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Review of Potential Measures for RPP2 - Agriculture

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ClimateXChange produced this brief early in the preparation of the second Report on Proposals and Policies. Its purpose was to help frame questions and lines of enquiry and as a result, did not fully take account of real-world constraints (economic, political, social, institutional) that mean that these theoretical abatement levels are unlikely to be achievable in practice. ClimateXChange produced these reports in early 2012, and some of the figures presented may have since been updated.

1. Background

The Scottish Government – specifically the team developing the second Report on Proposals and Policies (RPP2) – asked ClimateXChange to provide advice on potential abatement measures in the agricultural (and related land use) section of RPP2. Building on and re-examining the analysis in RPP1, RPP2 will specifically contain a section on possible abatement measures that could conceivably offer additional abatement beyond 2020 pending the appropriate policy environment, public acceptability and ultimate adoption. The need to identify this extra potential arises as a result of a perceived gap opening up between stated policy aims and specific sector ambitions.

The specific terms of reference for this report are set out in Annex 1. Note that we interpret these as focussing largely on new measures for RPP2 rather than dwelling on the assumptions relating to existing RPP1 measures. The latter have been subject to considerable analysis in existing RPP1 background documentation prepared by Vera Eory and Emma Close (RESAS).

This report offers some initial background to RPP1, before outlining the potential contribution of further abatement measures. The final sections of the document consider the enabling conditions for the added potential to be realised.

The UK GHG Inventory (Thomas et al. 2011) gives an indication of the magnitude of emissions sources in agricultural and related land use emissions in Scotland in 2009 (see Table 4 in Annex 2). By far the most important single source of emissions was land converted to cropland, contributing to the total emissions by 50%. Enteric fermentation and agricultural soil emissions combined were 63% of total emissions. Within this, direct and indirect nitrous oxide emissions from fertilisation amounted to 30% (emissions from leaching, inorganic fertilisers, wastes from grazing, organic fertilisers contributing by 10%, 9%, 8% and 3%, respectively), while ruminant enteric methane emissions were 14%, 7% and 4%, for beef, sheep and dairy, respectively. The 3 Mt CO_2e carbon sink provided by land conversion to grassland offset 22% of the GHG emissions, reducing them to a total of 10.6 Mt CO_2e. These numbers emphasise that the mitigation focus should be on increasing the efficiency of agriculture in order to reduce future land conversion, and also on reducing N_2O emissions from soil N management and CH_4 emissions from enteric fermentation, though it is much more difficult to achieve high abatement in the latter. Nevertheless, manure management and storage also have to be considered since they offer abatement options, often with a co-benefit of ammonia reductions (Eory et al. 2012), to which manure is the single most important source (Misselbrook et al. 2010).

Another important target must be high organic content soils (peatlands), which cover most of Scotland land area, and contain 900 Mt C (= 3300 Mt CO_2e) (Bradley et al. 2005). Protecting existing peatlands (especially avoiding the drainage of them) would save emissions and restoring degraded peatlands would contribute to CO_2 sequestration. Though much research has been done on this topic, given the scope of the current report, we could not identify the possible GHG savings in Scotland and the costs associated with it.

2. RPP1

RPP1 was based on the Scottish version of the marginal abatement cost curve (MACC) 2008 (Moran et al. 2008), and estimated an annual greenhouse gas (GHG) reduction of 0.9 Mt CO_2e in 2022, with measures supported by Farming for a Better Climate (FFBC), Scottish Rural Development Programme (SRDP) and the Single Farm Payment Scheme (Cross Compliance, from 2018). Measures included: “Improved timing of mineral N applications”, “Improved timing of organic N applications”, “Full allowance of manure N supply”, “Plants with improved N-use”, “Avoiding N excess”, “Using composts in preference to slurry”, “Separate slurry applications from fertiliser applications with several days”, “Improved genetic potential for beef cattle” and “Probiotics (feed additive) for beef”. Other measures assessed as part of the MACC analysis were excluded either due to their high cost, including high upfront cost (e.g. “Reduced tillage”); or were perceived to be in contradiction to other policy objectives (e.g. “Increased land drainage”); or were currently not applicable due to legislative restrictions (e.g. “Ionophores (feed additive) to dairy cattle”).

RPP2 projections (Close 2011) are based on the Scottish version of an updated MACC (MacLeod et al. 2010), and estimate lower emission savings of 0.4 Mt CO_2e for 2022 and for the third budgetary period of 2023-2027. The reduction in the abatement potential can be mostly explained by a reduction in the updated BAU activity data (especially animal numbers) and by changes in the assumptions for abatement and applicability rates for nitrogen application measures. Additionally, new cost formulas applied to anaerobic digestion (AD) calculations made these measures less favourable.

The following measures are included in RPP2: “Improved timing of mineral N applications”, “Improved timing of organic N applications”, “Full allowance of manure N supply”, “Plants with improved N-use”, “Avoiding N excess”, “Using composts in preference to slurry”, “Separate slurry applications from fertiliser applications by several days”, “Reduced tillage”, “Improved genetic potential for beef”, “Improved genetic potential for dairy (fertility)”, “Improved genetic potential for dairy (productivity)”, “More maize silage for dairy cattle”, “Covering slurry lagoons on dairy farms”.

Measures with CE > 40 £ tCO_2e^{-1} do not appear in the RPP2 (“Using biological fixation to provide N”, “Reduce N fertilisers below optimum”, “Species introduction (including legumes)”, “Nitrification inhibitors”, “Controlled release fertilisers”, “Adopting systems less reliant on inputs”, “More concentrates to beef”, AD measures), nor do measures considered unacceptable (“Proprionate precursors for dairy and beef”) or that are in conflict with other policy goals (“Land drainage”).

3. Extending the Abatement Potential of RPP1 Measures

3.1. Precision Farming

Precision farming use computerised technical solutions to target the highly variable nutrition needs of plants. It requires high upfront costs and investment in learning, but offers potentially significant savings in nutrient costs.

The abatement rate (AR) of the RPP1 MMs targeting plant nutrient efficiency ("Improved timing of mineral N applications", "Improved timing of organic N applications", "Full allowance of manure supply", "Avoiding N excess") could increase with the wider uptake of this option, based on the assumption that its costs will be significantly reduced in 10 years' time.

Table 1: Abatement rate and abatement potential of MMs likely to be affected by precision farming methods

Measure	Abatement rate Pessimistic-optimistic range in (MacLeod et al. 2010) (t CO_2e ha^{-1})	Abatement rate Value currently in use in the RPP2 MACC (t CO_2e ha^{-1})	Abatement potential (2027, MTP, incl. interactions) (kt CO_2e)
Improved timing of mineral N appl.	0 – 0.3	0.1	71
Improved timing of organic N appl.	0.3 – 0.3	0.3	166
Full allowance of manure N supply	0.02 – 0.16	0.45	79
Avoiding N excess	0.01 – 0.12	0.1	34

Given the current ARs in use (Table 1), the AR of "Improved timing of mineral N applications" can be expected to increase from 0.1 to 0.3 t CO_2e ha-1, raising the total abatement potential by 115 kt CO_2e (assuming 81% uptake in 2027, based on (Close 2011)).

3.2. Probiotics for Cattle

Probiotics (directly fed microbes, e.g. Saccheromyces cerevisiae and Aspergillus oryzae) are used to divert hydrogen from methanogenesis towards acetogenesis in the rumen, resulting in a reduction in methane production and improved productivity.

The current list of mitigation options includes this option only for beef cattle but not for dairy cattle. Assuming the voluntary uptake assumption of 15% in (Close 2011), the AP would be 9 kt CO_2e. Barriers to uptake include the difficulties of administering the additive to grazing herds.

3.3. Propionate Precursors for Ruminants

By adding propionate precursors (e.g. fumarate) to animal feed, more hydrogen is used to produce propionate and less CH4 is produced. These molecules are present naturally in the rumen and take part in the fermentation process. In addition, two of the three compounds found to be most effective on methane reduction in vitro by Newbold et al. (2005) are in human consumption (fumaric acid as E297 and 2-oxoglutarate (other name: α-Ketoglutaric acid) as dietary supplement), while the third one, acrilyc acid is toxic only in high quantities (http://www.inchem.org/documents/hsg/hsg/v104hsg.htm#SectionNumber:2.1).

SG assumes low acceptability of this option by farmers and consumers, but appropriate communication can reduce this risk. Similar to probiotics, implementation in grazing herds may be a difficulty.

This MM's MTP abatement potential is 71 and 80 kt CO_2e higher than the AP of probiotics for beef and dairy, respectively. Therefore it would offer 22 kt CO_2e more abatement for cattle – using SG's assumption of 15% uptake. Administering propionate precursors to sheep could provide an additional 24 kt CO_2e (15% uptake).

In total the three MMs described above could add 170 kt CO_2e to the mitigation effort in RPP2 (with uptake assumptions based on (Close 2011)).

4. Possibilities to extend RPP2

Table 2 identifies more than 20 further measures that could offer additional abatement potential over and above that identified in RPP1. Table 3 attempts an initial quantification of the extra potential assuming maximum applicability. We provide a ranking of those that could be most likely to be included in the time horizon under consideration.

Table 2 Possible measures for inclusion in RPP2

Measure	Short description
Controlled release fertilisers	CRFs supply N, usually in the urea form, at a progressive rate over 2- 6 months, reducing microbial conversion of the mineral N to N_2O and increasing N-efficiency.
Nitrification inhibitors	NIs slow the rate of conversion of fertiliser ammonium to nitrate, this way reducing N_2O emissions and increasing N-efficiency.
Improving land drainage	Improving drainage reduces N_2O emissions by increasing soil aeration, and also improves yield.
Improved crop varieties	(Further) improvements in yield, N-use-efficiency, or pest resistance can all lead to higher productivity and reduced GHG per output.
Avoid compaction of land	Preventing soil damage by high stock densities and heavy machinery (with especially high risk when the soil is wet) increases soil aeration and thus reduces N_2O emissions while improving soil structure and therefore yield.
Preventing peat degradation	Bringing peatlands under agricultural management unfavourably alter their GHG balance besides causing a significant loss in most of their valuable ecosystem functions.
Peat restoration	Well-chosen peat restoration techniques (e.g. grip blocking, improved grazing management, reseeding) can result in a slow regain of ecosystem function and reduced GHG emissions.
Biofilters for methane	In a methane biofilter methanotrophic bacteria convert the methane into carbon dioxide. Requires mechanically ventilation and applicable to both animal houses and covered slurry stores.
Low emission housing systems	Newly built animal houses can incorporate many features (e.g. improved manure handling, improved manure storage, biofilters to remove methane) to reduce GHG (and ammonia) emissions.
Frequent manure removal	Increasing the frequency of manure (esp. slurry) removal from animal houses to outdoor storage where temperature is lower reduces microbial activity and therefore methane emissions from slurry and nitrous oxide emissions from FYM.
AD	Anaerobic digestion of animal waste reduces methane emissions to almost zero by replacing them with the much less potent GHG of CO_2. The digestate can be used as fertiliser.
High sugar ryegrass	Improved sugar levels in the ryegrass improve milk and meat production and increase the amount of the nitrogen in the grass that can be used by the animal and less nitrogen is lost.
Ionophores	Ionophore antimicrobials (e.g. monensin) are used to improve efficiency of animal production by decreasing the dry matter intake (DMI) and increasing performance and decreasing CH_4 production.
Feed additives: vegetable oils	Adding vegetable oils to the feed increases the energy density of the diet without the increasing risk of acidosis, thus increasing efficiency and reducing methane emissions.
Feed additives: plant extracts (essential oils, saponins)	Essential oils potentially improve N and energy utilisation in animals, decreasing GHG emissions per unit of output by increasing productivity. Saponins might promote growth via protozoan defaunation.
Vaccination to suppress methanogenes	Invoking an immune response against specific rumen microorganisms might be effective in increasing productivity and decreasing methane emissions.
Defaunation	Defaunation is a treatment that decrease the protozoal population of the rumen, therefore decreasing the protozoa-associated methanogen population and methane production.
GM rumen microflora	Genetic modification of specific rumen microorganisms might be effective in increasing productivity

Measure	Short description
	and decreasing methane emissions.
Antibiotics	Peptide antibiotics are used for growth stimulation and can also induce a shift in the pattern of rumen fermentation in favour of propionate, thus reducing methane emissions. Poses concern regarding the development of resistant bacterial strains; prohibited in the EU.
Steroids	Steroids used as growth promoters improve feed efficiency and weight increase, thus decreasing GHG emissions per output. Questionable public acceptance; prohibited in the EU.
bST	bST increases milk production and lowers methane emissions per unit of milk.
Better animal health	Applying preventive measures (e.g. increasing biosecurity, vaccination) increases production per animal and thus reduces GHG emissions per unit of output.
Use bulls with high environmental lifetime index (like PLI)	Including GHG emission reduction into the breeding goals (as opposed to optimising breeding purely on financial basis) would result in lower cattle emissions per unit of output.

Table 3 Estimates for Scotland for the third C-budget period (2023-2027), assuming 100% uptake

Measure	Likelihood of becoming a feasible measure by 2023	Current barrier	Removing the barrier	Abatement rate (t CO_2e ha^{-1} y^{-1} or % of animal em.)	Applicability (% of land area or % of animals)	Stand-alone annual abatement (kt CO_2e y^{-1})	Upfront cost	Running cost	Stand-alone CE (£ CO_2e^{-1})	Sources
Controlled release fertilisers	2	High running cost (currently pays off only for high-value crops)	Improved technology	0.3	0.72-0.91	444	0	£47.60/ha/y	152	(MacLeod *et al.* 2010, Moran *et al.* 2008), new Scottish MACC
Nitrification inhibitors	1	Abatement rate uncertain for UK (widely used in NZ), probably high running cost	Research (e.g. Defra AC 0213)	0.12	0.72-0.91	179	0	£49.80/ha/y	397	(MacLeod *et al.* 2010, Moran *et al.* 2008), new Scottish MACC
Improving land drainage	2	Uncertainty regarding effects on diffuse water pollution	Research	0.6	0.3-0.4	430	£1850/ ha to build	£250/ha in every 5 years + yield increase	0.60	(MacLeod *et al.* 2010, Moran *et al.* 2008), new Scottish MACC
Improved crop varieties	1	Not available	Research	0.2	0.05-0.5	65	0	?	?	(Barraclough *et al.* 2010, Moran *et al.* 2008)
Avoid compaction of land	1	None	-	0.05	0.3-0.5	42	0	?	?	(Moran et al. 2008)
Preventing peat degradation	2	Uncertainty in efficiency	Research	2	0.05-0.1	298	?	?	?	(Moran *et al.* 2008)
Peat restoration	2		Research (e.g. Defra SP1202)	?	?	?	?	?	?	(Moxey 2011)
Biofilters for methane	2	Not established technology; upfront cost (appl. to new buildings)		50% of housing and manure storage CH_4	45% cattle	2161*0.5*0.45= 432	high	low	17	(Melse & van der Werf 2005, Sholefield *et al.* 2007)
Low emission housing systems	3	High upfront cost; not established technology for CH_4		>50% of housing CH_4	45% cattle, 90% pigs	>400	high	high	?	Assumption: higher efficiency than biofilters

Measure	Likelihood of becoming a feasible measure by 2023	Current barrier	Removing the barrier	Abatement rate (t CO_2e ha^{-1} y^{-1} or % of animal em.)	Applicability (% of land area or % of animals)	Stand-alone annual abatement (kt CO_2e y^{-1})	Upfront cost	Running cost	Stand-alone CE (£ CO_2e^{-1})	Sources
Frequent manure removal	1	None	-	50% housing and manure storage CH_4	38% cattle, 90% pigs	243*0.5*0.38 +59*0.5*0.9= 68	low	low	?	(Sommer *et al.* 2004)
AD	1	High upfront cost	Improved technology	70-90% of manure CH_4	38% cattle, 90% pigs	243*0.7*0.38 +59*0.7*0.9= 84	high	high	22-372	new Scottish MACC
High sugar ryegrass	2	Efficiency to be proved	Research	?	?	?	0	low	<0	(Edwards *et al.* 2007, IGER 2005)
Ionophores	3	Not legal; efficiency to be proved	Research	10% of enteric CH_4 + productivity gains	100% cattle	1918*0.1= 192	0	low	<0	(Beauchemin *et al.* 2008)
Feed additives: vegetable oils	2	Not available	Research	20% of enteric CH_4 + productivity gains	100% cattle	1918*0.2= 384	0	low	low	(Beauchemin *et al.* 2008, Hook *et al.* 2010)
Feed additives: plant extracts	2	Not available	Research	? 10-50%	100% cattle	1918*0.1= 192	0	low	low	(Hook *et al.* 2010)
Vaccination to suppress methanogenes	3	Not available	Research	? ~20%	100% cattle and sheep	2609*0.2= 522	0	low	low	(Hook *et al.* 2010)
Defaunation	3	Not available	Research	? ~10%	100% cattle and sheep	2609*0.1= 261	0	low	low	(Hook *et al.* 2010)
GM rumen microflora	3	Not available	Research	?	100%	?	0	?	?	
Antibiotics	3	Not legal	Legalisation		100%	?	0	?	?	
Steroids	3	Not legal	Legalisation		100%	?	0	?	?	
bST	3	Not legal	Legalisation		100%	28	0	high	191	(MacLeod *et al.* 2010)
Better animal health										

Measure	Likelihood of becoming a feasible measure by 2023	Current barrier	Removing the barrier	Abatement rate (t CO_2e ha^{-1} y^{-1} or % of animal em.)	Applicability (% of land area or % of animals)	Stand-alone annual abatement (kt CO_2e y^{-1})	Upfront cost	Running cost	Stand-alone CE (£ CO_2e^{-1})	Sources
BVDV, beef	n/a	Already compulsory – part of BAU		4.5%		83	0	£-27/cow/y	-0.22	(Stott et al. 2010)
Mastitis, dairy	1	None	-	1.4% of dairy GHG emissions	100% dairy	536*0.014= 8	0	?	?	(Stott et al. 2010)
All common sheep diseases	1	None	-	20% of sheep GHG emissions	100% sheep	691*0.2= 138	0	£1.75/ewe/y	31	(Stott et al. 2010)
Use bulls with high environmental lifetime index	1	Index is under development	Research (e.g. SAC)		100%		0			
Dairy				2% of dairy GHG emissions	100% dairy	536*0.02= 11	0	Low	low	Eileen Wall, personal comm..
Beef				2% of beef GHG emissions	100% beef	1625*0.02= 33	0	Low	low	Eileen Wall, personal comm..

Likelihood of becoming a feasible measure by 2023: 1: very likely, 2: moderately likely, 3: unlikely

The annual stand-alone annual abatement of those measures that are very likely to become feasible by 2023 amounts to 628 kt CO_2e, assuming 100% uptake of the measures and not accounting for interaction between the measures.

5. Conclusion

Further optimising nitrogen fertiliser using new technologies (precision farming, nitrification inhibitors, controlled release fertilisers) could offer high N2O savings. We assume that the cost of technology will fall and that research on nitrification inhibitors finds this technique suitable for Scottish conditions.

Land drainage is another area where significant mitigation could potentially be achieved, But some uncertainty remains. Though better drained land emits less nitrous oxide (and boosts plant productivity), some fear that more pollutants (especially nitrogen and phosphorous) are drained into water bodies, increasing diffuse water pollution. This debate has to be addressed, resulting in specific recommendations about where to improve the drainage system and where to leave it deteriorate.

Land use of organic soils has wider consequences as well. Both the restoration of peatlands and their protection means less land available for agriculture, but offers GHG and biodiversity benefits. But land management is complex. Site-specific restoration techniques (most often spanning over years) are needed for every area to achieve the appropriate mix of GHG reduction, biodiversity improvement and land management goals.

MMs targeting enteric methane emissions are potentially big GHG savers. They include reducing methane emissions from animal housing (end-of-pipe technologies) and reducing the rate of methanogenesis (feed additives, vaccination). The latter are still far from being commercially available, and most of them could prove difficult to administer to grazing animals.

Antibiotics, steroids and bST are used to increase livestock productivity in some parts of the world, but banned in the EU. Given potential issues of public acceptability around these issues, the legislation might not change within the next ten years. Other ways to increase productivity - not covered in the RPP1 but suggested for consideration here is better animal health.

In general, future reduction in the cost of technologies (e.g AD), research on the efficiency of some MMs (especially feed additives) and development on making them commercially available are needed to enhance voluntary uptake. A co-benefit on productivity (resulting in higher resource efficiency and therefore financial savings) can also help adoption. Continuing dialogue with farmers and land managers and making them accept that agriculture is an important sector in terms of emissions mitigation is also essential

Finally, for integrated environmental management effort the co-effects of these MMs have to be considered, especially where pollution swapping might occur (land drainage, protection of peatlands).

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Annex 1 Initial requirement

Task 1: Review of abatement measures in RPP1 and those presented by the Scottish Government as being considered for RPP2, and the identification of additional 'Possibilities'.

Task 2: Review of potential abatement yield estimates for the abatement measures considered under Task 1, and the method of their calculation.

Task 3: For each measure, and where possible, identify costs and cost effectiveness. Where data are available that allow an estimate to made of actual costs (and cost effectiveness), these costs should be highlighted. Where it is only possible to give an indication of potential costs, qualitative judgements will still be helpful.

Task 4: For each measure, identify additional interventions that could improve the yield or likelihood of success of the measure, and describe 'good practice'.

Task 5: A ranking of measures by contribution to abatement potential and likelihood of successful implementation in given timescales (i.e. by 2027).

Annex 2 Scotland's agricultural GHG emissions in 2009

Table 4 GHG emissions from agricultural and related land use, Scotland, 2009 ((Thomas et al. 2011) with details on soil emissions from (Choudrie et al. 2008)). The most important sources are highlighted in blue

Source	kt CO2e	% of total
Agricultural soils (incl. biomass burning and liming)	**4012**	**38%**
Indirect emission from leaching of organic and inorganic fertilisers	1062	10%
Inorganic fertilisers	986	9%
Wastes from grazing animals	835	8%
Organic fertilisers	341	3%
Ploughing in crop residues	266	2%
Indirect emission from atmospheric deposition	266	2%
Biological fixation in improved grass	30	0.3%
Cultivation of histosoils	8	0.1%
Cultivation of legumes	4	0.0%
Biomass burning	41	0.4%
Liming	173	2%
Enteric fermentation	**2637**	**25%**
Dairy cattle	431	4%
Other cattle	1487	14%
Sheep	691	7%
Other	27	0.3%
Livestock waste	**629**	**6%**
Dairy cattle - CH4	106	1%
Other cattle - CH4	137	1%
Sheep, goats and deer - CH4	16	0.2%
Pigs - CH4	59	0.6%
Other - CH4	23	0.2%
Liquid manure - N2O	6	0.1%
Solid manure - N2O	240	2%
Other manure - N2O	41	0.4%
Fuel and agrochemical use	**797**	**7%**
Mobile machinery	737	7%
Other	60	0.6%
Land conversion	**2555**	**24%**
Cropland remaining Cropland	-79	-0.7%
Wetlands remaining Wetland	51	0.5%
Non-CO_2 emissions from drainage of soils and wetlands	0	0.0%
Land converted to Cropland	5279	50%
N2O emissions from disturbance associated with land-use conversion to cropland	301	3%
Land converted to Grassland	-2997	-28%
Total	**10,629**	**100%**