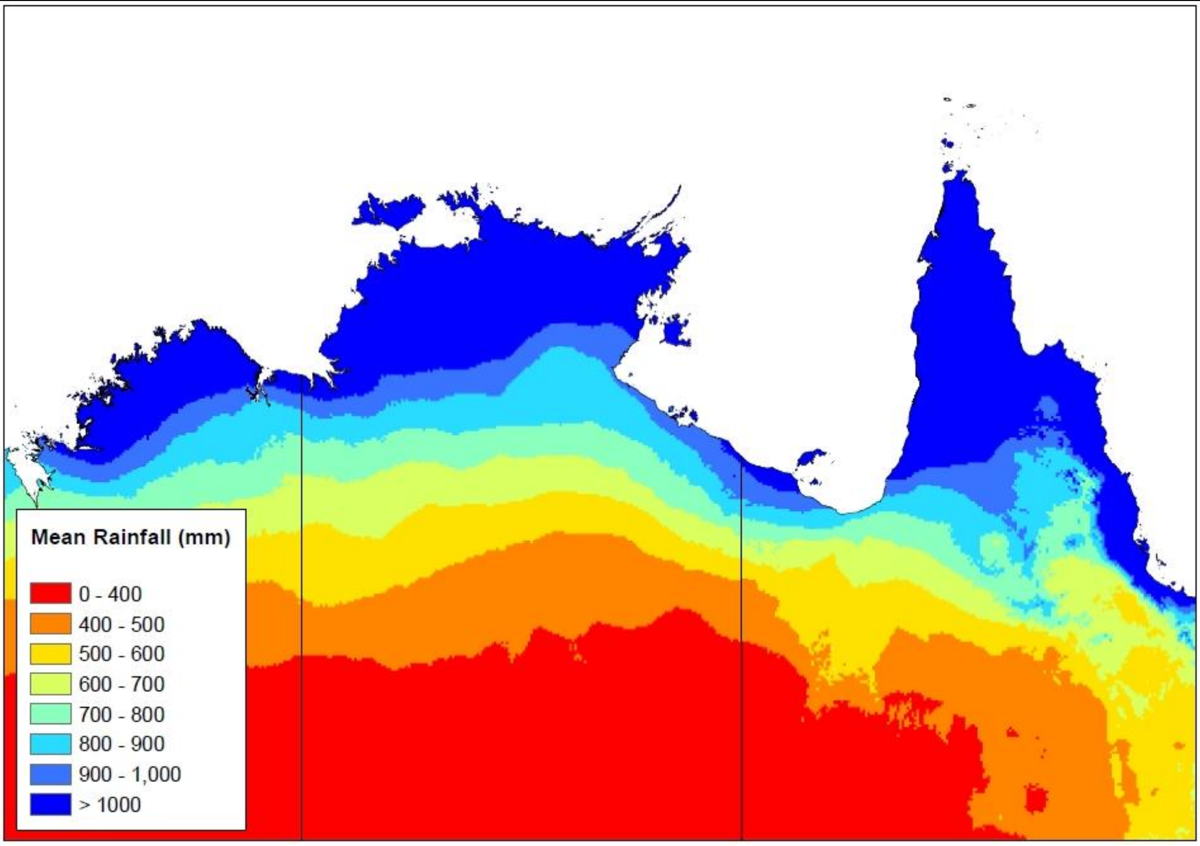
A new methodology will be required for other regions and vegetation classes.

This abatement activity requires that reductions in the area of fire and / or emissions released from fire per unit area (and the subsequent abatement generated) must be achieved by planned and purposeful deployment of prescribed EDS burns in combination with other natural and constructed barriers to stop the spread of fire. Active extinguishment of fires may also be used.

Project proponents cannot reduce the fire area within the project area by inducing an increase in LDS fires to create fire breaks immediately adjacent to the project area.

Other indirect methods for reducing fire area and emissions released from fire per unit area, such as the introduction of cattle to a project area, are not eligible abatement activities under this methodology. Cattle may be present on the project area but cattle should not be introduced, nor should cattle stocking rates be increased, to reduce fuel loads and emissions from fire under this methodology.

Figure 1: Average annual rainfall in Australia (indicative)



Sourced from Bureau of Meteorology monthly rainfall data

5.3 (Optional) Provide background information about the abatement activities, technologies or management practices. This could include case studies that demonstrate the successful implementation of the abatement activities, technologies or management practices

<u>Information on the scope of this methodology</u>

This methodology applies to specific nominated vegetation classes in areas that receive an average of over 1000 mm of annual rainfall. This methodology could be expanded to include new vegetation classes over time.

<u>Background on the abatement technology</u>

The annual weather patterns in Australia's savannas are characterised by a 3-5 month wet (growing) season followed by an increasingly fire-prone dry season.

On average, LDS fires emit 52% more emissions per unit area than do EDS fires (Russell-Smith et al., 2009). Unlike intense wildfires (~100,000 $kW.m^{-1}$) in southern temperate eucalypt forests and woodlands, nearly all savanna fires, including in the LDS, are typically of substantially lower intensity (from <<1000 - ~10,000 $kW.m^{-1}$) (Williams *et al*. 2003) and consume surface and near surface fuels only (i.e. not a crowning fire) and do not propagate ahead of the active fire edge.

Fine fuel (grass plus litter) accumulation varies with habitat conditions; in woodland and open forests it tends to plateau out after several years of having been burnt previously. In Spinifex dominated systems accumulation may continue to occur over longer periods. Significantly, various studies have shown that in savanna systems receiving at least 600 mm annual rainfall fires can recur annually under LDS fire conditions (Yates & Russell-Smith 2003; Edwards & Russell-Smith 2009; Russell-Smith *et al.* 2010).

This abatement technology does not rely on increasing sequestration in the landscape over time. Rather, the abatement activity is based on comparing a project's emissions (with management) against a pre-project (no management) baseline. This means that any abatement achieved by a fire management project in one year would be unrelated to fire regimes in future years because the fuel load sufficient for further ignitions are reset at the end of each wet season.

How does fire abatement reduce greenhouse gas emissions?

Biomass (in the form of carbon and nitrogen) in tropical savanna systems is recycled to the atmosphere through two alternative pathways: through fire, or through microbial decomposition. Reducing fire frequency reduces greenhouse gas emissions from savannas because a reduction in fire frequency means that more of the litter is decomposed/consumed via the microbial pathway, compared with the fire pathway. The microbial pathway produces fewer emissions per unit of litter than the fire pathway (Cook & Meyer 2009).

Biological decomposers and consumers of litter, such as termites, can emit CH_4. However, net CH_4 emissions from the microbial pathway are close to zero because the emissions are oxidised in the soil by methanotrophic bacteria (bacteria that are able to metabolize methane as their only source of carbon and energy) (Cook & Meyer 2009).

Biological decomposition of litter releases organic nitrogen into the soil and N_2O is released through microbial processes of nitrification and denitrification. Rates of N_2O emissions from savanna soils (Livesley et al. in press) and rangelands soils (Galbally et al. 2008) have been found to be low, which is likely due to low N availability and tight N cycling in these soils (Bustamante et al. 2006). Recent Australian research has found that soils from N-depleted savanna systems may be either a slight source or sink of N_2O, with no discernable fire effect on soil N_2O exchange (Livesley et al., in press).

Background on savanna fires

Emissions from savanna burning contribute between 2-4% of Australia's annual National Greenhouse Gas Inventory (DCCEE 2011), depending on the severity of the fire season.

Nearly all fire extent in the northern savannas is attributable to human (anthropogenic) sources of ignition (Russell-Smith *et al*. 2007). Human ignitions result from a variety of accidental (e.g. sparks from machinery, escaped planned fires) and deliberate (e.g. landscape management, arson) causes. Typically, EDS fires will extinguish overnight under dewy conditions. Later in the dry season, under low humidity and fully cured fuel conditions, fires will burn through the night. In situations where strategic prescribed burning (e.g. burning of fuel-breaks under early season conditions) hasn't been effectively undertaken, fires ignited in the latter half of the season can (and regularly do) burn unchecked across substantial tracts of country (>1,000 km^2), and will generally only self-extinguish when they reach a fuel break such as a road or a large river or, in the instances of very large fires, with the arrival of the wet season. Importantly, given very low rural population densities (comprising mostly Aboriginal people, but also people on pastoral stations, living in remote community settings) and limited economic activity across much of fire-prone northern Australia, there are very limited infrastructure, human, and financial resources available to manage fires at the scale that currently occur across the tropical savannas (Whitehead *et al*. 2003).

The current fire regime across the tropical savannas can be traced back to at least the start of the twentieth century, associated with rapid collapse of Aboriginal societies and resultant breakdown in customary modes of landscape fire management (e.g. Cooke 2009; Ritchie 2009). Despite such a collapse, a relatively clear and consistent account of customary Aboriginal fire management practice for the northern savannas is available from historical and ethnographic sources (Russell-Smith *et al*. 2003), and contemporary accounts (Yibarbuk *et al*. 2001). In short, Aboriginal people used (and in places still use) fire to actively manage landscape resources (and for a variety of other reasons, e.g. Garde *et al*. 2009) throughout the year, commencing with extensive but targeted burning in the EDS to facilitate access and generally reduce fuels in strategic locations ('breaking up the country'), in preparation for using more intense (and potentially extensive if not managed) fires later in the season (e.g. for hunting purposes). Across much of northern Australia, anecdotal evidence suggests customary Aboriginal landscape fire management practices were substantially supplanted by contemporary patterns by the early- to mid-twentieth century (e.g. Cooke 2009; Ritchie 2009).

<u>Case study: Western Arnhem Land Fire Abatement project</u>

A voluntary carbon market project applying this abatement activity currently exists. It is called the Western Arnhem Land Fire Abatement (WALFA). The WALFA project grew out of concerns expressed by traditional owners in the mid-1990s concerning the lack of fire management on the Arnhem Plateau, and in particular, their lack of capacity to access country and fulfil their customary management obligations. Funding for the program, focusing mostly on engagement of regional communities and capacity building, commenced in 1996 through the Natural Heritage Trust in recognition of the cultural and biodiversity values of the region. At the same time a research collaboration with the Tropical Savannas Cooperative Research Centre began to examine opportunities, as allowed for under the Kyoto Protocol, for undertaking greenhouse gas emissions abatement through prescribed fire management as a means for developing economically sustainable management.

In 2006 a 17-year voluntary offsets agreement between Darwin Liquefied Natural Gas (a subsidiary of the multi-national energy corporate, ConocoPhillips), the Northern Territory Government, and local land owners, commenced operation over 28,000 km^2 of the Arnhem Plateau, adjoining Kakadu and Nitmiluk National Parks. The agreement stipulates the provision of annual abatement of 100,000 t.CO_2-e against a pre-project business-as-usual baseline determined as the average emissions from savanna burning of the accountable gases methane (CH_4) and nitrous oxide (N_2O) over the ten-year period 1995-2004. The injection of substantial operational funding has resulted in a significant change in the seasonality of burning from 2007 to the present—from a fire regime previously consistently dominated by LDS wildfires, to one now reflecting a concerted effort to deliver a strategic prescribed EDS program.

This project has been successfully delivered more than 100,000 tonnes CO_2-e of abatement per annum over six years.

Importantly, the contemporary fire management regime is also delivering social, cultural, and environmental benefits.

Section 6: Identifying the baseline

6.1 Specify the process for identifying the project baseline.
A project's baseline will be the estimated average annual CH_4 and N_2O emissions from the project area in the 10 years immediately preceding project commencement. Where strategic fire management has been implemented within the project area for a period of at least one year but no more than six years immediately prior to project commencement, the baseline emissions can be estimated as the 10 years preceding this period of fire management. Baseline emissions will be calculated by determining the average annual emissions in the baseline period. Annual emissions are determined by calculating the potential emissions for each pixel of a project if it were burnt and multiplying this value by the area of the project that was actually burnt. The potential emissions are determined by burning efficiency, fuel loads, emissions factors, carbon content, and the nitrogen to carbon ratio (for N_20 only). The area of a project that is actually burnt is determined by the area of a project exposed to fire multiplied by the patchiness of the fire. The process for calculating annual emissions is described in detail in Section 9. The same process will be used for calculating annual emissions in the baseline period and the project period.

6.2 List and justify the assumptions on which the baseline is based.
The baseline period of 10 years provides a reliable long term sample of emissions from unmanaged fire in project areas. The 10 year baseline period is based on typical fire return intervals for relevant sites in the savannas (Edwards & Russell-Smith 2009, Russell-Smith et al., 2009). For example, fire interval data in a voluntary market carbon project area of West Arnhem Land show fires in consecutive years in 55% of pixels, with 83% of pixels experiencing another fire in two years or less. These fire return intervals are similar in other fire prone regions of the high rainfall areas of the savannas (Edwards & Russell-Smith 2009). A 10 year baseline period will therefore cover a number of fire cycles and provide a reliable baseline for estimating the emissions from project areas when fire is unmanaged or managed under a different management regime. For these projects, the calculation of baseline emissions would not accurately represent the emissions in the absence of the CFI if they were to be made over a time period that included government funded fire management. Consequently the methodology allows for the calculation of baseline emissions over the 10 year period immediately preceding government funded fire management. The methodology specifies that the end of the baseline period can be no more than six years prior to project commencement to ensure that project proponents do not have an unconstrained choice of baseline.

Section 7: Greenhouse gas assessment boundary

7.1 Describe the steps and/or processes involved in undertaking the abatement activity and identify

all emissions sources and sinks directly or indirectly affected by the activity.

Identify any emissions sources or sinks affected by the activity that will be excluded from the greenhouse gas assessment boundary.

Flowcharts may be used to illustrate typical greenhouse gas assessment boundaries.

This abatement activity involves the application of a strategic EDS burning regime that reduces the spatial extent of LDS fires. Fires could be ignited from aircraft, from vehicles, or on foot. The specific approach to strategic burning is not, however, prescribed in this methodology.

The successful implementation of this abatement activity reduces CO_2, CH_4 and N_2O from the combustion of fires. The CH_4 and N_2O emissions are included in the greenhouse gas assessment boundary. The CO_2 emissions are not included in the greenhouse gas assessment boundary as the CO_2 emitted is recaptured in vegetation during the next growing cycle (IPCC 1996).

The implementation of this abatement activity may involve fuel use, for example petrol and diesel in vehicles and drip torches, which generates CO_2, CH_4 and N_2O. Emissions from fuel use for both implementing managed fire and the validation of project data are included in the greenhouse gas assessment boundary.

A reduction in the frequency and spatial extent of LDS fires means more of the biomass is decomposed via microbial pathways. Directing more biomass through the microbial decomposition pathway does generate some emissions. However, emissions from the microbial decomposition pathway are very small compared to emissions from the biomass combustion (fire) pathway (per unit of litter consumed) (Cook and Meyer 2009).

Biological decomposers and consumers of litter can emit CH_4. In the savannas of northern Australia, termites are major consumers of litter and emit CH_4 as a by-product of microbial metabolism of food in their gut. However, savanna soils act as a CH_4 sink because of the oxidation activity of methanotrophic bacteria. Although biological decomposers and consumers of litter emit CH_4, the proximity of the soil, which is a CH_4 sink, means that net CH_4 emissions from biological decomposition are close to zero (Cook and Meyer 2009).

Biological decomposition of litter releases organic nitrogen into the soil and N_2O is released through microbial processes of nitrification and denitrification. Rates of N_2O emissions from savanna soils (Livesley et al. in press) and rangelands soils (Galbally et al. 2008) have been found to be low, which is likely due to low N availability and tight N cycling in these soils (Bustamante et al. 2006). Recent Australian research has found that soils from N-depleted savanna systems may be either a slight source or sink of N_2O, with no discernable fire effect on soil N_2O exchange (Livesley et al., in press).

Emissions from the microbial decomposition pathway are excluded from the greenhouse gas assessment boundary on the grounds that they are insignificant.

7.2 In the table below:

List all emissions sources and sinks affected by the project. Indicate whether the source or sink is to be included or excluded from the baseline or greenhouse gas assessment boundary and provide justification for any exclusions.

All emissions sources and sinks identified in Section 7.1 should be listed in this table. Expand the table to include additional sources and sinks, as necessary.

Additional information justifying the exclusion of emissions sources and sinks can be provided in Section 7.3.

Source		*Greenhouse gas/carbon pools*	*Included / excluded*	*Justification for exclusion*
Baseline	*Source 1* *Biological decomposition of vegetation*	CO_2	Excluded	These emissions are excluded as they considered to be recaptured during the next growing cycle (IPCC, 1996).
		CH_4	Excluded	Emissions from decomposition are offset by methane oxidation in the soil
		N_2O	Excluded	Insignificant emissions source
	Source 2 *Burning of flammable living and dead vegetation (fine, coarse and heavy fuels, and shrubs)*	CO_2	Excluded	These emissions are excluded as they considered to be recaptured during the next growing cycle (IPCC, 1996).
		CH_4	Included	
		N_2O	Included	
Project Activity	*Source 1* *Biological decomposition of vegetation*	CO_2	Excluded	These emissions are excluded as they considered to be recaptured during the next growing cycle (IPCC, 1996).

		CH_4	Excluded	Emissions from decomposition are offset by methane oxidation in the soil
		N_2O	Excluded	Insignificant emissions source
	Source 2 *Burning of flammable living and dead vegetation (fine fuels, coarse woody debris, shrubs*	CO_2	Excluded	These emissions are excluded as they are recaptured in vegetation during the next growing cycle (IPCC, 1996).
		CH_4	Included	
		N_2O	Included	
	Source 3 *Fuel use. Eg from helicopters and other motor-driven equipment or drip torches*	CO_2	Included	
		CH_4	Included	
		N_2O	Included	

7.3 (If required) Additional information justifying why a source or sink is excluded.

Section 8: Project Area

If applicable, provide instructions to project proponents on how to determine the Project Area.
Instructions for determining the Project Area are provided in Section 9.1.

Section 9: Estimating abatement

9.1 Provide instructions to project proponents on how to calculate baseline emissions and removals. Provide formulas and define parameters in each formula, including units.
Where parameters are to be derived through data collection, provide instructions on data collection methods in Section 10.

SUMMARY FORMULAS FOR EMISSIONS CALCULATIONS

The formulas for calculating methane and nitrous oxide emissions from savanna burning are provided in Equation A and Equation B below (Russell-Smith *et al* 2009).

For methane, CH_4

$$E_{oc} = M_o \sum_{pk}\left(A_{pk} P_k \sum_{l}\left(EF_{pl} FL_{npl} CC_l \sum_{m}\left(S_m BEF_{klm} \right)\right)\right)$$	**Equation A**

For nitrous oxide, N_2O

$$E_{on} = M_o \sum_{pk}\left(A_{pk} P_k \sum_{l}\left(EF_{pl} FL_{npl} CC_l NC_l \sum_{m}\left(S_m BEF_{klm} \right)\right)\right)$$	**Equation B**

Where the subscripts:

o = *greenhouse gas species o (oc=* CH_4, *on=* N_2O);

p = *vegetation class*

k = *fire season*

l = *fuel size class*

m = *fire severity class*

n = *number of years since the patch of land was last burned*

and parameters:

E_{oc} = Emission (Gg) of CH_4;

E_{on} = Emission (Gg) of N_2O;

M = Ratio of molecular mass to the elemental mass

A = Fire affected (scar) area (ha)

P = Patchiness

EF = Emission factor (% of fuel elemental content released in fire)

FL= Fuel load (t dry matter ha^{-1})

CC = Carbon content of fuel (gram of carbon per gram of dry fuel)

NC = Elemental nitrogen to carbon ratio

S = Severity class (fraction of fires of severity class *m* in fire season *k*)

BEF = Burning efficiency

This Section provides a step by step process for calculating annual emissions from savanna burning. The step by step process provides detailed guidance on how to implement Equations A and B using a combination of GIS software and spreadsheet calculations.

This Section is in 2 parts:

- Part 1 describes a step by step process to calculate annual emissions.
  - This process is the same for calculating annual emissions in the baseline and project periods. Some inputs and data standards (eg the resolution of fire mapping) differ between baseline and project emissions calculations. These differences are described in Part 2 (baseline emissions) and Section 9.2 (project emissions) respectively.
- Part 2 describes the process to calculate baseline emissions.

PART 1: CALCULATING ANNUAL EMISSIONS

This section provides detailed guidance on how to calculate annual emissions. This process will be used to calculate annual emissions in both the baseline period and the project period.

Calculating annual emissions involves 6 steps. Some tasks require the use of Geographic Information System (GIS) software and some would be optimised through the use of a spreadsheet. The requirements for using GIS software is indicated where relevant.

The steps are:

1. Source and validate vegetation maps and determine the area of each vegetation class (GIS)
2. Source and validate fire maps (GIS)

3. Determine the start of the LDS (GIS, spreadsheet)
4. Calculate the fire scar area in the EDS and LDS for each vegetation class (GIS)
5. Calculate the years since last burnt (YSLB) for each burnt pixel (GIS)
6. Calculate annual emissions (spreadsheet)

Each of these steps are described later in this section.

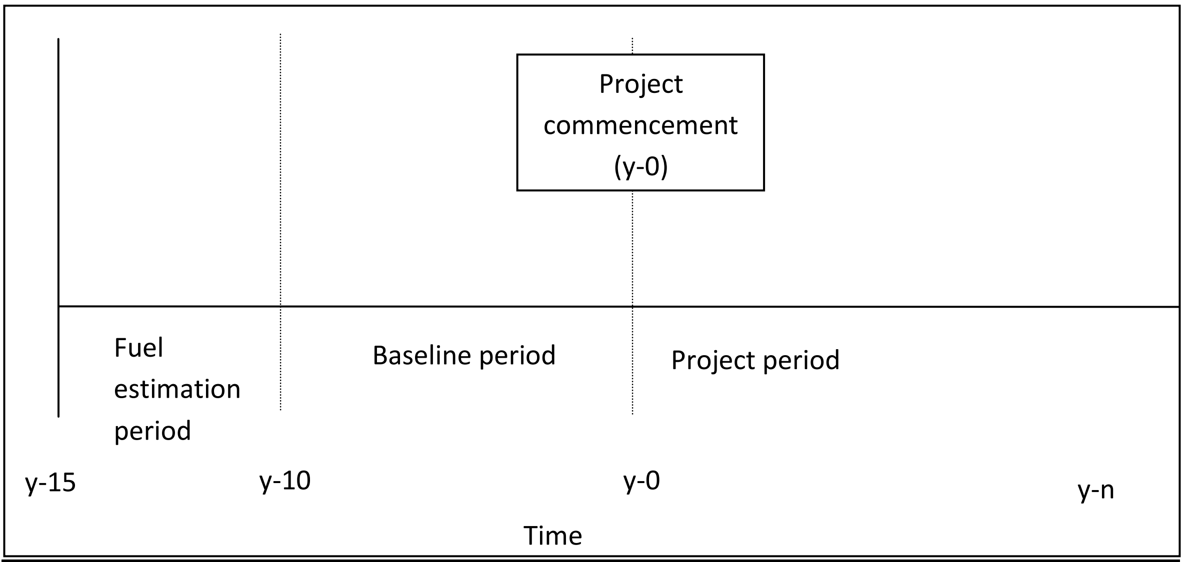
Defining phases of projects

For projects applying this methodology the following convention is applied to define various time periods:

- y-15 to y-10 is the fuel estimation period
- y-10 to y-1 is the baseline period
- y-0 to y-n is the project period

This is represented graphically below:

Figure 2: Project phases



Step 1 – Source and validate vegetation maps and determine the area of each vegetation class

This step requires the use of GIS software.

Step 1.1 –Develop a vegetation map of the project area

A description of the four vegetation classes covered by this methodology is provided in Table 1. Crown cover refers to the percentage of a site covered by the crowns of the dominant trees.

Table 1: Description of vegetation classes

Vegetation	Canopy	Crown	Characteristic species	Characteristic

class	Height (m)	cover (%)				substrates
			Canopy trees	***Shrubs***	***Grasses***	
EOF	Majority >15	50-80 (trees)	Tall eucalypts (e.g. *E. tetrodonta*, *E. miniata*, *Corymbia nesophila*)	Various—well developed shrub layer may / not be present	Native perennial and annual tussock grasses	Well drained deep soils, often sandy loams
EW	Majority >8	20-50 (trees)	Various eucalypts, often with other taxa (e.g. *Erythrophleum*, *Terminalia*, *Xanthostemon*)	Various—well developed shrub layer may / not be present	Native perennial and annual tussock grasses	Various situations, from well-drained gravely sites to those with impeded drainage
SW	Majority >8	20-50 (trees)	Various eucalypts, often with other taxa (e.g. *Erythrophleum*, *Terminalia*, *Xanthostemon*)	Various—well developed shrub layer may / not be present. Where present, may include woody heath taxa as listed for Sandstone heath	Mixture of native perennial and annual tussock and hummock (*Triodia*) grasses	Shallow to rocky substrates derived typically from sandstone, metamorphosed sandstone (e.g. quartzite), sometimes laterised
SH	Majority <5	<20 (shrubs)	Occasional trees	Conspicuous cover of heathy shrubs (e.g. *Acacia*, *Calytrix*, *Grevillea*, *Hibbertia*, *Hibiscus, Jacksonia, Tephrosia, Verticordia*)	Hummock (*Triodia*) grasses, with other perennial restios (*Lepyrodia, Dapsilanthus*) and sedges (*Schoenus sparteus*)	Shallow to rocky substrates derived from sandstone; sandsheets

(from Walker & Hopkins 1990)

Project proponents must develop a vegetation map for the project area. This map must be in raster form with a vegetation class assigned to each pixel. To develop this map, project proponents must assemble available vegetation structure mapping and other appropriate ancillary land cover mapping products (e.g. soil type, foliage projective cover) for the defined project area and, where not already available digitally, convert all mapping sources into digital form appropriate for GIS assessment. One of the inputs to the vegetation map must be cloud-free satellite imagery with a minimum pixel size of 250m sourced within the 3 years immediately preceding project commencement.

Using standard GIS approaches and with reference to the digital mapping products and imagery described above, project proponents must develop a GIS-based vegetation map of the project area which delineates the project area into the four vegetation classes described in Table 1. Mapping must be undertaken at a maximum scale of 1:100,000.

This GIS map will also be used to provide evidence that the project area receives an average of over 1000 mm of annual rainfall (Section 11).

Step 1.2 – Validate vegetation maps

Project proponents must undertake independent validation of the vegetation map prepared in Step 1 through comprehensive ground- and/or aerial-based *stratified random sampling* using the method described below (which is based on Edwards & Russell-Smith 2009).

- For projects over 10,000 km^2 project proponents must collect at least 500 independent data waypoints using a GPS to refine the vegetation map, and a further 500 independent data waypoints to separately assess the accuracy of the vegetation map. For projects under 10,000 km^2 project proponents must collect 250 independent data waypoints for each purpose.
- Independent data waypoints must be of the order of 1 ha to be congruent with the scale of the vegetation map. This data must be collected with reference to transects or a grid that samples all vegetation classes over the project area.

Project proponents must then undertake a validation assessment using GIS software, intersecting the independent data waypoints with the vegetation map for the purposes of deriving a standard error matrix including errors of omission and commission. Project proponents must use the data in the standard error matrix to determine the accuracy of the map as a percentage.

The data collected in this step should be used to improve the accuracy of the vegetation map developed in Step 1.1. The final vegetation map must be assessed as at least 80% accurate overall at 1:100,000 scale to be acceptable for emissions accounting purposes.

Step 1.3 – Calculate the area of each vegetation class

Using the vegetation map described above, project proponents must use GIS software to calculate the area of each vegetation class in terms of the number of pixels.

Step 2 – Source and validate fire maps

This step requires the use of GIS software.

Step 2. 1 – Acquire seasonal fire mapping (at least monthly)

Project proponents must acquire fire maps for the baseline period, the fuel load estimation period and the project period. A time resolution of one month or less is required for both baseline and project periods. These maps must be in raster form and show burnt and unburnt pixels in each month. Burnt pixels represent a fire scar. The sum of all burnt pixels represents the fire scar area.

Fire maps used to calculate baseline period emissions (y-10 – y-0), fuel loads (y-15 – y-10) and project period emissions must be from a consistent time series. The time series used to calculate the baseline period emissions, fuel loads and project period emissions do not, however, have to be consistent with each other (see Section 9.7). Consistency means that the maps are from a single satellite product.

Calculations to determine baseline emissions must use fire maps with a spatial resolution of at least 1 km per pixel. Calculations to determine project emissions must use fire maps with a spatial resolution of at least 250 m per pixel. Both the project and baseline fire maps can be sourced from current satellite products: eg MODIS for calculating project emissions and AVHRR for calculating baseline emissions. These fire maps must be independently validated by a registered Greenhouse and Energy Auditor using the methodology described in Step 2.3 or sourced from the North Australian Fire Information Service (NAFI).

Step 2.2 – Develop seasonal fire maps

For each year in the baseline and project periods, project proponents must combine all monthly fire maps from Step 2.1 into two maps: an EDS map and a LDS map.

All monthly fire maps before the start of the LDS (burnt and unburnt pixels) must be combined into an EDS map and all monthly fire maps after the start of the LDS (burnt and unburnt pixels) must be combined into a LDS map (see Step 3 for determining the start of the LDS).

Step 2.3 – Validating fire maps if not sourced from NAFI

If a project proponent uses fire maps that are not sourced from the NAFI the EDS and LDS fire maps described above must be validated for each year of the project by a registered Greenhouse and Energy Auditor using the following process.

At the end of the EDS and the LDS, a registered Greenhouse and Energy Auditor must collect at least 500 (for projects over 10,000 km^2) or 250 (for projects under 10,000 km^2) independent data waypoints using GPS based comprehensive aerial-based *random sampling that incorporates all vegetation types in the project*, where:

- independent data waypoints must be of collected along a series of transects that sample the areas containing fire activity for the EDS and LDS;
- at each independent data waypoint point the registered Greenhouse and Energy Auditor must undertake a visual assessment and note (a) the vegetation class, (b) whether the area is "burnt" or "unburnt".

A registered Greenhouse and Energy Auditor must then undertake a validation assessment using GIS software, intersecting the independent data waypoints with the EDS and LDS fire maps described above and derive a standard error matrix including errors of omission and commission for each fire map. A registered Greenhouse and Energy Auditor must use the data in the standard error matrix to determine the accuracy of the maps as a percentage and produce a detailed report. The project proponent must use the data collected by the registered Greenhouse and Energy Auditor to improve the accuracy of the fire maps.

The EDS and LDS fire maps must be assessed as at least 80% accurate overall at 1:100,000 scale to be acceptable for emissions accounting purposes.

Step 3 - Determine the start of the LDS

For each year of emissions calculation (both in the baseline period and the project period), project proponents will need to determine the start date (month) of the LDS.

Project proponents will need to use remotely sensed data from fire detection sensors that provide day and night time fire detections at a resolution of at least 250 meters per pixel.

During the LDS many fires burn through the night while in the EDS fires are typically extinguished during the night. Therefore the number of hot spot detections at night will be greater in the LDS than in the EDS. A hotspot is a pixel that represents a land area that carries fire at the time of a satellite overpass.

Project proponents must determine the number of hotspots in the project area during the night and during the day for every day and night in the months from May to September. The total monthly number of hotspots during the night is then divided by the total monthly number of hotspots during the day. This calculation generates a ratio for each month. The start of the LDS is defined as the first month where this ratio reaches 0.1 or more (i.e. when the number of night detections reaches 10% of the number of day detections).

If the required data are unavailable (for example this can occur with persistent cloudy conditions) then the default start of the LDS will be 1 August. Project proponents will need to provide evidence of why this method could not be applied if they claim this default (see Section 11).

Project proponents must present the results of this analysis in Tables 2 and 3:

Table 2: Ratio of hotspots per month

Month	**Number of hotspots during the night (a)**	**Number of hotspots during the day (b)**	**Ratio (a) / (b)**
May			
June			
July			
August			
September			

Table 3: Start of the LDS

Year	**Month that represents the start of the LDS**

Step 4 – Calculate the fire scar area (A) in the EDS and the LDS for each vegetation class

This step requires the use of GIS software.

Step 4. 1 – Determine the fire scar area in raster form

Project proponents must use GIS software to calculate the fire scar area within the project in the EDS and the LDS for each vegetation class. This must be done using GIS software and is achieved by overlaying the vegetation map developed in Step 1 with the EDS and LDS fire maps developed in Step 2.2. This process produces a raster map that allocates a vegetation class and a fire season value to each burnt pixel.

Step 4.2 – Convert these values into area (hectares)

Project proponents must convert the burnt pixel values in the raster map described in Step 4.1 into hectares using GIS software and enter the values into Table 4.

Table 4: Fire scar area (A) by vegetation class and fire season (ha)

Vegetation class	Fire season	
	EDS	LDS
EOF		
EW		
SW		
SH		

Step 5 –Calculate the years since last burnt for each burnt pixel

This step requires the use of GIS software. The results of this step will inform the fine fuel calculation in Step 6.

The process of determining the years since last burnt for a single year requires analysis of the 5 years previous to the single year being analysed. This process therefore requires the analysis of fire maps for 6 years; ie the year that is the focus of the analysis (analysis year) and the 5 previous years.

Step 5.1 – Start with monthly fire maps for the 6 years (the process for generating these maps is described in Step 2.1)

Project proponents must aggregate these monthly fire maps into 6 annual (calendar) fire maps showing each pixel as burnt or unburnt.

Step 5.2 – Assign values to burnt and unburnt pixels

Project proponents must assign the year (as a value) to all burnt pixels in each fire year and assign a zero value to all unburnt pixels.

For example, in a 2008 fire map, assign the value 2008 to all burnt pixels and the value zero to all unburnt pixels.

This creates a set of maps where burnt pixels have a year number and unburnt pixels have a value of zero. Attach a name to each map using the following convention: name the year under analysis (G_y) and the 5 maps for the years preceding it G_{y-1}..... G_{y-5}.

Step 5.3 – Generate maps

Project proponents must generate 5 maps that show the difference in values from the analysis year and each of the other 5 years. This is done by undertaking a standard grid operation in GIS software that takes the values from one map (in this case G_y) and subtracts the values in another map (in this case years G_{y-1}....G_{y-5}). This analysis will produce 5 maps (D_{-1} – D_{-5}).

For example, D_{-1} represents the values allocated to each pixel in G_y minus the values allocated to each pixel in G_{y-1}. D_{-2} represents the values allocated to each pixel in G_y minus the values allocated to each pixel in G_{y-2} and so on.

The 5 maps that are the product of this analysis will be:

1. $D_{-1} = G_y - G_{y-1}$
2. $D_{-2} = G_y - G_{y-2}$
3. $D_{-3} = G_y - G_{y-3}$
4. $D_{-4} = G_y - G_{y-4}$
5. $D_{-5} = G_y - G_{y-5}$

Step 5.4 – Calculate the minimum value of each pixel in each map and collate the results

Project proponents must calculate the minimum value allocated to each corresponding pixel in each map and collate the results in a single map.

This is done by performing a standard grid operation in GIS software that identifies the lowest value allocated to each corresponding pixel in each of the 5 maps (D_{-1} – D_{-5}) and converts the values into a single map.

There are four potential values in this map. These values and the outcomes that they represent are:

1. A pixel value of zero = no fire in that pixel in any year.
2. A pixel value of a large negative number (eg -2006) = not burnt in the analysis year but burnt in one or more of the other years. For example a value of -2006 would represent that pixel not being burnt in 2008 but being burnt in 2006 (in the Step 2 example where 2008 is the analysis year).
3. A pixel value of 1 to 5 = burnt in the analysis year and also burnt in another year. For example a value of 2 would represent that pixel being burnt in 2008 and 2006 (in the Step 2 example where 2008 is the analysis year).
4. A pixel value equal to the value of the analysis year (ie 2008 in the Step 2 example) = burnt in the analysis year but no other year.

Step 5.5 – Reclassify map values

Project proponents must perform a reclassification of the values in the map produced in Step 4.

This reclassification must be done using the following rules:

1. Zero values = 0
2. Negative values = 0
3. Values 1 – 5 = Values remain as 1 – 5
4. Values > 5 = 6

The output of this process is a single map with pixel values that show the time since last burnt. These values are in the range 0 – 6 where:

- Values of 1-5 represent the number of years since the previous fire on that pixel.
- A value 6 means that the pixel was burnt more than 5 years previously (or never burnt).
- A value 0 means that the pixel was not burnt in the analysis year.

This process will need to be repeated for each year requiring analysis and must use the 5 years preceding each analysis year. This process is applied slightly differently in the calculations for the baseline period and the project period.

In the baseline emissions calculation this analysis must be done for each year in the baseline: y-10 to y-1. When y-10 is being analysed the preceding years required for this analysis will be y-11 – y -15.

For annual project emissions calculations this process will need to be undertaken for the project year and will require analysis of data from the previous 5 years. As discussed above, a consistent time series is required for calculating project emissions.

Step 6 – Calculate annual emissions

The process for calculating annual emissions is represented by the following equation:

Annual emissions = Activity x Potential emissions	**Equation 1**

Where:

Activity is the fire scar area taking patchiness into account (hectares, ha); and

Potential emissions are the emissions per unit area that would occur if that area was burnt (tonnes per hectare, t ha^{-1}).

To operationalise Equation 1 project proponents must undertake a series of calculations and use some fixed values. Fixed values are provided in grey tables. Project proponents must populate the white tables using project data and fixed values.

Calculating annual emissions involves 3 steps:

1. Calculate the activity;
2. Calculate the potential emissions; and
3. Calculate annual emissions.

Step 6.1 – Calculate the activity

In many fires, particularly low-intensity fires, not all the fuel within the fire scar area is exposed to combustion. Patchiness is defined as the fraction of the area within the fire scar area that is actually burnt. To calculate the activity for each vegetation class and fire season, project proponents must use the following equation:

Activity = Fire scar area (A) x Patchiness (P)	**Equation 2**

Where:

Fire scar area (A) is the value (in hectares) from Table 4; and

Patchiness (P) is the value (fraction of fire scar area burnt) from Table 5.

Patchiness increases from the EDS to the LDS with increasing fire severity.

Table 5: Patchiness (P)

Fire season	Patchiness
EDS	0.709
LDS	0.889

(Russell-Smith *et al.* 2009)

Project proponents must present the results of these calculations in Table 6.

For example, to calculate the activity in the EDS for EOF, multiply the value in the first row and the first column in Table 4 by the EDS value in Table 5 (ie 0.709). The result would be presented in the first row and first column of Table 6.

Table 6: Activity by each fire season and vegetation class (ha)

Vegetation class	Fire season	
	EDS	**LDS**
EOF		
EW		
SW		
SH		

Step 6.2 – Calculate the potential emissions (P_e)

Project proponents must calculate the potential emissions of each gas (CH_4 and N_2O) in each fire season (EDS and LDS) for each pixel of a project if it were burnt.

The potential emissions (in t ha^{-1}) are calculated using the following equations:

For CH_4	P_{eCH4} = BEF x FL x EF x CC x M	**Equation 3**
For N_2O	P_{eN2O} = BEF x FL x EF x CC x NC x M	**Equation 4**

Where:

BEF = burning efficiency

FL = fuel load (t ha^{-1})_

EF = emission factor

CC = carbon content of fuel

NC = elemental nitrogen to carbon ratio

M = ratio of molecular mass to the elemental mass

The following steps define the values, or describe the calculations required to define the values, and describe a step by step process for calculating the potential emissions.

The word *calculate* is used in the step heading where calculations are required.

Step 6.2.1 – Burning Efficiency (BEF)

BEF is the mass of combusted fuel that is volatilised in a fire. BEF varies with fire severity, fuel size class and fire season. The values for BEF for each fuel size class and fire season, taking fire severity into account, are presented in Table 7.

Table 7: Burning Efficiency

Fuel size class	EDS	LDS
Fine	0.74	0.86
Coarse	0.15	0.36
Heavy	0.17	0.31
Shrub	0.29	0.39

The BEF values in Table 7 were derived by multiplying the burning efficiency for each fuel size class and fire severity class in Table 7A by the fraction of fires in each severity class in each fire season (S) in Table 7B, and summing the values for the three severity classes.

Table 7A: Burning efficiency for each fuel size class and fire severity class

	Fuel size class			
Severity	fine	coarse	heavy	Shrub
Low	0.69	0.05	0.12	0.26
Moderate	0.85	0.32	0.19	0.24
High	0.97	0.58	0.58	0.68

(Russell-Smith *et al*. 2009)

Table 7B: Fraction of fires in each severity class in EDS and LDS fires (S)

	Fire season	
Severity	EDS	LDS
Low	0.72	0.19
Moderate	0.20	0.47
High	0.08	0.34
Total	1	1

(Russell-Smith *et al*. 2009)

Step 6.2.2 – Fuel loads (FL)

Four fuel size classes are defined for this methodology:

1. fine fuel: defined as grass, leaf litter, bark and small twigs less than 6mm in diameter;
2. coarse: defined as twigs and dead branches between 6mm and 50mm diameter;
3. heavy: branches and logs >50 mm in diameter; and
4. shrubs: defined as living plants with a stem diameter of less than 50 mm at breast height (i.e. at 1.3 m).

Step 6.2.2.1 – Fuel loads for coarse, heavy and shrub

The fuel loads for the different fuel size classes (coarse, heavy and shrub) for each vegetation class are provided in Table 8. The fuel loads for fine fuels must be calculated (see Step 6.2.2.2).

Table 8: Fuel loads for each vegetation class (t ha^{-1})

Vegetation class	Fuel size class			
	Fine	Coarse	Heavy	Shrub
EOF	Import values from Table 12	1.4	4.8	1.5
EW	Import values from Table 12	0.90	2.2	0.5
SW	Import values from Table 12	1.2	3.4	1.7
SH	Import values from Table 12	0.6	1.7	1.8

(Russell-Smith *et al*. 2009)

Step 6.2.2.2 – Calculate fuel loads for fine fuels

Fuel loads for fine fuels vary depending on the time since a piece of land was burnt, ie years since last burnt (YSLB). For example, if an area of land was exposed to fire one year ago the fine fuel load will be lower than a comparable area of land that was exposed to fire five years ago. To calculate fine fuel loads, project proponents will need to assess the fire history of the project area in the five years prior to the analysis year.

This will need to be done for every year under analysis in both the baseline and the project period. For example, to calculate the fine fuel load for the first year in a project period, project proponents need to undertake analysis of the fire history in the last 5 years of the baseline period. This means that, to determine emissions in a 10 year baseline period, analysis of fire patterns must be undertaken for at least 15 years preceding project commencement.

Project proponents must calculate the fuel loads for fine fuels by following the steps below.

Step 6.2.2.2.1 – Fuel accumulation values

The fuel accumulation values for fine fuels have been calculated and are presented in Table 9.

Table 9: Fuel accumulation look up table for fine fuels (t ha^{-1})

Vegetation class	YSLB (n)					
	1	2	3	4	5	>5
EOF	2.74	4.25	5.07	5.53	5.78	6.06
EW	3.80	4.41	4.51	4.53	4.53	4.53
SW	2.08	3.41	4.25	4.79	5.14	5.68
SH	1.88	3.55	5.03	6.35	7.51	11.64

The fine fuel accumulation rates for each YSLB value in Table 9 were calculated using the data in Table 9A using the following equation:

$$\text{Fine fuel (t ha}^{-1}) = W_{max} \times (1-\exp(-Dt_{yslb}))$$

Where:

t_{yslb} is the number of years since the last fire (YSLB);

W_{max} is the equilibrium fuel load; and

D is a decay constant.

Table 9A: Regression coefficients (W_{max} and D) for fine fuel load calculations

Vegetation class	*Coefficient*	
	W_{max} (*t ha*$^{-1}$)	D (y^{-1})
Eucalypt open forest	6.08	0.60
Eucalypt open woodland	4.53	1.82
Sandstone woodland	5.74	0.45
Sandstone heath	16.65	0.12

(derived from Russell-Smith *et al*. 2009)

Step 6.2.2.2.2 – Calculate the frequency distribution of fire history

Project proponents must calculate a frequency distribution of fire history.

1) Start with the GIS map of YSLB developed in Step 5. This map contains values of 0, 1, 2, 3, 4, 5, or 6 in each pixel.

2) Overlay this map with the vegetation map developed in Step 1 and determine the number of pixels burnt in each vegetation class for each YSLB value. Project proponents must present these values (N_b) in the appropriate cell in the table below and sum across the rows to calculate N_{total}.

Table 10: Number of burnt pixels by YSLB

Vegetation class	**YSLB**						**Total**
	1	**2**	**3**	**4**	**5**	**>5**	
EOF	N_b	N_b	N_b	N_b	N_b	N_b	N_{total}
EW	N_b	N_b	N_b	N_b	N_b	N_b	N_{total}
SW	N_b	N_b	N_b	N_b	N_b	N_b	N_{total}
SH	N_b	N_b	N_b	N_b	N_b	N_b	N_{total}

3) Produce a frequency distribution of each YSLB value for each vegetation class using the values for N_b and N_{total} in Table 10 and Equation 5 and present the results in Table 11).

Frequency distribution of YSLB values = N_b / N_{total}	**Equation 5**

Where:

N_b= the number of burnt pixels in each vegetation class by YSLB value

N_{total} = the sum of N_b values for each vegetation class

For example, to calculate the value in the first row and the first column in Table 11 divide the value in the first row and the first column in Table 10 by the value in the *Total* column of the first row in Table 10.

Table 11: Frequency distribution of YSLB values

Vegetation class	**YSLB**						**Total**
	1	**2**	**3**	**4**	**5**	**>5**	
EOF							1
EW							1
SW							1
SH							1

Step 6.2.2.2.3 – Calculate the fuel load for fine fuels

To calculate the fuel loads for fine fuels, project proponents must multiply the corresponding values in Tables 9 and 11 to generate the fine fuel load values to be presented in Table 12.

For example, to calculate the value in the first row and the first column of Table 12 multiply the value in the first row and the first column of Table 9 with the value in the first row and the first column in Table 11.

Table 12: Fine fuel load (t ha-1)

Vegetation class	YSLB						Total
	1	2	3	4	5	?>5	
EOF							Transfer to table 8
EW							Transfer to table 8
SW							Transfer to table 8
SH							Transfer to table 8

Project proponents must total the values across each row of Table 12 and transfer the total values for each vegetation class to the fine fuel column in Table 8.

Step 6.2.3 – Emission factors (EF)

The emission factors for CH_4 for each vegetation class and fuel size class are presented in Table 13. The emission factors for N_2O for each vegetation class and fuel size class are presented in Table 14.

Table 13: Emissions Factors (%) – CH_4

Vegetation class	Fuel size class			
	Fine	Coarse	Heavy	Shrub
EOF	0.31	0.31	1.0	0.31
EW	0.31	0.31	1.0	0.31
SW	0.31	0.31	1.0	0.31
SH	0.15	0.15	1.0	0.15

(Meyer and Cook 2011)

Table 14: Emissions Factors (%) – N_2O

Vegetation class	Fuel size class			
	Fine	Coarse	Heavy	Shrub
EOF	0.75	0.75	0.36	0.75
EW	0.75	0.75	0.36	0.75
SW	0.75	0.75	0.36	0.75
SH	0.66	0.66	0.36	0.66

(Meyer and Cook 2011)

Step 6.2.4 – Carbon Content (CC)

The carbon content of each fuel size class is presented in Table 15.

Table 15: Carbon Content

Elemental content	Fuel size class			
	fine	coarse	heavy	Shrub
Carbon	0.49	0.50	0.50	0.50

(Russell-Smith *et al*. 2009)

Step 6.2.5 – Nitrogen to carbon ratio (NC)

The nitrogen to carbon ratio of each fuel size class is presented in Table 16. This is only required for calculations of N_2O emissions.

Table 16: Nitrogen to carbon ratio

Elemental content	Fuel size class			
	fine	coarse	heavy	Shrub
Nitrogen to carbon ratio	0.0101	0.0081	0.0081	0.0093

(Russell-Smith *et al*. 2009)

Step 6.2.6 – Molecular mass to elemental mass (M)

The calculations described in this step present emissions of N_2O or CH_4 as a molecular mass of gas. These values must be converted to an elemental mass using the conversion factors presented Table 17.

Table 17: Molecular mass to elemental mass conversion factors

Gas	Conversion factor
M_{CH4}	1.3333
M_{N2O}	1.5714

Step 6.2.7 – Calculate the potential emissions (tonnes ha^{-1})

Project proponents must calculate the potential emissions for each gas in each fire season.

Step 6.2.7.1 – Calculate potential emissions for each gas in each fire season.

These calculations are made for each vegetation type, fuel size class using the data in the tables above and the following equations:

For CH_4 $P_{eCH4} = BEF \times FL \times EF \times CC \times M$	**Equation 6**

For N_2O $P_{eN2O} = BEF \times FL \times EF \times CC \times NC \times M$	**Equation 7**

The potential emissions for CH_4 and N_2O must be calculated for EDS and LDS. These equations are operationalised by multiplying the corresponding values for each vegetation class and fuel size class in Tables 7, 8, 14, 15, 16 (N_2O only), and 17 and presenting the results in Tables 18 – 21.

For example:

For CH_4 P_{eCH4} = Table_7 x Table_8 x Table_14 x Table_15 x $Table\_17_{CH4}$	**Equation 8**

For N_2O P_{eN2O} = Table_7 x Table_8 x Table_14 x Table_15 x Table_16 x $Table\_17_{N2O}$	**Equation 9**

Worked example

For example, to calculate the potential emissions of CH_4 in the EDS from the combustion of coarse fuels in eucalypt open woodland project proponents must undertake the following calculation:

$Table\_7_{eds}$ (0.13192) x Table_8 (1.4) x Table_14 (0.31) x Table_15 (0.46) x $Table\_17_{CH4}$ (1.3333) = 0.0351144

This value would be presented in the column for coarse fuel size class and the EW row in Table 18.

Once each value in Tables 18 – 21 has been determined, total across each row to determine the potential emissions for each gas, in each vegetation class, in each fire season.

Table 18: Potential emissions for CH_4 in EDS (t ha^{-1})

Vegetation class	Fuel size class				
	Fine	Coarse	Heavy	Shrub	*Total*
EOF					
EW					
SW					
SH					

Table 19: Potential emissions for CH_4 in LDS (t ha^{-1})

Vegetation class	Fuel size class				
	Fine	Coarse	Heavy	Shrub	*Total*
EOF					
EW					
SW					
SH					

Table 20: Potential emissions for N_20 in EDS (t ha^{-1})

Vegetation class	Fuel size class				
	Fine	Coarse	Heavy	Shrub	*Total*
EOF					
EW					
SW					
SH					

Table 21: Potential emissions for N_2O in LDS (t ha^{-1})

	Fuel size class

Vegetation class	Fine	Coarse	Heavy	Shrub	*Total*
EOF					
EW					
SW					
SH					

Step 6.2.7.2 – Transfer the totals

Project proponents must transfer the values in the total columns from Tables 18 – 21 into columns 1 – 4 respectively in Table 22:

Table 22: Potential emissions for each gas in each fire season by vegetation class (t ha^{-1})

Vegetation class	Gas (CH_4)		Gas (N_2O)	
	EDS (totals from Table 18)	LDS (totals from Table 19)	EDS (totals from Table 20)	LDS (totals from Table 21)
EOF				
EW				
SW				
SH				

Step 6.3 – Calculate annual emissions

Calculating annual emissions (operationalising equation 1) requires the multiplication of a number of values in a number of tables above.

Step 6.3.1 – Determine the emissions by gas by vegetation class by fire season

Project proponents must multiply the corresponding values in Table 22 (potential emissions) and Table 6 (actual area burnt) and insert the value in Table 23.

For example, to determine the emissions of N_2O in the EDS for each vegetation class, project proponents must multiply the corresponding values in the third column in Table 22 with the values in the first column in Table 6.

The total emissions for each fire season (Total (fire season)) is the sum of the values EOF - SH in each column.

Table 23: Emissions by gas by vegetation class by fire season (tonnes)

Vegetation class	Gas (CH_4)		Gas (N_2O)	
	EDS	LDS	EDS	LDS
EOF				
EW				
SW				
SH				
Total (fire season)				
Total (Gas)				

The total emissions for each gas (Total (Gas)) is the sum of the two Total (fire season) values in each gas category.

Project proponents must transfer the Total (Gas) values from Table 23 to the *E* Column in Table 24.

Table 24: Total annual emissions (tonnes CO_2-e)

	GWP	E	E_{CO2}-e
CH_4	21		
N_20	310		
Total			

Project proponents must determine CO_2-e for each gas by multiplying the values in column GWP by column *E*.

To determine total CO_2-e annual emissions sum the two values in column E_{CO2}-e.

PART 2: CALCULATE BASELINE

Calculating baseline emissions requires the calculation of the average annual emissions for the baseline period. The baseline period is described in Section 6.1.

This calculation is undertaken by applying the process outlined in Part 1 above, with regard to the specific requirements related to fire maps as described in Step 2.1 and the specific requirements for the analysis of 15 years of fire history as described in Step 6.2.2.2.

Project proponents must present the results of the annual baseline emissions in Table 25 and sum the values to determine the total emissions over the baseline period.

The average annual emissions for the baseline period is calculated by dividing the total emissions by 10.

Table 25: Project baseline (tonnes CO_2-e)

Baseline year	**Annual Emissions (E_{CO2}-e)**
y-10	
y-9	
y-8	
y-7	
y-6	
y-5	
y-4	
y-3	
y-2	
y-1	
Total	
Average (project baseline, $E_{BL}CO_2$-e)	

9.2 Provide instructions to project proponents on how to calculate project emissions and removals. Provide formulas and define parameters in each formula, including units.
Where parameters are to be derived through data collection, provide instructions on data collection methods in Section 10.

Step 1: Calculate the annual project emissions from fire

Calculating annual project emissions is undertaken by applying the process outlined in Section 9.1 (Part 1), with regard to the specific requirements related to fire maps as described in Section 9.1 (Step 2.1).

Step 2: Present annual project emissions from fire

The calculation in Section 9.1 (Part 1, Step 6.3) will determine annual project emissions from fire and should be expressed as $E_{fire}CO_2$-e for a single year.

Project proponents must present the results of the annual project emissions described above in the table below.

Table 26: Annual emissions from fire (tonnes CO_2-e)

Year	Annual project emissions ($E_{fire}CO_2$-e)

Step 3: Calculate emissions from fuel use

If the project has involved the combustion of fuel (for example in aircraft or ground vehicles used to conduct strategic fire management or field data collection, or fuel used in drip torches) the emissions associated with this fuel use must be included in the annual project emissions.

Emissions from fuel use must be estimated using the energy content and emission factors outlined in Schedule 1 of the NGER (Measurement) Determination. Emissions from fuel use should be calculated for each fuel class and each greenhouse gas (ie. CO_2, N_2O, CH_4). These are also included, with worked examples, in the National Greenhouse Accounts Factors. These documents are available on the Department of Climate Change and Energy Efficiency website.

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000}$$	**Equation 10**

Total emissions from fuel use are calculated as the sum of all emissions calculated using the following equation.

$$E_f = \sum_{1}^{N_{i,j}} E_{ij}$$	**Equation 11**

Where:

E_{ij} = Emissions from fuel for each fuel class and each greenhouse gas

i = fuel type

j = gas type (CO_2, N_2O, CH_4)

Q_i = quantity of fuel type (i), measured in cubic metres or gigajoules

EC_i = energy content factor of fuel type (i) (gigajoules per kilolitre) (If Q_i is measured in gigajoules, then EC_i is 1)

EF_{ijoxec} = emission factor for each gas type (j) (which includes the effect of an oxidation factor) for fuel type (i) (kilograms CO_2-e per gigajoule)

E_f = total emissions from fuel use (tonnes CO_2-e)_

Project proponents must record the results for the total emissions from fuel use in Table 27 and calculate the total.

Table 27: Emissions from fuel use (tonnes CO_2-e)

	Fuel type	Amount used (litres)	Emissions from fuel use

Source a			
Source b			
Total ($E_{fuel}CO_2$-e)			

Step 4: Determine total annual project emissions

Annual project emissions must be calculated with information in Tables 26 and 27 using the following calculation:

$E_{total}CO_2\text{-e} = E_{fire}CO_2\text{-e} + E_{fuel}CO_2\text{-e}$	**Equation 12**

Project proponents must present the annual project emissions in Table 28 below:

Table 28: Annual project emissions (tonnes CO_2-e)

Year	Total annual Emissions ($E_{total}CO_2$-e)

9.3 Provide instructions to project proponents on how to calculate *net greenhouse gas abatement*. This should be the difference between the baseline and project emissions and removals.

Project proponents must calculate net annual project abatement by subtracting the project emissions for the project year (Table 28) from the baseline (Table 25). Net greenhouse gas abatement is calculated by:

Net annual greenhouse gas abatement ($A_{net}CO_2\text{-e}) = E_{BL}CO_2\text{-e} - E_{total}CO_2\text{-e}$	**Equation 13**

Table 29: Net annual project abatement (tonnes CO_2-e)

Year	Net annual project abatement ($A_{net}CO_2$-e)

9.4 For bio-sequestration projects provide instructions on the procedures to be used to account for variations that are likely to occur in the amount of carbon stored as a result of climatic cycles or harvesting over 100 years.
N/A
9.5 Provide instructions to project proponents on how to calculate net abatement number or net sequestration number for reporting purposes, *if different from the estimate of net greenhouse gas abatement (Section 9.3)*. For bio-sequestration projects, this calculation should take into account any adjustments to the abatement estimate to address variability, and any abatement already reported and credited.
N/A

9.6 Indicate whether the estimation methods and emissions factors are from the NGER (Measurement) Determination or Australia's National Greenhouse Accounts. If not, explain why new or different estimation methods are proposed. Note that the methods set out in the NGER (Measurement) Determination must be used to estimate emissions covered by NGERS.

The accounting methodology defined in Section 9.1 (Part 1) is an exact subset of the Tier 2 method used in the current National Greenhouse Accounts methodology and the revisions that will come into effect for the 2012 National Greenhouse Accounts.

For the following parameters, the methodology includes more up-to-date values than are used in the current National Greenhouse Accounts. The parameter values that are used in the methodology are also more dis-aggregated than the values used in the current National Greenhouse Accounts, i.e., the parameter values used in the methodology vary with vegetation class, fuel size class and (in some cases) fire severity class.

- **Fuel load (FL) (Table 8)** (varies with vegetation class and fuel size class)
- **Burning efficiency (BEF) (Table 7A)** (varies with fuel size class and fire severity class)
- **Carbon content (CC) (Table 15) and Nitrogen to carbon ratio (NC) (Table 16**) (varies with fuel size class)

The values for these parameters are based on Russell-Smith *et al* 2009. The equivalent parameters in the National Greenhouse Accounts will be updated to reflect Russell-Smith *et al* 2009 for the 2012 National Greenhouse Accounts.

The methodology includes different burning efficiencies and patchiness factors for different fires seasons (EDS and LDS), based on Russell-Smith *et al.* 2009. The methods used in compiling the current National Greenhouse Accounts do not differentiate between fire seasons (EDS and LDS), but a seasonality component will be implemented in the 2012 National Greenhouse Accounts.

The methodology described in this document requires the use of finer resolution maps for vegetation classes and fire than is used to compile the National Greenhouse Accounts.

9.7 Provide a detailed description of any formulas used and detailed explanations of the parameters included in each formula, along with a description of how each parameter is derived(noting that detailed instructions to proponents on data collection methods for deriving parameters are to be provided in Section 10). Where applicable, provide a citation for the source of equations and/or parameters.
Resolution of fire mapping This different fire map resolution requirements for baseline emission calculations and project emissions calculations (described in Section 9.1, Part 1, Step 2.1) recognise that satellite imagery at 250 m per pixel may not be available for the 15 year period prior to project commencement. Therefore, for the baseline period satellite imagery at 1 km (eg AVHRR) resolution is the minimum acceptable data source. This is a conservative approach. Comparison of the AVHRR maps with higher resolution maps using Landsat imagery indicates that AVHRR maps underestimates fire area, through the omission of fires less than 4 km^2 (Yates and Russell-Smith 2002). The use of coarser resolution maps in the baseline period will generally not detect small fires and will therefore underestimate baseline emissions. This will result in an underestimation of net greenhouse gas abatement. **Vegetation classes** The description of vegetation classes in Table 1 is based on research into habitat conditions in the western Arnhem Land region (eg Edwards and Russell-Smith 2009). These vegetation classes are characteristic of fire-prone savanna vegetation in higher rainfall (>1000 mm p.a.) areas across northern Australia, with specific exceptions—(1) seasonally inundated swamps, grasslands and woodlands, typically dominated by Melaleuca, (2) eucalypt open forests and woodlands with ground layers infested with large exotic perennial and annual grasses (e.g. *Andropogon gayanus, Panicum maximum, Pennisetum pedicellatum, P. polystachion*). This methodology does not apply in these examples. The descriptions in Table 1 are consistent with vegetation structural information contained in the Australian Vegetation Attribute Manual: National Vegetation Information System, Version 6.0 (http://www.environment.gov.au/erin/nvis/publications/avam/index.html).

Section 10: Data Collection

Provide instructions to project proponents on data collection methods for deriving the parameters used to calculate *baseline emissions and removals* (Section 9.1) and *project emissions and removals* (Section 9.2). Instructions may be provided in the table below.
Data collection methods associated with the development of the vegetation and fire maps are described in the Section 9.1 (Part 1). This Section provides instructions on data collection for parameters that are not described in detail in Section 9.1.

Parameter	Description	Unit	Measurement Procedure	Measurement Frequency
i	Emissions from liquid fuel used in the project	Litres	The quantity of fuel combusted must be calculated from the amount of liquid fuel purchased for use in the project.	Annual

Section 11: Monitoring and reporting

11.1 Outline the elements of the project that will be monitored and describe how monitoring will be undertaken, including: • frequency of monitoring; • the Australian Standards, or other relevant standards, that project proponents will need to comply with to calibrate and maintain measurement equipment; and • any qualifications that operators will need to operate measurement equipment. The information provided in this section should not duplicate the information provided in Section 10.
Project monitoring is incorporated into the instructions for estimating abatement (Section 9.1) through the requirements for project proponents to acquire and validate vegetation maps and acquire monthly fire maps.

11.2 Specify the data and other information about the project that must be included in project reports and project records, including:

- data required to estimate emissions and removals resulting from the project;
- data required to identify and justify baseline scenarios and to support baseline estimation and resetting; and
- information about project implementation or changes in environmental conditions that are required to determine whether the project remains within the scope of the methodology.

Part 1: Project records

Project proponents must retain records of all maps and supporting data sets described below in electronic form. Maps must be retained in standard GIS formats. Data sets must be retained in standard spreadsheet or text formats. All metadata associated with GIS maps and related data must also be retained.

Project proponents must keep the following records. Part 2 describes which of the project records are to be included in project reports.

1. Evidence of project rainfall

This abatement activity can only be implemented in an area that receives an average of over 1000 mm of annual rainfall. Project proponents must retain evidence that their project meets this criterion.

Project proponents must generate a GIS map that overlays the project area with a spatially based rainfall map generated from Bureau of Meteorology (BOM) rainfall data. Project proponents must use rainfall data from the standard reference period 1969 to the present from the BOM. These data are readily available from the BOM website and can be readily converted into a GIS map. Project proponents must retain GIS maps and supporting data sets from the BOM.

Project proponents must use the vegetation map that was produced in Section 9.1 (Part 1, Step 1) as the project area map to complete this requirement.

2. Primary maps and data

Project proponents must retain the primary GIS maps and data sets that were used as inputs into both baseline and project emissions calculations. The following maps and data are required to be retained in project records:

- The validated GIS vegetation map at 1:100,000 scale as described in Section 9.1 (Part 1, Step 1).
  - Project proponents must retain the data sources used for compiling the vegetation map, including copies of all mapping products consulted and produced.
- The monthly fire maps and supporting data sets that underpin the monthly fire maps as described in Section 9.1 (Part 1, Step 2.1). This includes:
  - Maps used to calculate baseline emissions.
  - Maps used to calculate annual project emissions.

3. Maps and data derived from primary maps and data

Project proponents must retain a number of the maps and data sets that were derived from the application of the primary project data. This is to retain evidence of the correct interpretation of primary maps and data. The following maps and data are required to be retained in project records:

- EDS fire maps described in Section 9.1 (Part 1, Step 2.2).
- LDS fire maps described in Section 9.1 (Part 1, Step 2.2).
- The monthly maps and supporting data used to determine the start of the LDS as described in Section 9.1 (Step 3).
- The YSLB maps and supporting data sets described in Section 9.1 (Step 5).

4. Evidence of the validation of the vegetation map

Project proponents must retain evidence of the validation of the vegetation map as described in Section 9.1 (Part 1, Step 1.1). The following maps and data are required in to be retained in project records:

- The results of the validation assessment, including a detailed breakdown of errors of omission and commission by vegetation class as described in Section 9.1 (Part 1, Step 1.2).
    - Project proponents must retain the data sources used for undertaking the validation assessment, including copies of all mapping and sampling products consulted and produced.
    - Project proponents must retain all GIS maps depicting the position of all independent data waypoints collected.
    - Project proponents must retain the GIS map that shows the intersection of the independent data waypoints and the vegetation map.
    - Project proponents must retain the matrix showing quantitative evidence of errors of omission and commission by vegetation class. This matrix must provide evidence that the final vegetation map is at least 80% reliable.

5. Evidence relating to fire maps

Project proponents must retain evidence relating to the fire maps as described in Section 9.1 (Step 2). The following maps and data are required in to be retained in project records:

- If the project proponent used NAFI sourced fire maps, the project proponent must retain evidence that the maps were sourced from NAFI.
- If the project proponent did not use NAFI sourced fire maps, the project proponent must retain the results of the registered Greenhouse and Energy Auditor's validation assessment, including a detailed breakdown of errors of omission and commission as described in Section 9.1 (Part 1, Step 2.3).
    - Project proponents must retain the registered Greenhouse and Energy Auditor's report relating to this validation process.
    - Project proponents must retain the data sources used for undertaking the validation assessment, including copies of all mapping and sampling products consulted and produced.
    - Project proponents must retain all GIS maps depicting the position of all independent data waypoints collected.

- Project proponents must retain the GIS map that shows the intersection of the independent data waypoints and the EDS and LDS fire maps.
- Project proponents must retain the matrix showing quantitative evidence of errors of omission and commission by vegetation class. This matrix must provide evidence that the final vegetation map is at least 80% reliable.

6. If the project proponent used the data collected by the registered Greenhouse and Energy Auditor's validation assessment to increase the accuracy of a fire map (Section 9.1, Part 1, Step 2.3) the project proponent must retain the original fire maps and the adjusted fire maps.Tables

A number of the tables described in Section 9 of this methodology contain key pieces of information that project proponents must retain in project records. These are:

- Table 2
- Table 3
- Table 4
- Table 6
- Table 8
- Table 10
- Table 11
- Table 12
- Table 18
- Table 19
- Table 20
- Table 21
- Table 22
- Table 23
- Table 24
- Table 25
- Table 26
- Table 27
- Table 28
- Table 29

7. Records of activities

Records of strategic EDS burning activities undertaken, including the location, timing and method (e.g., use of aircraft or vehicles of prescribed burns.

8. Other data

Fuel receipts

As described in Section 10, project proponents must collect data on the amount of fuel used during the project. Project proponents must retain all fuel receipts as a record of the amount of fuel used per annum in the project.

Evidence of the unavailability of data required to calculate the start of the LDS

If a project proponent is unable to source the required data to determine the start of the LDS as described in Section 9.1 (Part 1, Step 3) evidence must be provided. This evidence must show that the data is unavailable. For example, if cloudy conditions are persistent at the time of assessment, copies of the cloudy maps must be provided.

Part 2: Project reports

Project proponents must submit components of the project records in project reports. Project proponents will be required to submit:

- A report for the first reporting period; and
- Ongoing reports for subsequent reporting periods.

Report for the first reporting period

This report must be made at the end of the first reporting period. The following maps and data are required to be provided in this report:

- The GIS map to provide evidence of project rainfall as described in Part 1 of this Section.
- The validated GIS vegetation map at 1:100,000 scale as described in Section 9.1 (Part 1, Step 1).
- A description of the strategic EDS burning regime implemented, including the location, timing and method (e.g., use of aircraft or vehicles of prescribed burns.
- The EDS fire maps described in Section 9.1 (Part 1, Step 2.2).
- The LDS fire maps described in Section 9.1 (Part 1, Step 2.2).
- If the project proponent used NAFI sourced fire maps the project proponent must provide evidence that the maps were sourced from NAFI (Part 1, Step 2.1).
- If the project proponent did not use NAFI sourced fire maps, the project proponent must provide the registered Greenhouse and Energy Auditor’s report relating to the validation of the EDS and LDS fire maps (Part 1, Step 2.3).
- The following tables as described in this methodology:
    - Table 2
    - Table 3
    - Table 6
    - Table 23
    - Table 25
    - Table 26
    - Table 29

Reports for subsequent reporting periods

Ongoing report must be made at the end of each subsequent reporting period. The following maps and data are required in to be provided in these reports:

- A description of the strategic EDS burning regime implemented, including the location and timing and method (e.g., use of aircraft or vehicles) of prescribed burns.
- The EDS fire maps described in Section 9.1 (Part 1, Step 2.2).
- The LDS fire maps described in Section 9.1 (Part 1, Step 2.2).
- If the project proponent used NAFI sourced fire maps the project proponent must provide

evidence that the maps were sourced from NAFI (Part 1, Step 2.1).

- If the project proponent did not use NAFI sourced fire maps, the project proponent must provide the registered Greenhouse and Energy Auditor's report relating to the validation of the EDS and LDS fire maps (Part 1, Step 2.3).
- The following tables as described in Section 9 of this methodology:
    - Table 2
    - Table 3
    - Table 6
    - Table 23
    - Table 25
    - Table 26
    - Table 29

Section 12: References

Provide a full citation for all reports cited in the draft methodology.

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Section 13: Appendices

Append and list below all relevant documentation necessary for the DOIC to assess the methodology including cited reports.
Appendix A: *Appendix B:*

Section 14: Disclosure

Specify documents or parts of documents included as supporting information to the application that are marked CONFIDENTIAL and should not be published and the reasons why.

Acceptable justification would include that the information should not be published if it reveals, or could be capable of revealing:

- trade secrets; or
- any other matter having a commercial value that would be, or could reasonably be expected to be, destroyed or diminished if the information were disclosed.

Document/Part of document	*Reason for maintaining confidentiality*

Section 15: Declaration

This application must be signed by a duly authorised representative of the proponent. The person signing should read the following declaration and sign below.

Division 137 of the Criminal Code makes it an offence for a person to give information to a Commonwealth entity if the person providing the information knows that the information is false or misleading. The maximum penalty for such an offence is imprisonment up to 12 months.

By signing below, the signatory acknowledges that he or she is an authorised representative of the proponent, and that all of the information contained in this application is true and correct. The signatory also acknowledges that any of the information provided in this application may be copied, recorded, used or disclosed by the Department of Climate Change and Energy Efficiency for any purpose relevant to the CFI. Information will not be publicly disclosed by the Department where it has been identified as confidential by the proponent.

Full name of the person signing as representative of the proponent		*Date*	
Position			
Signature			