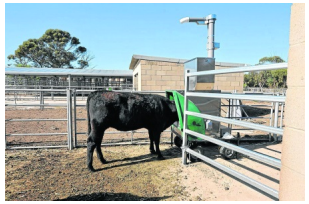
Table 1 Recommended techniques for estimating methane emissions from livestock

Method	Description	Suitability	Cost	Accuracy and precision	Key refere
Methods for indirect estimation These methods estimate CH4 emissions without direct measurements on animals					
1. Lab-based (*in vitro*) incubation	Feed substrate is incubated in air-tight bottles/bags to allow gas accumulation, and then gas samples analyzed for CH_4 concentrations.	Can be used as a first approach to test potential feedstuffs and additives under controlled conditions.	Less expensive and time consuming than respiration chambers.	May not represent whole-animal (*in vivo*) emissions.	Menke et a 1979 (man Pell & Schofield 1 (computer
2. Estimation from diet (models)	CH_4 is estimated from feed intake using models, usually developed from previous experimental data	Applicable in cases where measurements are not possible. Requires estimates of feed intake, which can be challenging to obtain.	Inexpensive to use once developed; eliminates need for CH_4 measurement.	The assumptions and conditions that must be met for each equation limit their ability to accurately predict methane production.	
Methods for direct measurement of daily methane production These methods monitor emissions continuously for extended periods and can be used to measure daily methane production					
3. Open circuit respiration chambers	Measures methane concentration within exhaled breath while the animal is in an enclosed	Not suitable for examining effects of grazing management.	Expensive to construct and maintain. Use is technically demanding.	Provides most accurate and precise measurements of	Pinares & Waghorn 2 Pinares-Pa

	chamber.	Restricts normal animal behavior and movement; may decrease feed intake. Only a few animals can be used for measurement at any one time.		emissions, including CH_4 from ruminal and hindgut fermentations.	et al. 2011
4. Ventilated hood 	An airtight box is placed to surround the animal's head. Gas exchange is measured only from the head rather than the whole body	Can be used to assess emissions from different feeds. Restricts normal animal behavior and movement; not suitable for grazing systems.	Lower cost than whole-animal chamber. Requires training to allow the test animals to become accustomed to the hood apparatus	Does not measure hindgut CH_4.	Fernández 2012 Place et al. Suzuki et a 2007
5. SF_6 tracer technique 	A small permeation tube containing SF_6 is placed in the cow's rumen, and SF_6 and CH_4 concentrations are measured near the mouth and nostrils of the cow.	Allows the animal to move about freely; suitable for grazing systems. Can be used to measure large numbers of individual animals. The challenge is that SF_6 itself is a GHG.	Lower cost, but higher level of equipment failure and more labour-intensive than respiration chambers. Animal must be trained to wear a halter and collection yoke.	Less precise than respiration chambers. Does not measure hindgut CH_4.	Johnson et 1994 Deighton 2014 Williams e 2014 Berndt et a 2014

6. Polyethylene tunnel 	A large tunnel made of heavy-duty polyethylene fitted with end walls and large diameter ports. The concentrations of air between the incoming and outgoing air are continuously monitored.	Suitable for measuring CH4 emissions under semi-normal grazing conditions. Can be used for individual or small group of animals. As with SF6 chambers, does not capture feed intake, so not suited for evaluating differences between imposed experimental treatments.	Operation simpler than respiration chambers. Portable.	With frequent calibration, provides high methane recovery rate, similar to respiration chambers. There is difficulty in controlling the tunnel's temperature and humidity.	Lockyer & Jarvis 199
7. Open-path laser 	Lasers and wireless sensor networks send beams of light across paddocks containing grazing animals. The reflected light is analyzed for greenhouse gas concentrations.	Measures CH_4 emissions from herds of animals and facilitates whole-farm measurements across a number of pastures. Emissions cannot be attributed to a single source.	Expensive. Requires sensitive instrumentation to analyse CH_4 concentration and capture micrometeorological data. Equipment requires continuous monitoring. Technically demanding.	Accuracy is highly dependent on environmental factors and the location of test animals. Data must be carefully screened.	Tomkins e 2011 Denmead Loh et al. Gao et al.
Methods for short-term measurements These methods measure emissions over as short period, which can be used to estimate daily methane production or relative methane emissions.					
Greenfeed® Emission	Patented device that measures and records	Suitable for comparing effects of feeds or	Patented device; must be purchased from supplier,	Provides comparable	Zimmerm Zimmerm

Monitoring Apparatus 	short-term (3–6 minute) CH_4 emissions from individual cattle repeatedly over 24 hours by attracting animals to the unit using a 'bait' of pelleted concentrate	supplements. Requires the use of a feed "attractant" to lure the animal to the facility, which alters results.	C-lock Inc. (Rapid City, South Dakota, USA)	estimates to respiratory chamber and SF_6 techniques. Does not measure hindgut CH_4.	2012 Hammond al. 2013
Portable accumulation chambers 	Clear polycarbonate box in which the animal is placed for approximately 1 hour; methane production is measured by the increase in concentration that occurs during that time.	Designed to measure large numbers of animals for genetic screening of relative methane production. Tested with sheep.	Similar in cost to open-circuit respiration chambers, but with much shorter measurement time.	Comparability with respiration chambers unclear. Further investigation is required before committing significant resources to this method.	Goopy et a 2011 Robinson