Review of Land Use Climate Change

An assessment of the evidence base for climate change action in the agriculture, land use and wider foodchain sectors in Wales

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Crynodeb Gweithredol

Cyd-destun a dull yr ymchwil

Mae Llywodraeth Cymru wedi ymrwymo i darged cyffredinol o leihau allyriadau nwyon tŷ gwydr 3% y flwyddyn mewn meysydd lle mae cymhwysedd wedi'i ddatganoli a disgwylir y bydd pob sector perthnasol yn gwneud cyfraniad. Mae hefyd yn anelu at ostyngiad o 40% yn yr holl allyriadau erbyn 2020 o'u cymharu â ffigurau 1990. Yn 2010 nododd y Grŵp Defnydd Tir a Newid Hinsawdd nifer o argymhellion er mwyn lleihau allyriadau yn y sectorau amaeth a defnydd tir. Er hyn, gwelwyd cynnydd o 1.2% mewn allyriadau yn y sectorau hyn yn 2011. Oherwydd hyn, a dechrau Cynllun Datblygu Gwledig newydd ar gyfer y cyfnod hyd at 2020, comisiynodd Llywodraeth Cymru'r adolygiad hwn o allyriadau ac ymaddasu i'r newid yn yr hinsawdd yn y sectorau amaeth a defnydd tir. Y nod yw darparu sail dystiolaeth gadarn i gynorthwyo'r rhai sy'n gwneud penderfyniadau yn ymwneud â pholisi newid hinsawdd a sicrhau cydlyniad â blaenoriaethau ehangach y llywodraeth ar gyfer swyddi, twf a thlodi.

Mae ADAS a'i bartneriaid ymchwil (Prifysgol Bangor, y Ganolfan Ecoleg a Hydroleg, IBERS a Rothamsted) wedi gwneud adolygiad desg o argymhellion adroddiad 2010 y Grŵp Defnydd Tir a Newid Hinsawdd ac wedi adolygu newidiadau i'r stocrestr nwyon tŷ gwydr er mwyn ystyried sut y gallai hyn effeithio ar gynllun cyflawni'r sector ar gyfer lleihau allyriadau. Yn ychwanegol at hyn, cynhaliodd y tîm adolygiad o'r risgiau sy'n gysylltiedig â newid hinsawdd fel sail i'r ymateb ymaddasu, a fydd yn cael ei ddatblygu gan Lywodraeth Cymru mewn Cynllun Ymaddasu Sectorol. Ymgynghorodd yr ymchwilwyr â rhanddeiliaid perthnasol ym maes polisi a diwydiant yng Nghymru ynglŷn â phob agwedd ar y gwaith er mwyn darparu dadansoddiad pragmatig a fydd yn sail i bolisi cydlynol ac effeithiol yn y maes hwn.

Adolygiad o argymhellion y Grŵp Defnydd Tir a Newid Hinsawdd

Defnyddiwyd templed yn seiliedig ar nifer o feini prawf ar gyfer cryfhau a gwneud cynnydd er mwyn adolygu'r 49 o argymhellion a oedd yn adroddiad 2010 y Grŵp Defnydd Tir a Newid Hinsawdd (gweler atodiad 2). Edrychodd y dadansoddiad ar yr argymhellion dan nifer o themâu, gan adlewyrchu gweithgareddau arbennig a sail gysylltiedig ar gyfer rhoi cyfrif am leihau allyriadau (mewn stocrestrau), sef:

i. Amaethyddiaeth gynhyrchiol.
ii. Defnydd tir a rheoli tir.
iii. Ynni adnewyddadwy.

Roedd argymhellion 2010 hefyd yn cynnwys camau gweithredu er mwyn datblygu a darparu capasiti ymchwil a thystiolaeth berthnasol (yn ymwneud yn benodol â Chymru), a nifer o gamau gweithredu trawsbynciol ehangach ar gyfer Llywodraeth Cymru. Adolygwyd y rhain hefyd.

Canfu'r dadansoddiad bod rhai o argymhellion 2010 yn ddyheadol, ac mewn rhai achosion heb gael eu diffinio'n dda o ran perchnogaeth na graddfa amser, ond bod y rhan fwyaf yn dal yn berthnasol i leihau allyriadau yng Nghymru. Yn y dadansoddiad hwn, rydym wedi awgrymu newid ffocws, gan bwysleisio'r camau gweithredu ar gyfer y cyfnod hyd at 2020 tra'n mapio camau gweithredu ac effeithiau parhaus hyd at 2050 a 2080.

Er bod cynnydd pendant wedi'i wneud ag ymchwil i allyriadau yng Nghymru, efallai mai'r hyn sydd fwyaf nodedig yw bod cynifer o'r camau i leihau allyriadau nwyon tŷ gwydr heb gael eu rhoi ar waith. O ran y mesurau hynny sy'n cael eu noddi gan y Llywodraeth, mae hyn yn ymwneud yn rhannol a diffyg eglurder (un enghraifft yw ble i roi creu coetir) a dim digon o gymhelliant i ffermwyr a pherchnogion tir (e.e. i greu coetir ac adfer mawndir). Mae digon o gymhellion a diddordeb gan ddiwydiannau mewn buddsoddi mewn ynni adnewyddadwy ond mae rhwystrau strwythurol (cael caniatâd cynllunio a chysylltu â'r grid yn bennaf) wedi cyfyngu ar y cynnydd sydd wedi'i wneud . O ran y camau gweithredu ar gyfer ffermio, roedd argymhellion 2010 yn cael eu hystyried yn rhy radical neu eang ac nid ydynt wedi llwyddo i ennyn diddordeb y gymuned amaethyddol.

Y cynllun cyflawni ar gyfer lleihau allyriadau a newidiadau i'r stocrestr

Mae asesiad o'r allyriadau, sy'n seiliedig ar gamau gweithredu adroddiad 2010 a rhai mesurau eraill o lenyddiaeth yn y maes hwn, yn awgrymu y gellid lleihau allyriadau'n sylweddol. Cyfeirir isod at gwmpas y diweddariad o'r cynllun cyflawni ar gyfer lleihau allyriadau a sut y bydd yn cael ei wireddu a'i gyfrif.

Yn y sector **amaeth**, mae mesurau lliniaru'n dibynnu llawer ar ddulliau mwy effeithlon o gynhyrchu, ond mae hyn yn tueddu i gynyddu allbwn yn hytrach na lleihau mewnbwn. O ganlyniad, mae'n debyg mai'r budd fydd gwella dwysedd yr allyriadau (allyriadau is am bob uned o gynnyrch bwyd) yn hytrach na lleihad absoliwt mewn allyriadau. Ni fyddai hyn yn cael ei gyfrif yn y stocrestr, er y gallai ddadleoli allyriadau tramor o newid defnydd tir (o fewnforion bwyd wedi'u dadleoli). Mae datblygiadau technolegol sy'n lleihau colli nitrogen o wrtaith a thail yn cynnig cyfleoedd ar gyfer lleihad absoliwt mewn allyriadau.

Yn gyffredinol, disgwylir y bydd y sector amaeth yn gallu sicrhau lleihad o hyd at 400 ktCO_2e y flwyddyn mewn allyriadau, ond gallai hyn fod yn llai, a gallem hyd yn oed weld cynnydd mewn allyriadau os bydd nifer y da byw'n cynyddu o ganlyniad i arbedion effeithlonrwydd. Ni fydd modd cofnodi'r lleihad hwn yn llawn yn y stocrestr amaethyddiaeth wedi'i gwella o 2016 ymlaen.

O ran **defnydd tir** a'r stocrestr "defnydd tir, newid defnydd tir a choedwigaeth" (LULUCF), y prif gyfleoedd o hyd yw ehangu coetir ac adfer mawndir sydd wedi dirywio. Mae'r ddau fesur yn dibynnu ar warchod a/neu cynyddu storfeydd carbon a lleihau allyriadau sy'n gysylltiedig â'u rheoli. Mae'r ddau'n cystadlu â chynhyrchu bwyd o ran defnydd tir ac mae angen iddynt barchu'r amcanion polisi ehangach ar gyfer tirwedd a bioamrywiaeth, yn ogystal â blaenoriaethau cymdeithasol-economaidd, yn enwedig yn yr ucheldir. Derbynnir bod angen lleoli coetir ar dir llai cynhyrchiol, mewn ardaloedd nad ydynt yn bwysig iawn ar gyfer gwasanaethau ecosystemau eraill, ac mae'r dadansoddiad yn awgrymu bod digon o dir i gyflawni'r targed o blannu 100,000 ha o goetir a nodwyd yn adroddiad 2010. Y broblem yw'r amser y mae'n mynd i'w gymryd i gyflawni hyn, sy'n dibynnu ar natur a maint y cymhelliant sydd ar gael (drwy grantiau Glastir) a rhywfaint o newid ymddygiad ymhlith ffermwyr a pherchnogion tir; gallai hyn gymryd cymaint â 50 mlynedd. Amcangyfrifir bod y lleihad mewn allyriadau net, ar ôl ystyried dal a storio carbon o gyfuniad o ehangu coetir ac adfer mawndir, yn 500 ktCO_2e y flwyddyn, ond dros gyfnod estynedig.

Mae'r drydedd thema, **ynni adnewyddadwy** yn elfen allweddol o bolisi ynni'r llywodraeth. Fodd bynnag, mae'r cynnydd yn araf oherwydd y broses gynllunio, sy'n adlewyrchu'r elfen o gefnogaeth gan y cyhoedd a materion yn ymwneud ag eglurder polisïau, a'r angen am welliannau i'r grid trydan. Gan fod modd rhoi sylw i'r rhwystrau hyn mewn egwyddor, gallai ynni adnewyddadwy sicrhau gostyngiad net o hyd at 1,600 ktCO_2e y flwyddyn mewn allyriadau â phwyslais ar y technolegau mwyaf costeffeithiol, sef ynni gwynt ac ynni'r haul. Gellir sicrhau lleihad sylweddol mewn allyriadau drwy ddatblygu cnydau bio-ynni (helyg a miscanthus) ynghyd â bio-nwy (treulio anaerobig) ond efallai y bydd cystadleuaeth am dir rhwng y rhain a chynhyrchu bwyd. Gellid lleihau'r ddibyniaeth ar ddefnydd tir drwy ganolbwyntio ar ddatblygu cadwyn gyflenwi tanwydd coed a/neu dreuliad anaerobig slyri da byw (yn hytrach na deunydd cnydau). Mae treulio anaerobig ar raddfa fwy yn debygol o ddigwydd ar safleoedd ar wahân i ffermydd gan mwyaf, ar gyfer treulio gwastraff bwyd a gwastraff gwyrdd.

O fewn y targed o 3% a osodwyd gan Lywodraeth Cymru, ni fyddai cynhyrchu mwy o drydan a gwres adnewyddadwy yn arwain at wrthbwysiad uniongyrchol mewn allyriadau cynhyrchu trydan gan fod cynhyrchu ynni ar raddfa fawr (a fyddai'n cael ei wrthbwyso) wedi'i eithrio o'r diffiniad o'r targed yn barod. Byddai safleoedd bio-ynni bach yng Nghymru (os ydynt y tu allan i system masnachu ynni'r Undeb Ewropeaidd) yn rhan o gwmpas targed Llywodraeth Cymru o 3% a gallent fod yn ffynhonnell allyriadau ychwanegol o fewn cwmpas y targed. Fodd bynnag, gallai ynni adnewyddadwy ar ffermydd leihau'r defnydd o drydan o'r grid gan ddefnyddwyr terfynol ym myd amaeth, a fyddai'n cael effaith uniongyrchol ar y targed o 3%

ar gyfer y sector. Ble bynnag y mae allyriadau'n cael eu cyfrif, bydd ynni adnewyddadwy'n gwneud cyfraniad gwerthfawr i'r nod cyffredinol o leihau allyriadau nwyon tŷ gwydr atmosfferig yn fyd-eang er mwyn lleihau effeithiau newid yn yr hinsawdd yn y dyfodol.

Mae'r gadwyn gyflenwi bwyd yn cael ei sbarduno gan reidrwydd masnachol i chwilio am arbedion effeithlonrwydd o hyd ac mae hyn yn arwain at leihad cynyddol mewn allyriadau ar ôl gadael giât y fferm. Fodd bynnag, yn y sectorau llaeth a chig, mae 85-90% o'r allyriadau'n ymwneud â gweithgaredd ar y fferm, a dyma lle mae angen y pwyslais mwyaf ar leihau allyriadau. Er hyn, gall y gadwyn gyflenwi wneud cyfraniad gwerthfawr tuag at leihad absoliwt mewn allyriadau ac mae'n bwysig iawn er mwyn helpu i hybu newid mewn arferion ar ffermydd yng nghyd-destun yr agenda gynaliadwyedd ehangach.

Mae'r gwaith sy'n cael ei wneud er mwyn datblygu'r stocrestrau nwyon tŷ gwydr ar gyfer amaethyddiaeth a LULUCF yn awgrymu y bydd cyfleoedd o 2016 ymlaen i wella cywirdeb cyfrifo ac adlewyrchu strategaethau lliniaru penodol ac ymhlyg ac, yn bwysig iawn, i gyfrif rhagor o'r allyriadau o reoli amaethyddiaeth a defnydd tir. Dylai'r rhain helpu i sicrhau rhagor o gynnydd tuag at dargedau lleihau allyriadau, ond dim ond y gwahaniaethau ers gwaelodlin 2006-2010 fydd yn cael eu hadlewyrchu a byddant yn gynyddrannol.

Ymaddasu i newid yn yr hinsawdd

Yn sector defnydd tir Cymru, y risgiau newid hinsawdd mwyaf arwyddocaol yw'r rhai sy'n gysylltiedig â llifogydd. Mae hyn yn cynnwys y risgiau i gartrefi ac eiddo busnes, effeithiau ar dda byw o ran tir pori a phorthiant, a'r effeithiau posibl ar gynnyrch yn y sectorau âr/garddwriaeth a choedwigaeth. Mae gan y sectorau amaeth a defnydd tir ran bwysig i'w chwarae wrth addasu i effeithiau llifogydd. Yn fwyaf arbennig, gallai plannu coed mewn ardaloedd penodol leihau perygl llifogydd a wynebir gan gymunedau/busnesau, ynghyd â lleihau effeithiau afiechydon da byw, megis llyngyr yr afu, drwy gyfyngu ar fynediad i ddarnau gwlypach o dir.

Mae cynnydd yn y pwysau a achosir gan blâu ac afiechydon yn y sectorau coedwigaeth a da byw yn risg sylweddol, yn bennaf oherwydd gaeafau mwynach a gwlypach. O ran coedwigaeth, mae sicrhau amrywiaeth rhywogaethau yn hollbwysig er mwyn lleihau effeithiau, a gall hefyd arwain at nifer o fanteision drwy ymaddasu i straen dŵr a dadwreiddio coed ar ôl gwynt cryf. O ran da byw, mae nifer o wahanol gamau ymaddasu ar gael ond efallai mai cynllunio da ac ymwybyddiaeth o'r arferion gorau yw'r camau ymaddasu gorau.

Nid yw straen dŵr yn gymaint o risg i Gymru oherwydd bod gennym lawiad cymharol uchel, ond ar adegau sych gall effeithio ar y rhan fwyaf o'r sectorau amaeth a defnydd tir. Bydd yr effaith fwyaf ar y sectorau coedwigaeth, cymunedau/busnesau gwledig a da byw. Gellir defnyddio dŵr glaw yn gymharol gosteffeithiol er mwyn lliniaru'r effeithiau. Gellir gwneud hyn yn syml iawn ar ffermydd da byw drwy osod cafnau, neu greu llynnoedd. Gall cwsmeriaid domestig osod systemau casglu dŵr glaw er mwyn ailddefnyddio dŵr llwyd. Ar raddfa fwy, gellir adeiladu cronfeydd dŵr i ddiwallu cynnydd tymhorol yn y galw; fodd bynnag, bydd angen ystyried costau gwneud hyn ochr yn ochr â'r budd.

Mae tanau gwyllt, sy'n effeithio ar laswelltir ac ardaloedd coedwigaeth, ac mewn rhai achosion ar gymunedau gwledig, ar gynnydd yng Nghymru wrth i gyfnodau sychach yn yr haf ddod yn fwy cyffredin. Gall tanau gwyllt fod yn gostus, felly gall mesurau ymaddasu fod yn gosteffeithiol iawn. Mae mesurau o'r fath hefyd yn cynyddu ymwybyddiaeth y cyhoedd ac yn annog gweithio mewn partneriaeth er mwyn lleihau troseddau sy'n gysylltiedig â llosgi bwriadol, yn ogystal â darparu stribedi atal tân.

Cyfleoedd ar gyfer synergedd a gwrthdaro

Mae dau brif fater sy'n ymwneud â chydlyniant yng nghyswllt polisïau newid hinsawdd. Yn gyntaf, sut y mae mesurau lleihau allyriadau yn effeithio ar wasanaethau ecosystemau ehangach ac yn ail, beth yw'r cyfleoedd ar gyfer synergedd a'r siawns o wrthdaro â chamau ymaddasu. Mae dadansoddiad o'r materion hyn yn tynnu sylw at gyfleoedd sylweddol ar gyfer synergedd, yn deillio o'r camau defnydd tir ar goetir a mawndir yn fwyaf arbennig, ond y rhain hefyd yw'r meysydd lle mae'r gwrthdaro mwyaf i'w weld oherwydd eu bod yn cystadlu am ddefnydd tir (llai yng nghyswllt ailwlychu gorgors sy'n cael ei phori). Mae rhai technolegau ynni adnewyddadwy yn cystadlu am dir (rhai biomas a bio-nwy sy'n deillio o gnydau) ond mae eraill nad ydynt yn cystadlu am dir (gwynt, ynni'r haul ar doeau ac ynni dŵr). Rhaid rhoi sylw i reoli'r cyfleoedd a'r risgiau hyn drwy ymagwedd strategol at ddefnydd tir ar lefel genedlaethol a lleol a dulliau priodol o hyrwyddo camau sy'n ymwneud â newid hinsawdd.

Nid canfod synergedd a meysydd lle mae gwrthdaro yw'r her i'r llywodraeth, ond gweithredu polisi sy'n rhoi sylw priodol iddynt ac yn ystyried y cyfaddawdu sydd ei angen rhwng blaenoriaethau er mwyn cyflawni ymrwymiadau'r agenda hon.

Blaenoriaethau strategol ac argymhellion ar gyfer gweithredu

Mae'r dadansoddiad yn nodi pum maes blaenoriaeth ar gyfer llunwyr polisïau a nifer o argymhellion cysylltiedig ar gyfer gweithredu. Mae'r rhain fel a ganlyn:

<u>Blaenoriaethau ar gyfer y llywodraeth ac eraill: Dull strategol a chydgysylltiedig o gysoni blaenoriaethau polisi a chynllun gweithredu cydlynol ac effeithiol.</u>

1. Llywodraeth Cymru i fapio'r blaenoriaethau polisi sy'n berthnasol i amaethyddiaeth a defnydd tir a sefydlu hierarchaeth, ar gyfer achosion lle mae gwrthdaro rhwng dau ddewis, er mwyn sicrhau sail gytunedig ar gyfer penderfynu pa un ddylai gael blaenoriaeth. Dylai'r broses hon ymgysylltu ag asiantaethau'r llywodraeth a chyrff eraill megis Awdurdodau Lleol sydd â rôl weithredol i'w chwarae wrth roi polisïau newid hinsawdd ar waith.
2. Llywodraeth Cymru ac Awdurdodau Lleol i sicrhau bod y seilwaith ar gyfer gweithredu polisïau newid hinsawdd wedi'i sefydlu, gan gynnwys adnoddau cyfalaf a dynol, a'i fod yn cyfateb i'r dasg a'r amserlen.
3. Llywodraeth Cymru a sefydliadau ymchwil sydd wedi'u lleoli yng Nghymru i gytuno ar flaenoriaethau ar gyfer ymchwil i newid hinsawdd a defnyddio'r cyllid sydd ar gael a gweithio gyda phartneriaid allanol er mwyn darparu tystiolaeth gadarn i'r sector.
4. Llywodraeth Cymru i sicrhau bod y fframwaith ar gyfer gwerthuso polisïau a rhaglenni'n ystyried yr effaith y mae pob polisi'n ei gael o safbwynt newid yn yr hinsawdd a sicrhau tystiolaeth gadarn o weithrediad ac effaith ymchwil a rhaglenni newid hinsawdd y Llywodraeth. Dylai hyn olygu nad yw rhaglenni'n cael eu hystyried ar eu pen eu hunain a bod rhaglenni cysylltiedig yn cael eu gwerthuso mewn ffordd gyfannol.
5. Cyfoeth Naturiol Cymru (CNC) i sefydlu ymarfer mapio gofodol er mwyn blaenoriaethu defnydd tir ledled Cymru, gan adeiladu ar y mapiau presennol o gynefinoedd a warchodir, ardaloedd sy'n addas ar gyfer datblygu ffermydd gwynt, ansawdd pridd, perygl llygredd ac ati. Y nod yw darparu fframwaith y gall CNC, Awdurdodau Cynllunio Lleol ac eraill ei ddefnyddio i wneud penderfyniadau sy'n ymwneud â defnydd tir e.e. y lle gorau i blannu coed neu i ganiatáu datblygiad ynni adnewyddadwy ac ati.

<u>Blaenoriaethau ar gyfer amaethyddiaeth gynhyrchiol: Menter sy'n seiliedig ar wella cynhyrchiant ac effeithlonrwydd, sy'n defnyddio ymchwil a throsglwyddo gwybodaeth, ac yn cael ei chefnogi gan gymhellion i fuddsoddi mewn technoleg.</u>

6. Sefydlu menter i hyrwyddo camau gweithredu yn ymwneud â chynhyrchiant da byw drwy gyllid Cynllun Datblygu Gwledig 2014-2020 ar gyfer cyfnewid gwybodaeth a chymhelliant i fuddsoddi mewn sgiliau a thechnoleg. Cytuno ar dargedau a sefydlu sail i fonitro cynnydd. Dylai hyn gysylltu ag ymchwil Llwyfan Dwysáu Cynaliadwy Defra a Strategaeth Dechnoleg Amaethyddol y Deyrnas Unedig.

7. Sicrhau bod gan sefydliadau ymchwil a rhaglenni cynghori sy'n gwasanaethu Cymru y gallu a'r offer i gefnogi twf mewn cynhyrchiant a datblygu/treialu technolegau newydd sy'n berthnasol i'r wlad er mwyn helpu ffermwyr i wireddu newid mawr.
8. Ymchwilio a chefnogi'r arferion gorau wrth reoli gwrtaith, tail a biosolidau er mwyn gwneud y defnydd mwyaf effeithlon o nitrogen a thrwy hynny leihau allyriadau N_2O. Yr elfennau allweddol yw cynllunio maethynnau (gan gynnwys rheoli pridd sylfaenol), calibradu offer a gwneud defnydd effeithiol o dechnolegau newydd ar gyfer gwrteithio.
9. Ymchwilio i dechnolegau newydd, fel atalyddion nitreiddiad ar gyfer gwrtaith a thail, gwrtaith y gellir rheoli sut y mae'n cael ei ryddhau a gwasgaru gwrtaith yn dra-chywir ar gyfer cnydau gwerth uchel, a chefnogi'r technolegau hyn. Dal i ddatblygu'r sail dystiolaeth ar arferion fel meillion mewn tir pori ac amrywiadau cnydau sy'n gwneud gwell defnydd o nitrogen.

<u>Blaenoriaethau ar gyfer defnydd tir: Dull wedi'i dargedu'n ofodol o gynyddu coetir ac adfer mawndir sydd wedi dirywio er mwyn diogelu a chynyddu storfeydd carbon a lleihau allyriadau.</u>

10. Cynyddu'r arwynebedd coetir newydd yng Nghymru o leiaf 50,000 ha erbyn 2040 drwy ddulliau trefnus o nodi'r tir gorau ar gyfer plannu a thrwy gynnig cymhellion priodol i berchnogion tir yn yr ardaloedd hyn drwy Glastir. Dylid cael hyblygrwydd i blannu y tu allan i'r ardaloedd blaenoriaeth hyn os oes tystiolaeth dda o effaith gadarnhaol net e.e. lleihau llifogydd neu adloniant. Cefnogi adfywiad naturiol coetir ac ehangu gwrychoedd a nodweddion coediog llinol eraill.
11. Cytuno ar sail ar gyfer mesur faint o garbon y gellir ei leihau drwy sefydlu neu reoli gwrychoedd a nodweddion coediog llinol ac adrodd ar hyn mewn stociau carbon ynghyd â choedwigoedd bach (0.1-0.5 ha). Ceisio cofnodi hyn yn y Stocrestr a monitro'r cyfraniad tuag at leihau allyriadau a gwasanaethau ecosystemau eraill.
12. Gweithredu rhaglen adfer ac ailwlychu mawndir wedi'i ddraenio ledled Cymru er mwyn diogelu'r stoc carbon, osgoi allyriadau a darparu manteision ehangach ar gyfer bioamrywiaeth a rheoli llifogydd (lle bo'n berthnasol). Dylai hyn gynnwys rhaglen ymchwilio a monitro er mwyn amcangyfrif ffactorau allyriadau ar gyfer draeniad ac ailwlychu mawndiroedd yng Nghymru.
13. Monitro llif y nwyon tŷ gwydr a'r carbon tawdd a gollir yr un pryd yn yr un lleoliadau fel bod modd canfod potensial cynhesu byd eang net dulliau amrywiol o ddefnyddio a rheoli tir.

<u>Blaenoriaethau ar gyfer ynni adnewyddadwy: Cysoni ymrwymiad y llywodraeth i gynhyrchu ynni adnewyddadwy a datblygiad y sector yng Nghymru, gan roi sylw i faterion adnoddau a seilwaith.</u>

14. Ehangu'r sector ynni adnewyddadwy drwy ddefnyddio costeffeithiolrwydd uchel ynni gwynt ac ynni'r haul lle bo modd a thrwy ynni dŵr, biomas a threulio anaerobig lle bo'r rhain yn cynnig manteision cymdeithasol-economaidd heb wrthdaro'n ormodol â'r amgylchedd. Dylid cael cytundeb cyffredinol ar flaenoriaethau polisïau ar gyfer cyfuniad cytbwys o dechnolegau a hysbysu'r Awdurdodau Lleol a rhanddeiliaid eraill ynglŷn ag ef.
15. Sicrhau bod y system gynllunio'n gweithio'n effeithiol ac yn effeithlon wrth ddatblygu ynni adnewyddadwy yn unol â blaenoriaethau polisi tra'n diogelu'r amgylchedd a budd cyhoeddus ehangach yn lleol. Bydd hyn yn galw am rywfaint o gonsensws ynglŷn â'r blaenoriaethau strategol ar gyfer defnydd tir er mwyn sicrhau nad yw caniatâd cynllunio'n rhwystro'r dechnoleg liniaru bwysig hon rhag ehangu.

16. Y Llywodraeth a diwydiant i weithio gyda'i gilydd er mwyn trafod a chytuno ar y blaenoriaethau ar gyfer buddsoddi mewn seilwaith caled a meddal a fydd yn hwyluso datblygiad cyflym ynni adnewyddadwy yng Nghymru hyd at 2020 yn unol ag ymrwymiadau polisi.
17. Y Llywodraeth a diwydiant i weithio gyda'i gilydd er mwyn hwyluso camau gweithredu sy'n ymwneud â newid hinsawdd ar sail synergedd rhwng y sector amaeth, y sector defnydd tir a'r sector ynni adnewyddadwy. Gallai hyn gynnwys cysylltiadau rhwng prosesu biomas a miscanthus/helyg neu goedwigaeth, treulio anaerobig ar fferm a gwastraff bwyd neu ddefnyddio gwres o ynni adnewyddadwy.
18. Ymchwilio i effeithlonrwydd ac effeithiau'r prif dechnolegau ynni adnewyddadwy, gan gynnwys treulio anaerobig a biomas, mewn nifer o wahanol gyd-destunau yng Nghymru er mwyn gwella gwybodaeth am bosibiliadau lliniaru a hefyd am fanteision ategol (cymdeithasol-economaidd ac amgylcheddol) a chanlyniadau anfwriadol.

<u>Blaenoriaethau ar gyfer ymaddasu i newid yn yr hinsawdd: Defnyddio'r asesiad risg i gynhyrchu cynllun ymaddasu sectorol ar gyfer amaethyddiaeth a defnydd tir a'i hyrwyddo i sefydliadau a'r diwydiant.</u>

19. Paratoi cynllun ymaddasu sectorol ar gyfer y sectorau amaeth a defnydd tir a datblygu nifer o ymatebion ymaddasu y gellir eu hyrwyddo i'r diwydiant a chymunedau gwledig. Mapio'r camau ymaddasu ochr yn ochr â meysydd polisi eraill er mwyn deall y posibiliadau ar gyfer synergedd a gwrthdaro a rhoi sylw i'r rhain yn ôl y galw.
20. Busnesau preifat a sefydliadau cyhoeddus yng Nghymru i sefydlu cofrestr risg newid hinsawdd a chyflwyno camau ymaddasu yn ôl y galw.

Executive Summary

Research context and method

The Welsh Government (WG) is committed to an overall target of reducing greenhouse gas (GHG) emissions in areas of devolved competence by 3% per annum with an expectation that all relevant sectors will make a contribution. Additionally it aims to cut all emissions by 40% by 2020 against a 1990 baseline. In 2010 the Land Use Climate Change Group (LUCCG) set out a series of recommendations to achieve emissions reduction in the agriculture and land use sectors. However, these sectors showed an increase in emissions of 1.2% in 2011. Given this and the start of a new Rural Development Plan (RDP) for the period to 2020, WG commissioned this review of climate change emissions and adaptation in the agriculture and land use sectors. The aim is to provide a robust evidence base to support decision makers on climate change policy and to ensure coherence with wider government priorities on jobs, growth and poverty.

ADAS and its research partners (Bangor University, CEH, IBERS and Rothamsted) have undertaken a desk-based review of the recommendations from the 2010 LUCCG report and reviewed GHG inventory changes to consider how this might affect the emissions delivery plan for the sector. Additionally the team undertook a review of the risks presented by climate change to inform the adaptation response, which will be taken forward by WG in a sector adaptation plan (SAP). Across all the work, the researchers consulted with relevant policy and industry stakeholders in Wales in order to provide a pragmatic analysis to inform coherent and effective policy in this area.

Review of LUCCG recommendations

A template based on a number of sharpening and progress criteria was used to review the 49 recommendations set out in the 2010 LUCCG report (see annex 2). The analysis considered the recommendations under a number of themes, reflecting distinct activities and associated basis for emissions reduction accounting (in inventories), namely:

i. Productive agriculture.
ii. Land use and management.
iii. Renewable energy.

The 2010 recommendations also included actions for the development and delivery of related (Wales specific) research capacity and evidence, and a number of wider cross-cutting actions for WG. These were also reviewed.

The analysis found that while some of the 2010 recommendations were aspirational and in some cases not well defined in terms of ownership or timescale, most were still relevant to delivering emissions reduction in Wales. In this analysis, we have suggested a change of focus, with an emphasis on the actions for the period to 2020 while mapping ongoing actions and impacts to 2050 and 2080.

While real progress has been made in terms of research on emissions in Wales, perhaps the most notable finding is the extent to which many of actions to reduce GHG emissions have not been taken forward. For those measures sponsored by Government, this relates in part to a lack of clarity (a prime example being where to place woodland creation) and a lack of sufficient incentives for farmers and landowners (e.g. for woodland creation and peatland restoration). There are sufficient incentives and interest from industry for investment in renewable energy but structural barriers (primarily securing planning consent and grid connection) have limited progress. For farming actions, the 2010 recommendations were either seen as too radical or broad and have failed to engage the farming community.

Emissions delivery plan and inventory changes

An assessment of the emissions available from the actions set out in the 2010 report and some additional measures from the literature in this area suggests that there is scope for substantive emissions reduction. The scale of this updated emissions delivery plan and issues around how it will be realised and counted, are discussed below.

In the **agriculture** sector, mitigation measures rely heavily on improved efficiency of production and this tends to increase outputs rather than reduce inputs. As such the benefit is likely to be seen as improved emissions intensity (lower emissions per unit of food product) rather than an absolute reduction in emissions. This would not be counted in the inventory, although it may displace overseas emissions from land use change (from displaced imports of food). Technological developments in reducing losses from fertiliser and manure nitrogen offer opportunities for an absolute reduction in emissions.

Overall, it is expected that the agriculture sector can deliver up to 400 ktCO_2e emissions reduction per year but this could be less or even an emissions increase if livestock numbers increase as a result of efficiency gains. Not all of this abatement can be captured in the improved agriculture inventory from 2016.

In terms of **land use** and the “land use, land use change and forestry” (LULUCF) inventory, the main opportunities remain an expansion of woodland and restoring degraded peatland. Both measures rely on protecting and/or building carbon stores and reducing emissions associated with their management. Both can compete with food production in terms of land use and need to respect wider policy objectives for landscape and biodiversity, as well as socio-economic priorities, notably in the uplands. It is accepted that woodland needs to be located on less productive land, in areas which are not significant for other ecosystems services and the analysis suggests that there is sufficient land to deliver the 100,000 ha woodland planting target set out in the 2010 report. The question is the timescale over which this can be achieved, which relies on the nature and scale of incentive available (through Glastir grants) and a degree of behaviour change among farmers and landowners; this could take as long as 50 years. Net emissions reduction, allowing for carbon storage and sequestration from a combination of woodland expansion and peatland restoration, is estimated at 500 ktCO_2e per year but over an extended time period.

The third theme, **renewable energy** is a key element of government energy policy. However, progress is constrained by the planning process, reflecting both an element of public acceptance and issues of policy clarity, and a need for improvements in the electricity grid. Given that these barriers can in principle be addressed, there is scope for renewables to deliver a net emissions reduction of up to 1,600 ktCO_2e per year with an emphasis on the most cost-effective technologies, wind and solar. Significant emissions reductions are available from development of bioenergy crops (willow and miscanthus) and from biogas (anaerobic digestion (AD)) but these may compete for land with food production. Reliance on land use could be reduced through a focus on developing a wood fuel supply chain and/or anaerobic digestion (AD) of livestock slurries (as opposed to crop material). Larger scale AD is likely to be mainly based on off-farm plants to digest food waste and green waste.

Within the 3% WG target, enhanced generation of renewable heat and electricity would not lead to a direct offset of power generation emissions because large scale energy generation (that would be offset) is already excluded from the target definition. Small scale bio-energy plants in Wales (if outside EU-ETS) would be within the scope of the WG’s 3% target and may represent an additional emissions source within the target scope. However, on-farm renewables could reduce agriculture’s end-use electricity consumption from the grid, which would directly impact the 3% target for the sector. Regardless of where emissions reductions are counted, renewables will make a valuable contribution to the overall aim of reducing global atmospheric GHG emissions to mitigate future climate change.

The food supply chain is driven by a commercial imperative to continually seek efficiency gains and this means that there are progressive reductions in emissions post-farmgate. However, for the milk and meat sectors, 85-90% of emissions relate to on-farm activity and this is where the emphasis on mitigation is most needed. Nevertheless the supply chain can make a valuable contribution to absolute emissions reductions and is very important in helping drive change in farm practices in the context of the wider sustainability agenda.

Ongoing development of the GHG inventories for agriculture and LULUCF suggest that from 2016 there are opportunities to improve the accuracy of accounting and reflect both explicit and implicit mitigation strategies, but importantly to count more of the emissions from management of agriculture and land use. These should help secure further progress against emissions reduction targets but will only reflect differences since the 2006-2010 baseline and will be incremental.

Climate change adaptation

In the Welsh land use sector, the most significant climate change risks are those related to flooding. This includes the risks to domestic and business property, impacts on livestock from grazing and availability of feed, and potential yield impacts in the arable/horticulture and forestry sectors. The agriculture and land use sectors have an important role to play in adapting to flooding impacts. In particular planting of trees in specific areas may reduce risk of flooding to land and communities/businesses, whilst also minimising the effects of disease in livestock such as liver fluke by restricting access to wetter areas of land.

An increase in pest and disease pressure in both the forestry and livestock sectors is a significant risk, largely due to milder and wetter winters. For forestry, ensuring species diversity is key to minimising impacts, and can also have multiple benefits by adapting to water stress and wind throw. For livestock, a range of adaptation actions are available but good planning and awareness of best practice may be the best adaptation action.

Water stress is a less significant risk for Wales due to relatively high rainfall but in times of drought, it can affect most agriculture and land use sectors. The largest impact is on forestry, rural communities/businesses and livestock sectors. Relatively cost effective actions to harness rainwater can be taken to mitigate impacts. This is most straightforward on livestock farms in the form of provision of troughs, or ponds. For domestic customers, grey water can be harnessed using rainwater harvesting systems. At a larger scale, reservoirs can be built to meet increased seasonal demand; however the cost of doing so needs to be judged against the benefits.

Wildfires, affecting both grassland and forestry areas, and in some cases rural communities are increasing in Wales as drier conditions in summer become more prevalent. Given the high cost of wildfires, adaptation measures can be very cost effective and include raised awareness amongst the general public and partnership working to reduce arson related crime, as well as provision of fire breaks.

Opportunities for synergy and conflict

There are two key issues in terms of coherence for climate change policy. Firstly, what are the impacts of emissions reduction measures on wider ecosystem services and secondly, what are the opportunities for synergy and conflict with adaptation actions. An analysis of these issues highlights substantial opportunity for synergies, mainly from the land use actions on woodland and peatland but these are also the greatest areas of conflict in terms of competing for land use (less so for rewetting grazed blanket bog). Renewable energy technologies can compete for land (some biomass and crop-based biogas) but others do not (wind, roof-based solar and hydro). Attention must be given to managing these opportunities and risks through a strategic approach to land use at a national and local level and appropriate promotion of actions on climate change.

The challenge for government is not in recognising these synergies and conflicts but in implementing policy which pays due regard to them and addresses the necessary trade-offs between priorities in order to meet commitments on this agenda.

Strategic priorities and recommendations for action

The analysis sets out five areas of priority for policymakers and a number of associated recommendations for action. These are:

Priorities for government and others: A strategic and joined up approach to reconciling policy priorities and a coherent and effective plan for implementation.

1. Welsh Government to map the policy priorities that relate to agriculture and land use and establish a hierarchy, namely where there is conflict between two options, ensure there is an agreed basis for deciding which takes precedent. This process should engage with government agencies and other bodies such as Local Authorities which have an executive role in implementing climate change policies.
2. Welsh Government and Local Authorities to ensure that the infrastructure to implement climate change policies is in place, including capital and human resources, and is proportionate to task and the timescale.
3. Welsh Government and Wales-based research institutes to agree priorities for research on climate change and to draw on available funding and work with external partners to deliver robust evidence for the sector.
4. Welsh Government to ensure there is a framework for policy and programme evaluation which takes account of the climate change impacts of all policies and which secures robust evidence on the uptake and impact of Government's climate change research and programmes. This should avoid looking at programmes in isolation and where possible evaluate programmes which are linked in a holistic way.
5. NRW to establish a spatial mapping exercise to prioritise land use across Wales, building on existing maps of protected habitats, areas suitable for wind farm development, soil quality, pollution risk etc. The aim is to provide a framework within which NRW, local planning authorities and others can make decisions on land use e.g. where best to plant trees or allow renewables development etc.

Priorities for productive agriculture: An initiative based on improving productivity and efficiency using research and knowledge transfer, backed up with incentives for investment in technology.

6. Establish an initiative to promote livestock productivity actions through RDP 2014-2020 funding for knowledge exchange and incentives for investment in skills and technology. Agree targets and establish a basis for monitoring progress. This should link to the Defra Sustainable Intensification Platform (SIP) research and the UK Agri-Tech Strategy.
7. Ensure that research institutes and advisory programmes serving Wales have the capacity and tools to support productivity growth and develop/trial new technologies relevant to the country to help farmers realise step change.
8. Research and support best practice management of fertilisers, manures and biosolids to improve nitrogen use efficiency and consequently reduce N_2O emissions. Key components are nutrient planning (including basic soil management), calibration of equipment and effective use of new technologies for application.
9. Research and support the adoption of new technologies such as nitrification inhibitors for fertilisers and manures, controlled release fertilisers and precision application of fertiliser for high-value crops. Continue to develop the evidence base on practices such as clover in pastures and crop varieties with improved nitrogen use efficiency.

<u>Priorities for land use: A spatially targeted approach to increasing woodland and restoring degraded peatland to protect and enhance carbon stores and reduce emissions.</u>

10. Increase the area of new woodland in Wales by at least 50,000 ha by 2040 through methodical identification of the best land to plant and by offering appropriate incentives to landowners in these areas through Glastir. There should be flexibility to plant outside these priority areas where there is good evidence of net positive impact e.g. flood mitigation or recreation. Provide support for natural regeneration of woodland and expansion of hedges and other linear woody features.
11. Agree a basis for quantifying the carbon mitigation available from establishment or management of hedgerows and linear woody features and reporting this in carbon stocks along with small woods (0.1-0.5 ha). Aim to capture this in the Inventory and monitor the contribution to emissions reduction and other ecosystem services.
12. Implement a programme of restoration and rewetting of drained peatland across Wales in order to protect the carbon stock, avoid emissions and provide wider benefits for biodiversity and flood management (where applicable). This should include a programme of research and monitoring to estimate emissions factors for drainage and rewetting of peatlands in Wales.
13. Monitor the fluxes of all GHGs and dissolved carbon losses simultaneously in the same locations so that the net global warming potential of a range of land uses and management can be determined.

<u>Priorities for renewable energy: Alignment of government's commitment to renewable energy generation and the development of the sector in Wales, addressing resource and infrastructure issues.</u>

14. Expand the renewables sector through utilising the high cost effectiveness of wind and solar where possible and through hydro, biomass and anaerobic digestion where these bring socio-economic benefits and do not impinge unduly on the environment. Policy priorities for a balance of technologies should be broadly agreed and communicated to Local Authorities and other stakeholders.
15. Ensure the planning system is working effectively and efficiently in implementing the development of renewables in keeping with policy priorities while safeguarding the environment and wider public interest locally. This will require a degree of consensus on the strategic priorities for land use to ensure planning consent is not a barrier to expansion of this important mitigating technology.
16. Government and industry to work together to scope and agree the priorities for investment in hard and soft infrastructure to facilitate rapid development of renewables in Wales to 2020 in line with policy commitments.
17. Government and industry to work together to facilitate climate change actions based on synergies between the agriculture, the land use sector and the renewables sector. This might include links between biomass processing and miscanthus/willow or forestry, on-farm anaerobic digestion and food waste or utilising heat from renewables.
18. Research the efficacy and impacts of the main renewable technologies, including anaerobic digestion and biomass, across a variety of contexts in Wales to improve knowledge on mitigation potential but also on co-benefits (socio-economic and environmental) and unintended consequences.

<u>Priorities for climate change adaptation: Using the risk assessment to produce a sector adaptation plan for agriculture and land use and promote to institutions and industry.</u>

19. Prepare a sector adaptation plan (SAP) for the agriculture and land use sector and develop a suite of adaptation responses which can be promoted to industry and rural communities. Map the adaptation actions against other policy areas to understand the scope for synergies and conflicts and address these as necessary.

20. Private businesses and public institutions in Wales to establish a climate change risk register and put in place adaptation actions as necessary.

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1. Introduction

Policy context

The Welsh Government (WG) is committed to an overall target of reducing greenhouse gas emissions (GHGE) in areas of devolved competence by 3% per annum from 2011. The baseline against which the "3% target" will be measured is the average of emissions from 2006 to 2010. The Climate Change Strategy for Wales (October 2010)[1] outlines that there is an expectation that all relevant sectors (which includes all aspects of Land Use) will make a contribution to meeting the overall target. The 2010 Strategy also set a separate target to achieve at least a 40% reduction in emissions in Wales by 2020 against a 1990 baseline. However, data for the first reporting year (2011) of the 3% target indicates that the agriculture and land use sectors did not achieve a reduction in emissions between the baseline and 2011 (increase of 1.2%). As such, there is a need to review the emissions reduction policy measures to ensure that the sector contributes effectively to the targets.

In 2010 the Land Use Climate Change Group (LUCCG) submitted its landmark report to the then Welsh (Assembly) Government. In view of the 2014 CAP reform and a new Rural Development Plan (RDP) for the period to 2020, WG commissioned this review of climate change emissions and adaptation in the agriculture and land use sectors to provide a robust evidence base to support decision makers on climate change policy and to ensure coherence with wider government priorities on jobs, growth and poverty.

Project objectives and structure

This project has three component parts:

<u>Part 1: A review and assessment of the evidence to support (net) emission reduction interventions in the agriculture and land use sectors and the wider food chain</u>.

This comprised of three linked tasks:

1.1. A review and update of the 2010 LUCCG report in **Chapter 3** based on detailed technical analysis as set out in annexes 4-9

1.2. Evidence to support a refresh of the Climate Change Strategy for Wales Delivery Plan for Emission Reduction for the agriculture and land use sectors (**Chapter 4**)

1.3. An assessment of whether, and to what extent, the identified emission reduction measures would be picked up in the current and improved GHG Inventories for the agriculture and land use sectors (**Chapter 5** and annexes 10 and 11)

<u>Part 2: A review and assessment of the evidence to support climate change adaptation interventions in the agriculture and land use sectors</u>.

This workstream ran in parallel with the review of climate change mitigation measures and utilised the same stakeholder fora to help scope and quantify risks and priorities for adaptation. This is summarised in **Chapter 6**, with a more detailed analysis in annex 13 and a separate excel-based matrix of risks for agriculture and land use (available from WG).

<u>Part 3: An outline of the opportunities for multiple benefits to allow decision makers to balance emission reduction and adaptation interventions taking into account wider socio and economic factors including jobs, growth and poverty</u>.

An analysis of the wider impacts of GHG mitigation measures and potential policy synergies and conflicts is set out in **Chapter 7** and all the workstreams are brought together in the summary and priorities for action in **Chapter 8**. The latter sets out priority actions for achieving a step change in climate change mitigation and adaptation and provides specific recommendations to achieve them.

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[1] Climate Strategy for Wales (October 2010) http://wales.gov.uk/docs/desh/publications/101006ccstratfinalen.pdf

2. Methodology

Our approach for this study has been based on making full use of the research capacity based in Wales and the views and knowledge of local stakeholders – from both policy and industry – to provide a robust but pragmatic analysis to take forward the work instigated in the 2010 LUCCG report. The research team worked with the Land Use Sub-Group (LUSG) of the Climate Change Commission for Wales over the course of the project to ensure stakeholder views were accounted for and that any proposed actions had broad scientific, policy and industry support. In addition to a LUSG workshop, the project was presented to the WG Natural Resources and Food Policy Forum to capture the views of policymakers. Finally, consultations were held with industry bodies and companies (see annex 15).

The approach used for the three components of the work is detailed below:

1. **Review and update the actions for reducing GHGE set out in the 2010 LUCCG report.**

   A desk-based review of the LUCCG report recommendations was undertaken against the (sharpening and progress) criteria listed in the specification (this is available as a separate document). This considered the continued relevance of the recommendation, the extent to which it has clear ownership and the progress made to date, including actions to address barriers. Where appropriate, estimates of net GHGE abatement are updated and any new potential mitigation strategies identified.

   The key objective was to review and refresh the existing recommendations so that policymakers can build appropriate actions into policy and prioritise funding. An important element of the analysis was to provide estimates of the net emission reductions available from mitigation actions. This relied on secondary data on maximum technical potential (MTP)[2] and effectiveness of each measure, estimates of cost-effectiveness (e.g. from Marginal Abatement Cost Curve (MACC) studies), and barriers to adoption.

   Finally, an analysis was undertaken of proposed changes to the Agriculture and Land Use, Land-Use Change and Forestry (LULUCF) GHG inventories, which set out protocols for how emission reductions are counted in the WG's Climate Change Strategy (2010) Delivery Plan for Emission Reduction.

   It was agreed at the outset that the analysis would consider the likely contribution of the agriculture and land use sector to emissions reduction rather than focusing on what interventions were required to deliver the 3% annual emissions reduction target[3]. This recognises wider ambitions for growth in the agriculture and food sector[4] as well as the need to be pragmatic in identifying realisable targets.

2. **Review and assess sector adaptation plans over defined time periods.**

   Climate change projections from the UK Climate Projections 2009 (UKCP09) for Wales were used to detail the likely climatic changes which can be expected under a medium emissions scenario for the 2020s, 2050s and 2080s. A recent report by Defra and the Met Office Hadley Centre concluded that despite modelling improvements, UKCP09 remains credible and should be used for planning for a changing climate at this stage[5]. Climatic events outside the scope of UKCP09, for example extreme wind events were

[2] Maximum technical potential is the amount that could be saved if all mitigation potential was secured regardless of cost.
[3] In response to climate change, Welsh Government has committed to cut emissions of all greenhouse gases by 80% by mid-century and to an annual 3% reduction from 2011 in devolved sectors.
[4] Delivering Growth: An Action Plan for the Food and Drinks Industry 2014-2020.
[5] Personal communication.

also included. Economic, environmental and social impacts arising from each climatic variable were detailed and source of information stated.

A risk rating system was adapted from the WG's Preparing for a Changing Climate guidance[6] which drives an overall risk score for each risk/opportunity identified by multiplying a consequence score (severity of the impact) by a likelihood score (likelihood of the impact occurring). The overall rating allows impacts to be prioritised when making policy decisions on adaptation interventions.

Uncertainty in future climate change presents a key challenge for adaptation planning. The UKCP09 climate projections used contain significant uncertainty and should be interpreted with caution. The projections are used as a steer to provide best estimates to what the most likely changes in the climate will be. As such, the risks and opportunities identified in this section also contain a degree of uncertainty and should be independently understood and assessed before actions and/or adaptation measures based on the evidence/expert reviews provided in this report are implemented.

3. Guidance for a balanced policy response.

Actions for reducing GHG emissions from the land use sector may not always be consistent with adaptive actions and/or wider WG policies. Through consultations with policymakers, stakeholders and team experts, interaction with the wider policy landscape and potential areas of synergy and conflict were identified along with opportunities for wider socioeconomic gains.

Scientific, industry and policy knowledge and expertise within the delivery team and consultation with government and industry stakeholders has provided the basis for this analysis. This is a highly technical area and in order to ensure clarity, an overview of the analysis is contained in the body of the report and the detailed evidence presented in a number of technical annexes. The overview aims to bring together the key elements of the science and high-level actions which the evidence supports. The main output is a set of actions for WG and its agencies, local authorities, farmers and the food supply chain as well as wider stakeholders in the renewables and forestry sector.

[6] http://wales.gov.uk/topics/environmentcountryside/climatechange/publications

3. Review and update of the 2010 LUCCG report

A template was used to review the 49 recommendations set out in the 2010 LUCCG report, based on a number of sharpening and progress criteria (see annex 2). It is important at the outset to place the 2010 report in context. It considered the capacity of the industry to meet the wider target reduction in GHG emissions of 80% by 2050 (as set out in UK Climate Change Act) and in doing so looked to developing technologies and potentially radical changes in farming practice in order to realise the target. There was also a focus on what research was needed to develop the evidence base around these measures for Wales and while this provides an important steer for the research community, it is less helpful to policymakers in prioritising actions for the short to medium term.

In this update of the work, the authors have been tasked with taking a more pragmatic perspective in terms of what can be achieved in the short term as well as the opportunities in the medium to long term. On this basis we have set out priority actions to 2020, the lifetime of the next Rural Development Programme (RDP), recognising that many actions will involve delivery over a much longer timeframe. We have also highlighted evidence gaps and areas for research which are necessary to improve understanding of emissions and their mitigation, which will be key to delivering step change in the medium term.

From the outset it was clear that it would be helpful to allocate the recommendations to a number of themes in order to ensure appropriate skills (within the delivery team) were applied to the analysis and also to provide a coherent overview of the actions in aggregate. The themes are:

i. **Productive agriculture –** voluntary actions by farmers (and the wider food chain) to improve resource efficiency and take up of anaerobic digestion (AD) of slurry/manure;

ii. **Land use and management –** voluntary actions by farmers and land managers funded under the Glastir programme e.g. afforestation and peatland management;

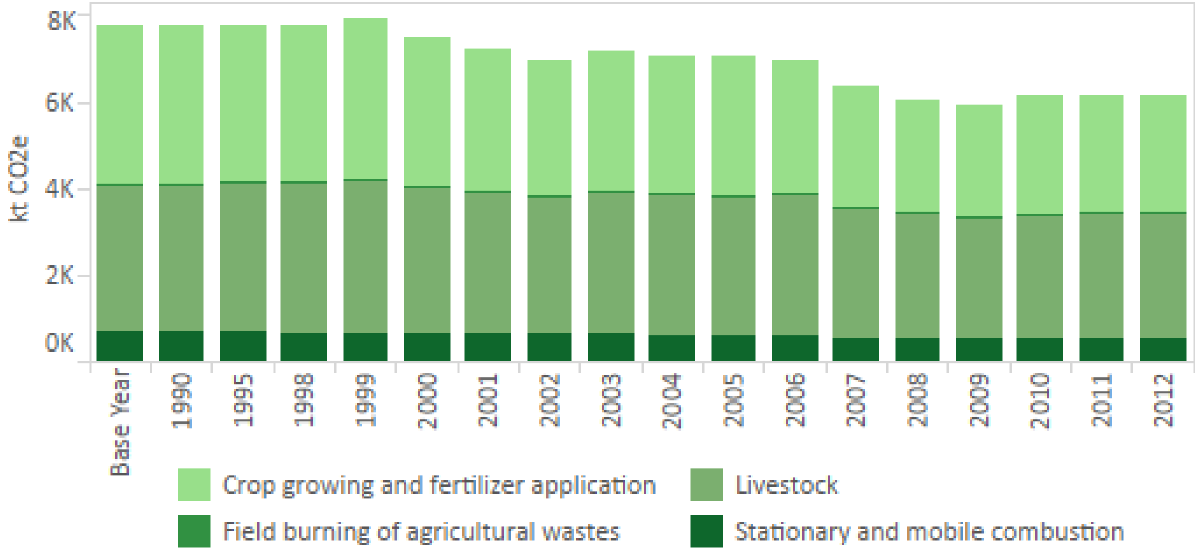
iii. **Renewable energy –** development and uptake of renewables technologies.

The 2010 recommendations include actions for the development and delivery of related (Wales specific) research capacity and evidence to provide a reliable baseline and toolkit for measuring and monitoring GHGE. Where appropriate these have been considered under the most relevant theme. There are also a number of wider cross-cutting actions for WG, including Wales-level economic analysis of the strategy, provision of emissions data, and awareness raising of climate change actions. These are considered separately at the end of the chapter.

This thematic approach was also used in discussions with stakeholders and as a basis for presenting the findings of the research. The themes are considered in turn below along with a summary of the review of recommendations in terms of their continued relevance, mitigation potential and actions needed to progress. This analysis is supported by a detailed narrative in technical annexes 4 – 9.

3.1 Productive agriculture

GHGE from the agriculture sector are primarily methane (CH_4) and nitrous oxide (N_2O) from livestock and agricultural soils respectively, with some carbon dioxide emissions from fuel use. Sector emissions have decreased by 21% between 1990 and 2012, (-16% for methane and -25% for nitrous oxide) (Ricardo-AEA, 2014). The trends result from a general decline in livestock numbers and in fertiliser nitrogen use (particularly to grassland) but stabilisation of numbers in recent years means that there was no significant change in emissions between 2011 and 2012 (0.2% increase).

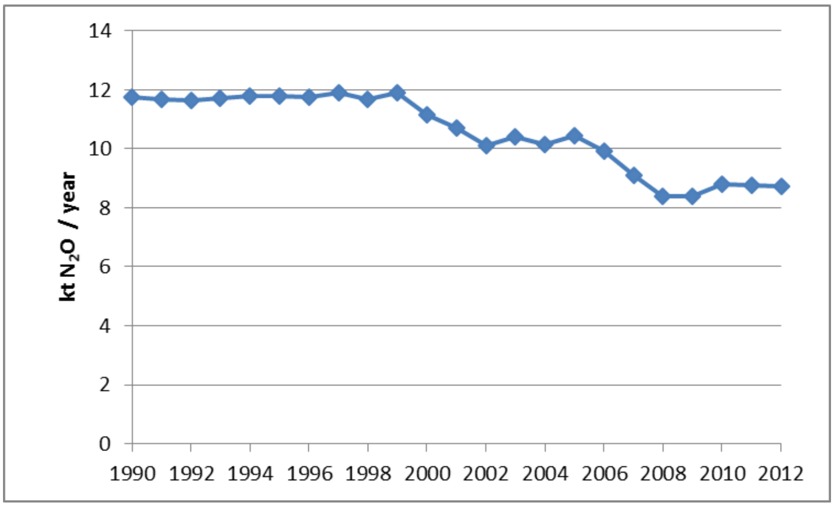


Source: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990-2012

Figure 1: Total GHG emissions from Agriculture, 1990-2012, Wales

Enteric fermentation in ruminant livestock contributed 80% (2,294 kt carbon dioxide equivalent (CO_2e)) to total agricultural CH_4 in Wales in 2012. In the same year CH_4 emissions from beef and dairy cattle (enteric and manure management sources combined) accounted for 63% and sheep 34% of the total CH_4 from agriculture. In recent years, there has been a decrease in emissions from cattle but a more significant increase in emissions from sheep, reflecting cattle numbers decreasing by 1% and numbers of sheep increasing by 3% (see annex 3).

N_2O emissions are largely driven by fertiliser nitrogen use, manure applications and grazing returns of dung and urine to soils. Agriculture is the most important source of N_2O in Wales and 90% (2,491 ktCO_2e) of the total emissions in the sector arose from applications and deposits to agricultural soils. This source accounted for 79% of total N_2O emissions in Wales in 2012. Agricultural emissions of N_2O in Wales have decreased by ca. 25% since 1990, although emissions have stabilised over the 2010-2012 period after a small increase from 2009 (Figure 2).



(Source: UK Agriculture Greenhouse Gas Emissions Inventory)

Figure 2: Trends in N_2O emissions from agricultural sources in Wales (1990-2012)

However it is important to note the extent of heterogeneity across farms between sectors and within sectors. Table 1 below shows the variance in GHG emissions per unit of red meat product and per hectare from an analysis by HCC and Bangor University based on data collected and information from a representative range of Welsh farms in 2010. This suggests that while there is considerable scope to share best practice between farms there is also considerable difference in management systems, stocking rates and reliance on bought-in feeds, which may limit a simple one-size-fits-all mitigation response.

Table 1: Carbon footprints from Welsh farms, 2010

Unit measured	Average	Lowest	Highest
Sheep (kgCO_2e/kg lwt)	23	7	51
Beef (kgCO_2e/kg lwt)	25	5	61
Hectare (kgCO_2e/ha per year)	4,718	2,103	8,797

Source: A Sustainable Future - The Welsh Red Meat Roadmap

3.1.1 Review of 2010 LUCCG recommendations for agriculture

The recommendations from the 2010 LUCCG report which relate to this theme placed an emphasis on managing livestock emissions through AD technology (as well as encouraging efficiency of production and input use). The analysis for these recommendations is summarised in the tables below (see also annexes 4, 5 and 9 (renewable energy)). The recommendations are ranked red, amber and green to denote limited, some and good progress, respectively, with commentary as relevant.

Table 2: Review of LUCCG 2010 recommendations relating to anaerobic digestion (AD)

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
7	To provide support for all manure/slurry from the dairy herd and attendant beef/veal systems to be processed through anaerobic digestion (AD) and to exploit the biogas potential.	Very few farms in Wales have sufficient numbers of cattle (300+) for AD to be economically viable (Rural Futures, 2010). There are also issues of grid connection. Where crops are used as a co-feedstock there is a risk that this competes for land with food production.	Only 3 agricultural AD plants are listed in Wales.	This technology should continue to be supported but targeted at larger farms with housed systems and based on business models using slurry only or food sector waste as a co-feedstock.
9	To promote the maximum synergy between AD of slurry/manure and other wastes (that can't be utilised more efficiently) from the food chain – process, distribution and consumer wastes - through co-operation with food processors, major retailers and local authorities.	A relatively small proportion of the CH_4 emitted by ruminants comes from their manures. However also potential to reduce emissions from food waste which currently goes to landfill.	In Wales, a number of AD plants have been built for food waste. See WRAP's "Hub and PoD" research.	Continue research but as with Rec 7 recognise limitations in terms of farms of sufficient size. The focus should be on the use of AD for food waste as it can be digested without other feedstocks, linking with slurry where economic and practical.
38	To assess the fertiliser value of AD digestate and the N_2O emissions from its application to land.	Potential for around 4.5% less direct N_2O emissions from reduced fertiliser use.	DC-Agri Project – see 3.1.2 below	Continue the work from the current project and application of knowledge.

Table 3: Review of LUCCG 2010 recommendations relating to livestock management

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
8	To explore with the dairy and beef industry the adoption of zero-grazed systems to minimise CH_4 and N_2O emissions and to exploit the compressed biogas potential. The impacts of zero-grazing on biodiversity and other ecosystem services need to be assessed.	While there is some potential to reduce emissions via better control over grazing emissions, it would not be economic for most livestock farms in Wales to house and zero-graze. Economic pressures will see more large dairy units and increased uptake of robotic milking will lead to more year-round housed herds.	Technology to capture on-farm CH_4 emissions does not exist.	This is not a technology which is currently available or is widely relevant to naturally ventilated buildings in Wales. No action required.
10	To encourage increased efficiency within dairy, beef and sheep sectors to decrease GHG emission per unit of productive output and to ensure cuts in emissions.	Increasing animal nitrogen use efficiency (NUE) from 25 to 35% can reduce N excretion by 40%. This is applicable to all dairy cows in Wales. There is also scope to reduce protein-N in cow rations. These approaches would reduce N emissions from N_2O, ammonia and nitrates.	Breeding programmes have led to higher milk yields but there is still a large variation in efficiency between farms.	Encourage use of modern livestock genetics to improve output per unit of breeding ruminant livestock in a Wales context. Also exploit opportunities to improve efficiency through better animal health, improved feed use efficiency and dietary manipulation.
32	To research further the basic science on rumen function and modification, in particular to decrease loss of feed energy.	Potential to reduce CH_4 production from 12% of consumable energy to 2-3% representing approx. 80% reduction in CH_4. This might not be possible for all systems.	Progress has been made but potential exists for further reduction.	More funding required for research.
33	To research further the varying traits for reducing GHG emissions between and within breeds.	16% reduction in emissions from individual beef herds has been shown possible.	Residual feed intake has been improved via programmes	More funding required for research.
34	To improve the understanding of potential CH_4 production from different feeds and transfer of this knowledge to the farmer.	Potential reductions but difficult to quantify.	Good research but higher uptake required	More funding is required for research and improved awareness by farmers.
35	To assess the effects of hill and upland environments on CH_4 emissions where indigenous plants in the diet may alter rumen fermentation to reduce the amount of CH_4 that is produced.	Emissions are unlikely to be cut by this recommendation, but a better understanding of current rates of emission would be achieved.	Little work to date. Limited research via Defra project AC0115.	Could combine with recommendation 34. More funding required for research.

Table 4: Review of LUCCG 2010 recommendations relating to crops and fertilisers

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
11	To encourage maximising NUE through best practice management of fertilisers, manures and biosolids.	Potential to reduce N_2O emissions by increasing manure NUE from 30% to 40% via good practice in fertiliser use and low trajectory spreading of livestock slurries, and rapid incorporation of high available N content manures on arable land.	WRAP funded project on NUE	Promotion of good practice and new technologies (e.g. precision application; nitrification inhibitors) for inorganic N fertiliser and for use of organic resources as nutrient sources and soil conditioning.
30	Welsh Assembly Government to collect statistics for Wales to provide a more accurate estimate to replace extrapolated statistics from UK.	No direct emissions cuts would be achieved.	Yes. Defra project has pulled out available data from British Survey of Fertiliser Practice (BSFP).	Further data collection in Wales to supplement existing data from BSFP. Other activity data (as relevant) to support the new inventory.
36	To research the key factors that influence the fluxes of N compounds in soils and to monitor emission fluxes under a variety of management conditions including organic and conventional farming systems and identify new mitigation options.	Potential for around 4.5% less direct N_2O emission from reduced fertiliser use.	Concept notes to Welsh Government in 2013.	Emission measurements need to be integrated with livestock productivity to enable GHG emissions intensity to be compared between systems (upland and lowland; organic vs conventional). Focus where less well understood.
44	To quantify the effects of grazing intensity and type, and re-seeding of lowland pastures (an important mechanism to improve productivity), and the impacts of tillage methods on GHG emissions.	Emissions are unlikely to be cut but a better understanding of current rates of emission would be achieved. Only applies to ‘arable’ land (includes grass leys < 5 years) - about 13% land in Wales.	Reduced GHG emissions from grazed lowland grassland.	Further research required to identify practices which lead to lower emissions.
45	To breed new grass varieties that enhance carbon storage below ground.	Would increase carbon sequestration but long timescale; ≈15 years from initial selection to market availability, 10+ years to see amounts of carbon sequestered.	IBERS has a breeding programme underway.	Need new varieties listed on EU recommended list. Partition of nutrients below ground potentially reduce crop yields and failure to make the list. Needs to be addressed.

The potential use of nitrification inhibitors (NIs) to reduce N_2O emissions from arable and grassland is closer to reality, and offers potentially significant reductions. We believe that field-scale evaluation of commercial products is required under Welsh soil and climate conditions, whilst effort should also be directed at development of cost-effective delivery techniques and public perceptions of their use. WG would need to consider how the use of nitrification inhibitors could be incentivised.

A wider set of recommendations [improvement of agriculture GHG inventory (29), validation of emissions reductions achievable by dietary manipulation (31), research into technical feasibility of housed systems (37) and research into association between GHGs and organic vs. conventional systems (42)] have shown some progress since the 2010 report but none of these directly reduce GHG emissions. Nevertheless, several of these recommendations relate to increasing knowledge on actions to reduce GHG emissions and remain valid.

3.1.2 Addressing barriers and gaps

In the 2010 report a key knowledge gap and constraint identified was the lack of available methods to monitor enteric CH_4 and soil N_2O emissions *in vivo* at the field-scale under farm conditions. Examples of equipment for this purpose now exist in Wales (IBERS and Bangor University have been successful with WG, NERC and BBSRC funding programmes). As such, research capacity in Wales has increased since the 2010 report and will enable large-scale trials and field evaluations to take place on farms to e.g. test how well dietary manipulation can be used to reduce both CH_4 and N_2O emissions; evaluate the efficacy of, and develop and test cost-effective delivery mechanisms of NIs at the field scale; assess N_2O emissions from urine deposited in upland systems. As part of the Glastir Measurement and Evaluation Project (GMEP), integrated field-scale measurements of CH_4 and N_2O from improved upland pastures in Wales will be made, to provide validation data for mechanistic modelling. However, these measurements will not generate emissions factors (EFs).

The 2010 report also listed the lack of knowledge of the fertiliser value of AD digestate and the emissions from its application to land. To some extent this knowledge gap has been bridged via the WRAP funded DC-Agri experiments (see earlier), although not under Welsh soil and climatic conditions. Additional plot-scale experiments may be required to validate the *MANNER-NPK* decision support tool used to generate farmer guidance on nutrient availability under Welsh conditions.

Remaining gaps include:

- N_2O emissions from grazed upland systems, where quality of grazed vegetation will impact on urine composition, and soil and climatic conditions will affect the N_2O EF from deposited urine;
- Integrated N_2O and CH_4 emissions from clover-rich pastures - to generate C balances and C footprints for ruminant systems;
- Data on AD digestate quantities generated annually in Wales, and knowledge of the digestate composition;
- Digestate and compost fertiliser value under Welsh conditions;
- Census data for fertiliser and manure management practices are limited. If the British Survey of Fertiliser Practice survey was linked to the Farm Business Survey in Wales, which is face-to-face, then more valuable data could be collected.

3.2 Land use and management

The 1990-2012 Land Use, Land-Use Change and Forestry (LULUCF) inventory shows Wales is a small net sink for GHGs from LULUCF activities in the period 1991-2012 (Figure 3) (Miles et al, 2014). In 1990 Wales was a small source at 0.07 $MtCO_2e$, becoming a small net sink in 1991 and net emissions gradually decreased thereafter until 2007 at -0.6 $MtCO_2e$. After 2002, net emissions fluctuate slightly between -0.6 $MtCO_2e$ and -0.5 $MtCO_2e$. The main influences on the trend for the LULUCF sector in Wales are emissions from Cropland and

Settlement, outweighed by removals from Forest land and historic conversion to Grassland. The emissions from Wetland arise from peat extraction sites and are low for Wales relative to other emissions, as are removals from Harvested Wood Products (HWP).

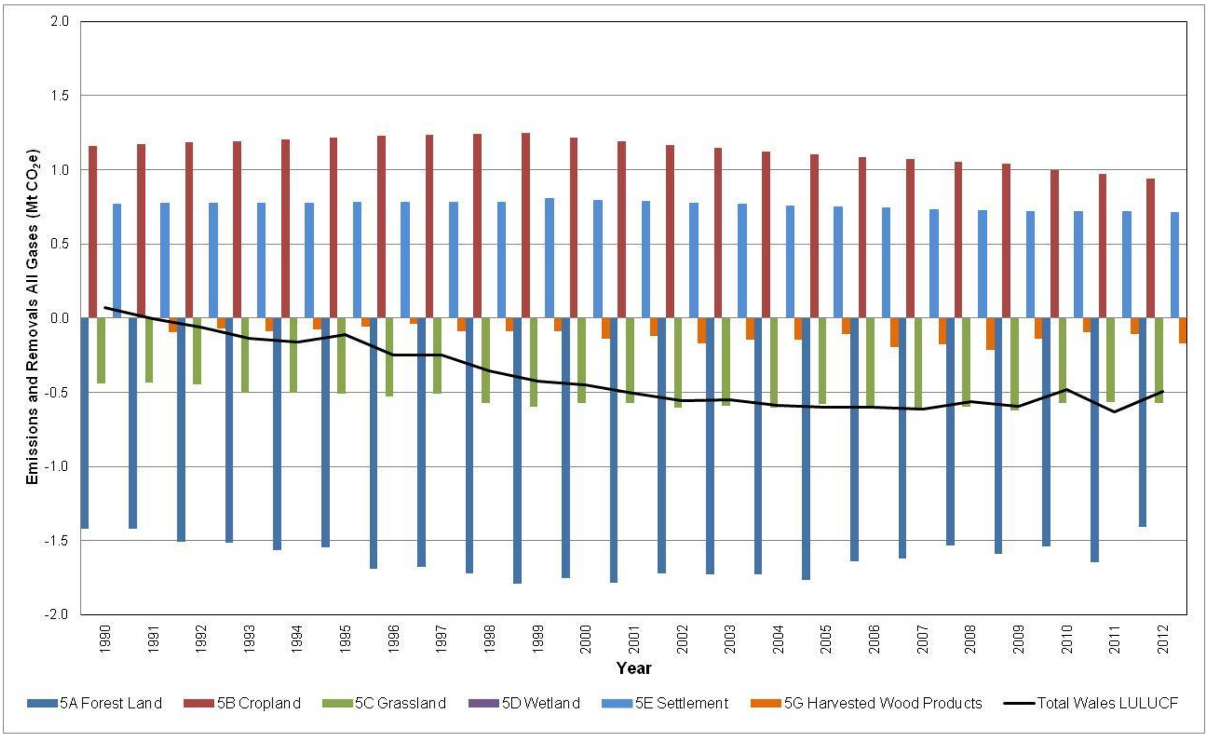


Figure 3: Emissions and removals from all gases by category for the LULUCF sector in Wales 1990 – 2012.

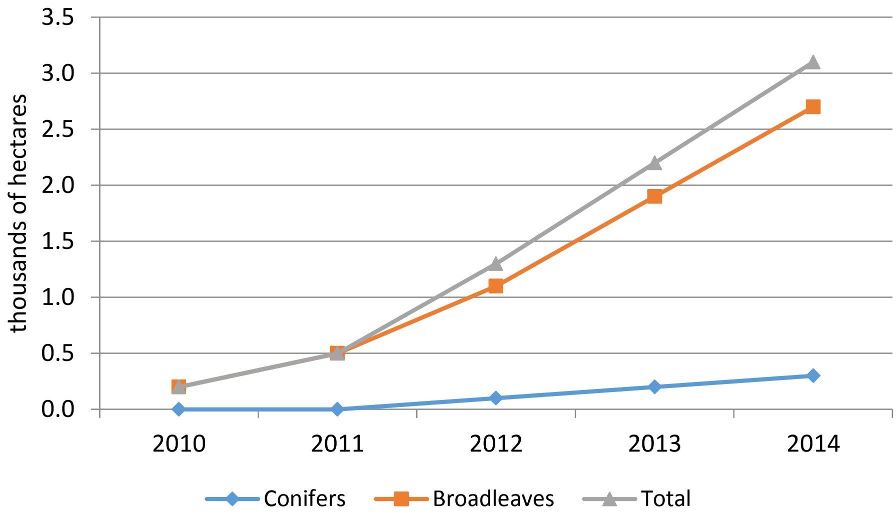
Cropland produces the largest emissions source in Wales; between 1990 and 2002 levels were fairly constant at approximately 1.2 $MtCO_2e$, gradually decreasing after 2003 to 0.9 $MtCO_2e$ in 2012. The Settlement category is a small net source at approximately 0.8 $MtCO_2e$ for 1990-2004, decreasing to 0.7 $MtCO_2e$ for 2005-2012. The Forest land and Grassland categories are net sinks from 1990 to 2012. Between 1990-2006 Forest land is a generally increasing sink in Wales increasing from -1.4 $MtCO_2e$ in 1990 to -1.7 $MtCO_2e$ in 1996 and remaining fairly constant until 2006. After 2007, net emissions fluctuate between -1.7 $MtCO_2e$ and -1.4 $MtCO_2e$. Grassland net emissions have fluctuated between -0.4 $MtCO_2e$ and -0.6 $MtCO_2e$ between 1990 and 2012.

3.2.1 Review of 2010 LUCCG recommendations for land use

Recommendations relate to on the ground action, addressing knowledge gaps and improving data collection in the LULUCF inventory. Although some of these emissions arise from agricultural land, they are accounted for in the LULUCF inventory. The individual recommendations are reviewed in summary in the tables below with a full technical analysis in annex 6 (forestry) and annex 7 (land management options).

Forestry

The planting of woodland is a major issue for climate change policy in Wales. The area of woodland in Wales has increased by 3,100 ha (300 ha coniferous and 2700 ha broadleaved) since 2010 which is substantially below the 20,000 ha target by 2014 set out in the LUCC report. Rates of coniferous tree afforestation have remained constant for the last three years, whilst the rate of broadleaved forest creation was eight times faster but remained constant for the last two years (Figure 4).



Source: Forestry Commission, 2014.

Figure 4: Cumulative new woodland area since 2010.

The expansion of woodland within Wales has been triggered mainly by Glastir woodland creation grants. Prior to the Glastir scheme the rate of woodland creation was approximately 200 ha/yr; subsequently an increase, averaged over 4 years, of 775 ha/yr was achieved and is a positive step forward. Despite this increase, it is apparent from the rate of uptake of the Glastir scheme that barriers to woodland creation still exist. Recent stakeholder consultation for Glastir indicates that there are some administrative uncertainties over operational prescriptions, minimum area requirements and where woodland can be planted but the main barrier is a lack of confidence by farmers and landowners that this is an economic option, given the long-term nature of the investment and risks from pests and diseases.

Woodland creation remains a strong candidate for reducing emissions but the addition of woody linear features to the Inventory and their expansion offers additional abatement as would the Glastir-entry scheme categories: woodland edge expansion and streamside corridor planting. Woodland creation should be targeted towards less productive agricultural land e.g. ffridd land, subject to wider ecosystems impacts e.g. on biodiversity.

Recognition of natural regeneration as an establishment method and greater flexibility on controlled grazing within woodland would also support higher afforestation rates. Natural regeneration should be encouraged to establish forest cover with minimal financial outlay and establishment efforts where appropriate seed sources are available to improve Glastir scheme engagement and uptake. Permission to allow controlled grazing at low densities to promote natural regeneration and seedling recruitment should be encouraged to increase Glastir participation. Synergies with current farming practices should be identified (e.g. bracken control, understory control, gap creation, soil disturbance) and utilised to increase engagement and woodland expansion.

The LUCC recommendations also include actions to research the life cycle benefits of wood fuel compared to fossil fuel and improvements to inventory methodology.

The review of the LUCC recommendations on forestry are shown below.

Table 5: Review of LUCCG 2010 recommendations relating to forestry

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
3	Expand current woodland / forest cover by about 100,000 ha over the next 20 years	Increase sink by 1,600 $ktCO_2e$ if enough suitable land available.	Only 15% of target	This should continue to be a priority for WG in view of mitigation potential but the targets need to be revised to a practical level.
4	Ensure that forests are managed to optimise their GHG sink potentials as well as providing a sustainable source of fuel wood and other timber products that form long term "carbon sinks" and/or substituting for fossil fuels	Uncertain. More work is required to quantify the life cycle benefits of wood fuel compared to fossil fuel.	Progress on Woodland Carbon Code, education and LISS	1) Removal of trees on Peatlands. 2) Restrictions on planting on highly organic soils. 3) Advocacy services to provide advice.
26	Resolve best ways of modelling forest soils	N/A. Improvement to inventory methodology only.	Changes to LULUCF	Investigation of soil organic carbon (SOC) stock modelling in organic soils in the CARBINE model (underway).
48	To assess the effects on soils carbon stocks in organic soils throughout the life cycle particularly newer forest management methods	N/A. Improvement to inventory methodology only.	Inventory improved by change to CARBINE model	Continuation of ongoing work to improve modelling of effect of forest on SOC stocks of organic soil.

Woodland that is not under management in Wales is often at the mature or degenerative stage with little additional C sink capacity. Bringing woodland into active management would increase the C sink but also promote synergies that will improve the resilience of woodlands to climate change drivers and the provision of ecosystem services. The use of low impact silvicultural systems (LISS) is recommended to reduce soil C losses, and promote resilience to pests, diseases and extreme events.

Soils and crops

Wetlands in Wales such as bogs, mires and fens store large amounts of C as peat in their soils (stored peats are estimated to hold 121.3 Mt of C (Smith et al, 2007)). In addition some peatland areas have been damaged by activities such as drainage and erosion, and may be losing C. The LUCCG recommendations on soils and crops aimed to stop further depredation of peatlands. However, if these sites can be restored then these C losses can be reduced or possibly even reversed. Active management and a more ambitious plan to place all degraded peatlands under restoration actions, in line with WG policy in this area, would have more wide-ranging impacts.

Better activity data and emissions factors are also needed to be able to estimate the mitigation potential. The LUCCG recommendations recognise this and include actions to improve reporting in the LULUCF inventory and improvements to inventory methodology. It is important that these are completed.

A summary of the review of recommendations for soils and crops is shown below.

Table 6: Review of LUCCG 2010 recommendations relating to soils and crops

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
5	Ensure that no steps are taken which might undermine the carbon stores in bogs, mires and fens.	No mitigation potential in the measure as it stands, as it only prevents additional emissions.	Positive action has been ongoing since the 2010 LUCCG report	Expand to include restoration and re-wetting of degraded wetlands. Peatland Action Group to develop a framework for targeting areas for restoration, implementing actions and monitoring progress.
24	Crop rotation land use statistics - CEH to investigate classifying as a separate land use type instead of the inclusion of frequent transitions between land uses	N/A. This measure would improve reporting in the LULUCF inventory, and could result in a net reduction in reported emissions from rotational grassland.	Defra SP1113 project assess rotation patterns	In progress. It is planned to implement the vector approach (using spatially referenced data) to reporting land use change in the 1990 - 2014 Inventory.
43	Improve estimates of the impact of moving from one land use to another on soil carbon storage particularly in relation to soil type.	N/A. Improvement to inventory methodology only.	Work on land use reversal underway. No further fieldwork.	CEH is responsible for improvements to the LULUCF inventory.
49	Develop the soil carbon model, ECOSSE, for representative catchments using finer vegetation categories and underpinning soil data.	N/A. Improvement to inventory methodology only.	Research tool	Better activity data and EFs are needed to be able to estimate the mitigation potential.

Livestock and grazing

The LUCCG recommendations under this category relate to evidence gaps and the research needed to address them. The summary review is shown in Table 7.

Table 7: Review of LUCCG 2010 recommendations relating to livestock and grazing

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
39	Develop a clearer analysis of the value of ruminant livestock for delivery of ecosystem services.	N/A. Overarching data and analysis need.	Some research	Continue to research.
44	Quantify the effects of grazing intensity and type, re-seeding of lowland pasture and the impacts of tillage methods on GHG emissions	N/A. Inventory improvement measure only. Field data on effects of grassland management is sparse.	Reduced GHG emissions from grazed lowland grassland	Better capture of the effect of grassland management could prompt more targeted measures.
45	Breed new grass varieties that enhance carbon storage below ground.	Some mitigation potential, but size of potential emissions reduction very uncertain.	Limited, some breeding programmes	Continue to research as a long term measure given the time needed for a crop breeding programme.

Some literature suggests that intensification of grazing on improved grassland on mineral soils can increase soil C stocks as higher grass yields lead to increased inputs of crop residues and root exudates to soil. However, there is a lack of evidence on the effect of intensification of rough grazing on organic or organo-mineral soils and a risk that measures such as drainage, liming, and cultivation on these soils could lead to loss of soil C.

<u>Land use and management practices</u>

A summary of the review of the recommendations under this category are shown below. These mainly relate to LULUCF inventory improvements and as such have no inherent mitigation potential. Nevertheless they are an important component of the evidence base for informing actions and effective monitoring and quantifying of their impact.

Table 8: Review of LUCCG 2010 recommendations relating to land use and management

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
6	Ensure that Glastir prescriptions are consistent with the need to reduce GHG emissions.	Mitigation potential, but this is an overarching measure, so effect cannot be quantified.	Modelling ongoing via GMEP project.	Continuation of project; new measures could be included, e.g. use of NIs.
22	Refine current estimates of land use change in Wales	N/A. Improvement to inventory methodology only.	Vector approach developed	CEH are responsible for making improvements to the LULUCF inventory. The model used for reporting emissions and removal from Forestry has recently been improved by changing from CEH's C-Flow model to Forest Research's CARBINE model.
23	Develop the LULUCF inventory so that it is able to take account of reverse transitions.	N/A. Improvement to inventory methodology only.	Improved model	
25	Assess ways to improve the LULUCF inventory to include agri-environment practices aimed at increasing soil organic matter, or innovations in forest management and the use of harvested wood products that substitute for fossil fuel use.	N/A. Improvement to inventory methodology only.	Improved model now uses CARBINE – more complete coverage	
27	Improve current assumptions for soil carbon changes for land converted to Settlement.	N/A. Improvement to inventory methodology only.	Work to develop an earth observation method	Not a priority for the LULUCF Inventory given the small areas involved
47	Monitor the fluxes of all GHGs and dissolved carbon losses simultaneously in the same locations so that the net global warming potential can be determined.	N/A. Measure to fill knowledge gap and improve inventory reporting.	Estimates of C balance from Upper Conwy blanket bog, data collection and collation.	Funding for additional flux measurements could be targeted at priority land-use categories (land-use change, restoration, implementation of Glastir measures etc.) that may lead to significant reductions in GHG emissions.

Other relevant recommendations include: integration of estimates (21), improved crop rotation land use statistics (24), projections of emissions (28) and information on impact of tillage on N_2O (46). All these recommendations relate to improving information available rather than direct emissions reductions although they may lead to subsequent recommendations to that end. None of the recommendations are complete although some have made some progress towards completion.

3.2.2 Addressing barriers and gaps

Several actions and projects have removed some of the barriers to action and reporting identified in the 2010 LUCCG report. Modelling of forest management practices has changed with the move to use Forest Research's CARBINE model rather than CEH's C-Flow model in the LULUCF Inventory. Also, a Defra-funded project[7] on cropland and grassland management impacts on soil carbon has enabled a methodology to be developed which will allow these to be included in the LULUCF Inventory. Finally, a vector approach to assessing land use change has been piloted which will improve reporting of land use change in the LULUCF Inventory. Some further development of the methodology is needed.

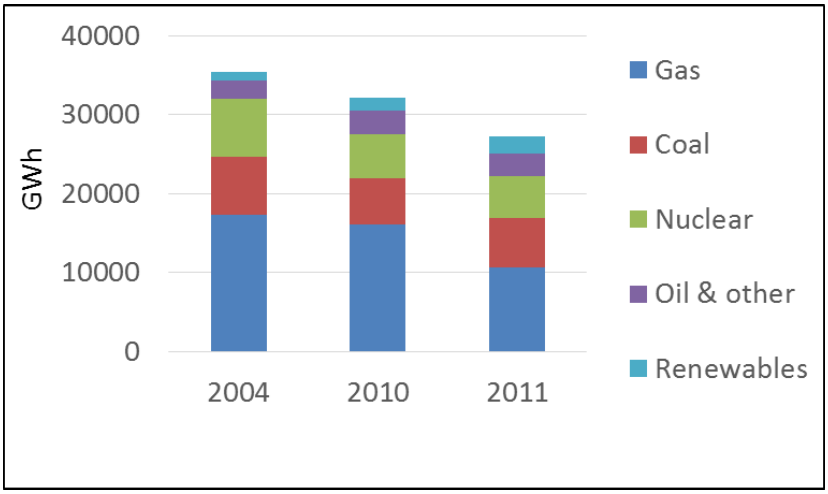
Remaining knowledge gaps are:

- Up to date mapping of available land which is suitable for afforestation.
- Area of small woods covering 0.1-0.5 ha.
- Activity data and stock change factors on hedgerow creation.
- The effect that improvement of grassland on organic and organo-mineral soils has on soil carbon stocks.
- Extent of peatland drainage in Wales and appropriate EFs for drainage and rewetting.
- Fate of soil organic carbon in land converted to settlements.

3.3 Renewable energy

Natural gas, coal and nuclear remain the major sources of electricity generation in Wales, accounting for 81% of generation in 2011, despite a significant drop in natural gas generation over recent years (Figure 5). Natural gas and coal are finite fossil fuels that give rise to electricity with a high C footprint; 0.42 and 0.95 $kgCO_2e$ per kWh generated by gas and coal, respectively (Defra, 2012). Fossil fuel electricity generation also gives rise to significant emissions of NOx and other polluting gases, whilst £billions are spent importing these fuels to Wales, with negative consequences for the balance of trade and indigenous economic activity.

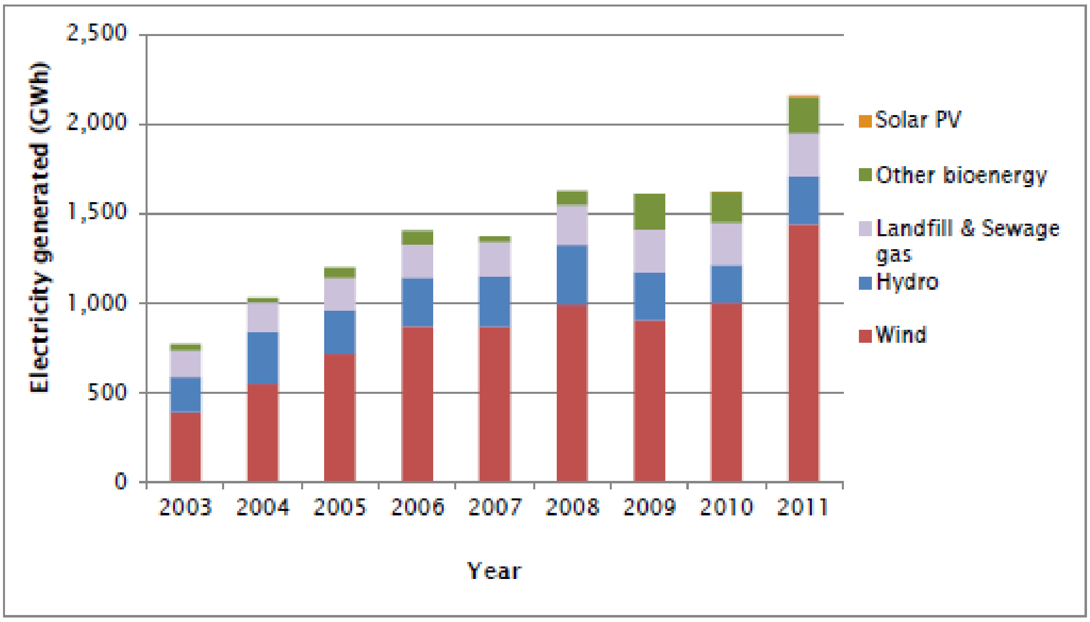
[7] Capturing cropland and grassland management impacts on soil carbon in the UK Land Use, Land Use Change and Forestry (LULUCF) inventory - SP1113



Source: Statistics for Wales, 2013.

Figure 5: Electricity generation by source in 2004, 2010 and 2011

In 2012, 2,276.8 GWh of renewable electricity (RE) was generated in Wales (DECC, 2013), up from 2,159 GWh (7.9% of total generation) in 2011, and up from just over 1,000 GWh in 2004. In 2012 60% of electricity generation from renewable sources in Wales was from wind and wave, 14% from hydro and just 3% from solar photovoltaic (PV) (Figure 6 and annex 3).

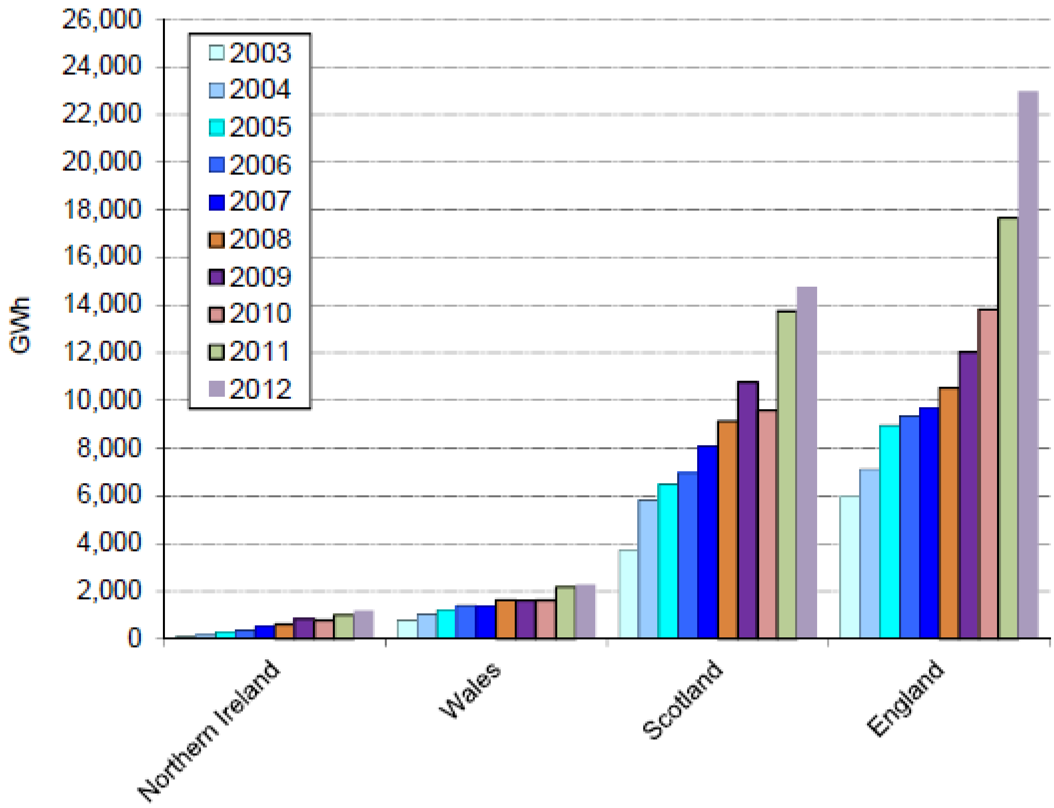


(Source: NAW, 2013)

Figure 6: Renewable electricity generation in Wales 2003-2011

Two thirds of 2013 generation was from wind, primarily in large arrays. However, progress with small scale RE deployment was slower, with just 57 small scale schemes (0.5-5 MW) operational in 2013 (NAW, 2013). This compares against a WG target for 7,000 GWh to be generated by renewables in 2020. As of 2013, approximately 96 MW of renewable electricity was generated by FiT-eligible (< 5 MW) generators, mostly at the micro scale (<0.05 MW capacity), and mostly solar PV (NAW, 2013). The aspirational target for micro generation set in 2010 is 1,000 MW by 2020. This will require an exponential increase in the 28,300 domestic micro-RE systems installed so far.

The limited progress on renewables in Wales is illustrated below in a comparison on RE development across the UK countries. Given the scale of the targets to be achieved and the mechanisms in place to drive uptake, attention should urgently be given to understanding the barriers to development of renewables in Wales. An indication may be provided by the mid-term evaluation of Ynni'r Fro, the WG programme of support (advice, grants and loans) to community-scale renewable energy schemes. It found significant external challenges that have limited progress, including local opposition, the high costs of preparatory work and difficulties in gaining planning approval and consent.



Source: DECC Energy Trends 2013

Figure 7: Trends in generation from renewables by country

Rural areas, and farms in particular, have high potential for RE deployment, including wind turbines, solar PV (on south-, west- and east-facing roofs), the production and use of wood as a heating fuel, and biogas production from small-scale AD units (see 2010 recommendations 7 and 9). However, rural areas are also important in terms of their landscape and biodiversity and are necessarily protected from unsuitable development. Planning Policy Wales (PPW) Edition 5 sets out WG's land use planning policies and has been revised in the context of the WG's energy policy. PPW identifies that Local Planning Authorities (LPAs) should facilitate all forms of renewable development and ensure decisions are consistent with national and international climate change obligations as well as renewable energy targets (para 12.8.9). At the same time, LPAs should ensure development meets statutory environmental obligations and considers mitigation where necessary, whilst ensuring the economic viability of the proposal (para 12.8.10).

It is clear that there are some contentious issues associated with renewables development which are limiting capacity. These need to be understood and addressed if government generation targets are to be met but progress could also provide significant GHG mitigation.

3.3.1 Review of 2010 LUCCG recommendations for renewables

The 2010 recommendations relate to broader actions for supporting renewables, such as grid connectivity and utilisation of renewable heat, rather than focusing on individual renewable energy technologies. A summary review is shown in Table 9 below with a full technical analysis in annex 9 (Renewables). It is clear that progress has been very limited on renewables relative to the ambitions set out in the 2010 analysis and in government policy commitments.

Table 9: Review of LUCCG 2010 recommendations relating to renewable energy

Rec.	Summary of Measure	Mitigation potential	Progress	Action required
12	To encourage an increase in the horticultural / glasshouse sector taking advantage of renewable heat sources.	The horticultural sector is very small and fragmented in Wales. Step change would rely on inward investment but is very uncertain.	No evidence of progress	Medium-term aspiration to utilise renewable heat. Explore existing business models.
14	To promote all elements of the renewable energy potential of (rural) Wales in appropriate locations and to ensure the obstructions to uptake and grid connectivity are minimised with all speed.	Achieving the WG target of 7,000 GW RE generation by 2020 would lead to a national GHG reduction of 1.98 $MtCO_2e$ relative to 2012.	Increasing uptake but still behind targets.	Use FiTs and RHI to encourage micro-scale systems. Address planning and grid connection concerns. Provide better guidance and support to facilitate uptake of renewables.
15	To promote a range of woodland (biomass) planting to create a source of renewable heat energy as a significant contribution to renewable energy from the rural sector.	Assuming 5% of Welsh land area could be used to cultivate short rotation coppice or similarly productive biomass production, could lead to the avoidance of 1.36 $MtCO_2e$ annually.	Unclear due to lack of data	RHI will assist. Barriers to address include long payback time, lack of pelleting plants and behavioural barriers.
16	To work with industry to ensure as rapid as possible take-up of compressed biogas (CBG) and electric plug-in/hybrid vehicles and machinery in rural Wales and the food chain.	Mitigation potential exists but timescales for market penetration are long.	Little progress	Further encouragement required, installation of strategically located electric vehicle charging points could assist.

There are increased opportunities for solar PV, wind and hydro as well as for AD and biomass. Given the particular opportunities and constraints for each of the technologies, it is considered that a separate recommendation is set out for each of these (as existing Recommendation 15 for woodland biomass) alongside an overarching action on facilitation of uptake and issues of grid connection (existing Recommendation 14).

The longer-term need to develop infrastructure for electric vehicles and exploit opportunities for step growth in the horticultural sector using renewable heat remain valid but are not priority actions for the period to 2020. Recommendation 19, which aims to "… *ensure that planning regulations are designed to facilitate installation of rural renewable energy generation, subject to essential environmental protection and respect for listed buildings*" has not been progressed as is evident from the consultations with stakeholders during this study and from wider consultation with industry. This remains a priority issue to be addressed.

3.4 Other recommendations

There is a number of measures which are not aimed at reducing emissions *per se* but instead relate to supporting actions for measures that do reduce emissions. These include: economic assessment (1), public awareness and involvement (2), research capacity (17), government capacity (18 &19) and government responsibility (20). They fall into three distinct categories:

(a) Completed. Recommendation 20 - to commission a report on climate adaptation mechanisms likely to be required in the land use sector – is addressed as part of this work.

(b) Progressed but ongoing. Recommendation 2 (public awareness and involvement) which has been effectively actioned but will need to continue as responses to climate change develop and impact on the wider population. Similarly Recommendations 17 and 18 relate to working with the research community to implement recommendations and ensuring that the climate change agenda is represented across government policy. These are strategic actions and have in part been progressed but remain critical to facilitate implementation and are ongoing.

(c) Not done. Includes Recommendation 1 (economic assessment of climate change actions) which remains outstanding and should be completed.

4. Updating the Delivery Plan for Emissions Reduction

This section presents the evidence on available GHG emissions reduction, in terms of Maximum Technical Potential (MTP), from implementation of the measures (from chapter 3) in isolation. This abatement is relative to the baseline period and represents average annual emissions reduction over the lifetime of the measure; as such it is repeatable but not additive and may be uneven over time. Measures are scored for uptake available (allowing for existing implementation and structural or behavioural barriers) and for cost effectiveness (extent of economic incentive for land managers to implement, allowing for current public support measures and market returns). The last two columns are highlighted red, amber and green (to denote low, medium and high scores, respectively).

4.1 Mitigation measures and available GHG emissions reduction

4.1.1 Productive agriculture

The estimates of abatement available from mitigation measures in agriculture relative to the baseline period emissions data for Wales and estimates of impact are shown in Table 10.

Table 10: GHG abatement measures for productive agriculture in Wales

Mitigation measure	Abatement rate	Annual Abatement ktCO₂e MTP	Applicability (uptake available)	Cost effectiveness of measure*
High genetic merit livestock	10% of enteric emissions	229	Medium	High
Improved animal nutrition	10% of enteric emissions	229	High	Medium
Improved animal health	10% of enteric emissions	229	High	Medium
High sugar grasses	10% of enteric emissions	229	Medium	Medium
Nitrification inhibitors for fertiliser and organic manures	30-50% reduction in N_2O	432	High	Low
Calibrate fertiliser spreader	<5% reduction in N_2O	35	Medium	High
Calibrate manure spreaders	5-10% reduction in N_2O	28	Medium	High
Adopt fertiliser recommendation system	5-10% reduction in N_2O	53	Medium	High
Adopt a manure management plan	15-20% reduction in N_2O	81	Medium	High
Use of crop varieties with improved N use efficiency	5-10% reduction in N_2O	53	Low	Medium
Substitute fertiliser N with legume-fixed N	10% reduction in fertiliser N use	71	Medium	High
Improve N availability of manures	2% reduction in N_2O from fertiliser use	15	Medium	High
Controlled release fertilisers for high value arable crops	0.3 tCO_2e/ha	9	Low	Medium
Precision application – crops	5% reduction in N fertiliser use on Welsh cropland	5	Low	Medium

* High cost effectiveness represents a good economic return for land managers.

The values for mitigation potential (MTP) are based on the latest evidence available, and are broadly similar to those reported in ClimateXChange[8].

In practice we might expect some combination of measures to be taken up, reflecting the availability and cost effectiveness of each. The mitigation measures are not all additive and account needs to be taken of interaction and double-counting. Note that AD is not counted here but as an energy generation measure as its primary effect is through displacement of fossil fuel use (for heat and possibly for electricity) – see 4.1.3. A key constraint is that many of these measures represent efficiency gains and as such will result in increased agricultural output rather than reduced input use; in practice, we might expect a combination of both.

Relative to current emissions from agriculture and, allowing for efficiencies secured to date and output expansion plans, it would be realistic to budget for a **5-10% net emissions reduction or around 400 ktCO_2e per year** by 2020**,** as captured in the new Inventory.

4.1.2 Land use and management

In terms of land use change the main changes are expected to be a gradual increase in the area of woodland and restoration of degraded peatland. There is not expected to be any substantive land use change between Cropland and Grassland while Settlements will continue to grow incrementally.

Table 11: GHG abatement measures for land use and management in Wales

Mitigation measure	Abatement rate	Annual Abatement ktCO_2e MTP	Applicability (uptake available)	Cost effectiveness of measure*
Woodland planting - 100,000 ha available for planting.	420-694 tCO_2e/ha for a 100-year period	590	Medium	Medium
Natural regeneration of woodland – estimated at 10% of planted area.	420-694 tCO_2e/ha for a 100 year period	59	Medium	Low
Woodland edge expansion and streamside corridor planting (assuming addition of woody linear features to the inventory).	Estimated at 10% of traditional woodland rate	25	High	Medium
Hedgerow restoration / expansion (assuming addition of woody linear features to the inventory).	Increase hedgerow biomass by 10% by 2030	15	High	Medium
Restore all degraded peatland.	Based peatland areas by type and associated abatement (0.9 tCO_2e/ha/yr for rough grassland to 27.3 tCO_2e/ha/yr for arable land).	324	Medium	Low
Reduce agricultural lime use by 10%.	Based on emissions from liming of 54 ktCO_2e (2012).	5.4	Low	Low

* High cost effectiveness represents a good economic return for land managers.

[8] ClimateXChange is Scotland's centre of expertise on climate change www.climatexchange.org.uk

Another action would be to cease peat extraction in wales, based on current emissions from peat extraction in Wales of 353 tCO_2e pa. However, this does not appear in the Inventory and would not be counted in the Delivery Plan.

Woodland is incentivised largely by the Glastir Woodland Creation option but also by support for linear features (woodland edge expansion and streamside corridor planting) which although currently not captured by the LULUCF inventory is expected to be. Additionally, there is an element of on-going natural regeneration of woodland on hill slopes which have an ingress of bracken or scrub and have limited agricultural or biodiversity value. For context, the area classified as acid grassland and bracken in Wales is 284,500 ha and the area of neutral grassland (rough grassland in the Land Cover Map (LCM)) is 227,100 ha, a total of 511,600 ha or 24.6% of the Wales land area. The 100,000 ha target for afforestation in the 2010 LUCCG report therefore represented around one fifth of this area. Afforestation under Glastir should also aim to utilise ffridd, gorse scrub and bracken land that cannot be easily farmed due to frequency of rocky outcrops, scree, and the slope of the terrain as the ideal location for woodland establishment to maximise woodland expansion whilst minimising the impact of existing farming practices.

Linear woody features are not currently included in the National Forest Inventory, but the UK has 527,000 ha of linear features, which when scaled to Wales' land area equates to 2.2% of Wales' or 45,000 hectares (Morton *et al*. 2011). Data on the C sequestration potential of linear features is limited but making the pessimistic assumption that this land area would store one tenth of the C stored in a traditional woodland it would effectively add between 2.4 and 4.0 MtCO_2e of sequestered Carbon. Emmett *et al.* (2014) modelled the potential impact of Glastir Woodland Edge Expansion (option AWE 24) and Streamside Corridor Planting (option AWE 9b) scheme participation and found that under both Low and High participation scenarios between 8,000 ha and 12,000 ha of woodland habitat could be created through this mechanism. This represents approximately 10% of the increased area of woodland cover that the WG has committed to achieve and as a currently unaccounted carbon sink could contribute to between 6 and 11 MtCO_2e by 2100.

In terms of peatland, there is a strong case for restoration of all degraded sites based on limited agricultural productivity (excepting arable and improved grassland) and benefits for other ecosystem services. However, action is dependent on sufficient incentives being in place through Glastir although there is some scope for development of private funding e.g. through the Peatland Carbon Code[9]. A recent review of the opportunities for PES in Wales (Cascade Consulting, 2014) notes that the draft IUCN[10] Peatland Code, although it provides guidance on quantifying climate and other benefits, is not currently intended for use in C offset schemes, corporate C reporting or for C trading on international Carbon markets.

The mitigation from land use measures is additive in principle but will not all be taken up due to barriers to land use change. Achievement of **50% of the total potential abatement would represent around 500 ktCO_2e per year.** However, this would mostly available after 2020, with perhaps half counted in the Inventory by 2050, given the profile of net emissions. For example, new woodland enters the Inventory at planting and follows a variable trajectory, allowing for emissions from soil disturbance during planting and harvesting and variable C sequestration rate over that period. For peatland restoration, the effect of restoration will enter the Inventory as soon as steps are taken to raise the water table, and the emissions/removals will then follow a variable trajectory from that date (most likely recording an increased emission for 5 - 10 years which then reduces and may become a removal).

[9] Payments for ecosystem services (PES) PES pilot research projects (2012-13): Peatland carbon code, Project 5 - NE0141
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18642
[10] International Union for Conservation of Nature

4.1.3 Renewable energy

The evidence presented in annex 9 highlights the extent of policy commitments made to develop renewables, in particular renewable electricity, in Wales and associated abatement available from the displacement of fossil fuel use. It should be noted that generation from renewables would, in itself, be an emission source and much of the CO_2e offset/abated from displacement of fossil fuels may not be counted in the Inventory at Wales level. However, for the purposes of capturing the contribution of this technology to overall global warming, abatement levels have been presented in the analysis below.

Wind and solar PV achieve the greatest GHG mitigation per hectare of land utilised by some margin. These technologies can make a significant contribution to national energy security and GHG mitigation, whilst creating employment compared with the use of imported fossil energy. The main barriers to these technologies are planning objections and grid connection (the transmission network may need upgrading in some cases). Clear guidance on how local factors are weighed against national interest for individual projects involving these technologies could facilitate strategic national deployment of these crucial RE technologies.

Biomass energy can achieve modest GHG mitigation per hectare of land in comparison. Where high yielding crops such as Miscanthus can be grown on fertile land, GHG mitigation can be over 20 tCO_2e/ha/yr, or 16 tCO_2e/ha/yr assuming carbon leakage via displacement of food production (Styles et al., 2014). There may be opportunities to deliver other ecosystem services such as soil C sequestration, erosion protection, and water quality/flow regulation from perennial bioenergy crops. National policy should focus on how to maximise the delivery of RE and associated GHG mitigation alongside additional ecosystem services, for example by encouraging tree planting along riparian buffer zones and on low productivity farmland. The RHI is likely to encourage a market in biomass heating, but to date, farmer income per GJ energy supplied in biomass output has been low compared with final (pelleted) sales prices. Processing, especially pelleting, appears to be a major bottleneck for more widespread uptake of biomass heating that could be overcome through targeted support to develop strategically located pelleting facilities.

AD of waste feedstocks can lead to significant GHG avoidance and modest RE generation. However, growing annual crops for electricity generation in AD units is not an efficient land use for GHG mitigation, and is associated with significant risks of soil erosion and eutrophication of waters. Current policy in the form of high FiT for AD electricity generation is encouraging crop-fed AD but not much livestock waste AD, leading to poor environmental outcomes. The considerable GHG mitigation potential of AD could be realised if on-farm AD of waste feedstocks was encouraged by a shift in subsidies away from AD electricity generation and towards waste management. This is reflected in the MTP of the individual technologies set out in Table 12.

It is also notable that the uptake available is generally not limiting and that cost effectiveness is high or medium, with the exception of slurry-based AD systems.

The scale and availability of RE mitigation is substantial across the main technologies. While some compete with agriculture for land, notably biomass, the others can co-exist with food production while roof-based solar and hydropower do not compete at all. With public funding incentives through FiTs and RHI, the economic case is good for most and the main barriers are the planning system, acceptability by the public and limitations of access to the grid. Allowing for genuine environmental limitations and planning constraints near settlements, the scale of **mitigation at 50% of the combined technical potential would be around 1600 $ktCO_2$e per year.** This is a very uncertain estimate and is based on land-area based “plausible” scenarios; the technical potential is ultimately much higher. The timescale for realising this abatement is highly dependent on the pace of development of this sector.

Table 12: GHG abatement measures for renewable energy in Wales

Mitigation measure	Abatement rate	Annual Abatement $ktCO_2e$ MTP	Applicability (uptake available)	Cost effectiveness of measure*
Wind energy on 1% of Welsh land area	520 tCO_2e/yr per net ha utilised	1290	Medium	High
Biomass energy	0.286 $kgCO_2e$/kWh	869	Medium	Medium
Solar PV arrays on 0.1% of Welsh land area	179 tCO_2e/ha/yr	326	High	High
Solar PV (roofs)		315		
Hydropower 26 to 63 MW	Load factor of 75%	63-153	Medium	High
AD (slurry only)	From 240 $kgCO_2e$/t slurry for Heat-only Tank systems to 1787 $kgCO_2e$/t slurry for Lagoon systems with CHP	349	Medium	Low (relative to co-digestion or crop-only systems).

* High cost effectiveness represents a good economic return for land managers.

4.2 Contribution of the agriculture and land use sector to Welsh targets

The WG is committed to an overall target of reducing GHG emissions in areas of devolved competence by 3% per annum from 2011[11] against a baseline of the average emissions from 2006-2010. This broadly equates to UK and international targets to reduce emissions by 80% in 2050[12]. WG has an additional target to achieve at least a 40% reduction in emissions by 2020 against a 1990 baseline.

The Climate Change Strategy for Wales (October 2010)[13] outlines that there is an expectation that all relevant sectors will make a contribution to meeting the overall targets. The focus of the 2010 LUCC report, was to identify measures by which agriculture and land use sector could achieve an 80% cut in emissions by 2050. The report was aspirational and took a strategic view on opportunities for emissions reduction and their implementation. The wide-ranging recommendations also recognised the need for government support and scientific research in facilitating uptake of the mitigation measures. In the event, very limited progress has been made.

For this review, we have taken a bottom-up approach of what mitigation is available rather than basing it around meeting a sector target. As such a more pragmatic approach has been taken which accepts the wider tensions between reducing GHG emissions and policies which are focused on economic development (e.g. the Food Strategy for Wales) or on environmental protection. In effect, these wider policy goals together with market drivers may limit the scope to reduce emissions and may even see them increase. In terms of land use, there are constraints on where new woodland planting can be accommodated and for renewables on where developments can secure planning consent.

[11] Programme for Government
[12] UNFCCC and UK Climate Change Act
[13] Climate Strategy for Wales (October 2010)

4.2.1 Productive agriculture

In the 2010 analysis, it was estimated that increased dairy, sheep and cattle productivity from improvements in husbandry and efficiency might reduce emissions by 582 ktCO_2e (excluding AD). In the updated analysis the estimated abatement is 400 ktCO_2e per year by 2020, assuming that the RDP 2014-2020 is effective in driving productivity. This also assumes static livestock numbers and increased output of milk and meat; if livestock numbers increase, the sector may deliver a net increase in emissions over the period. Productivity gains in agriculture are expected to be ongoing, if increasingly challenging, so that additional abatement (over and above the 400 ktCO_2e) should be available by 2050 and again by 2080.

Actions in the dairy and associated beef production sectors and on AD were estimated to provide about 1,500 ktCO_2e in the initial analysis. In this Review, AD is considered as part of the renewables sector (see 4.2.3).

4.2.2 Land use and management

The headline measure in the 2010 analysis was an expansion of woodland over 20 years by about 100,000 ha to create an additional major GHG sink of 1,600 ktCO_2e annually by 2040, with a net sink of 1,200 ktCO_2e, and an additional fuel wood potential - perhaps 1.4 TWh per year by 2030-2040, off-setting emissions of a further 350 ktCO_2e from fossil fuels. In practice, progress has been very limited due to issues of uncertainty about which land is suitable for planting and the need to improve incentives for farmers to take up the option.

In the updated analysis, we consider that the 100,000 ha target can be met but over an extended period of time, perhaps as much as 50 years. Given the further lag in C sequestration as the woodland matures, we assume that minimal abatement is available by 2020, only 20% by 2050 and 70% by 2080. Further abatement can be achieved through natural regeneration of woodland, estimated at 10% of the annual average area planted of 2,000 ha but again there is delayed impact on the Inventory. Additionally, some abatement will be available from woodland edge expansion and streamside corridor planting and hedgerow restoration / expansion (assuming addition of woody linear features to the Inventory). This gives a total potential emissions reduction of 689 ktCO_2e of which only half may be realised.

The other main recommendation was to ensure that no steps are taken which might undermine the carbon stores in bogs, mires and fens. In essence this is about the avoidance of additional emissions rather than reducing existing emissions from degraded peatland. Our analysis suggests that it is important to restore all degraded peatland, which is estimated to deliver 324 ktCO_2e. In practice only 60-70% of this might be available due to issues over farmers' resistance to rewetting land and the timescale for addressing forestry on peat. As with woodland, there is a time lapse before this is picked up in the inventory with no abatement in 2020, around one third by 2050 and 100% by 2080. These estimates are very uncertain and rely heavily on the profile of land use change.

4.2.3 Renewable energy

In the 2010 report, RE generation from small-scale hydro, wind, dedicated biomass, solar - heat and PV - and ground-source heat were assessed and broadly estimated to be of the order of 3 TWh of electricity, and 3 TWh of heat annually. This would equate to a decrease in Wales' GHG emissions of about 1,500-2,000 ktCO_2e annually. The role of Feed in Tariffs (FiTs) and dependence on the cost and ease of connectivity to the grid was noted.

This updated analysis has noted the very limited progress on renewables and looked again at the potential mitigation by technology and uptake. The data now shows an abatement potential of 3,253 ktCO_2e annually, albeit only half of this may be realised due to issues of competing land use (mainly for bioenergy feedstock production), difficulties in securing planning consent and access to the grid and environmental concerns. Nevertheless the scale of abatement from renewables is line with the previous estimate and represents the single greatest potential across the three themes considered in this study. It should be noted that reductions in emissions due to RE would not be allocated to Agriculture or LULUCF in the Inventory.

4.3 Contribution of the food supply chain

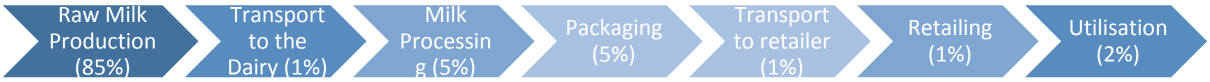
The earlier sections have considered on-farm food production and this section will look briefly at the post-farmgate situation and scope for emissions reduction. In practice any abatement will not be captured in the Agriculture or LULUCF Inventories but given the close commercial links, it is worthwhile considering opportunities which might be relevant to agriculture and land use. Given the structure of the Welsh agriculture industry with high reliance on cattle and sheep, the food chain is similarly dominated by products from ruminants, namely milk and red meat.

4.3.1 Dairy post-farmgate emissions

Cheese is the dominant end point for milk processing in Wales, accounting for nearly 90% of all milk processed in the country, or 88,000 t of cheese (DairyCo, 2014). For cheese 90% of GHG emissions are pre-farm gate. Figures are similar for liquid milk production with 85% of emissions related to on-farm production; so this should be the main focus for reduction of emissions in order to achieve the greatest impact. Nevertheless, there are still post-farm gate opportunities for abatement.

For example DairyUK found energy reductions of 24% could be achieved with potential for a further 10% reduction and even further cuts (9%) with grant support (DairyUK, 2014). Under the Dairy Roadmap[14] there is a target for all dairy manufacturers to have a C management programme in place by 2015 and to achieve a 15% improvement in energy efficiency by 2020. Additionally there is an aspiration for the installation of AD plants at Dairy Roadmap sites which will reduce GHG emissions associated with milk manufacture (Dairy Roadmap, 2013). The installation of RE to provide electricity requirements will reduce emissions during processing and aligns with the 2010 report goal of all electricity used at any stage of the lifecycle being generated from renewable sources.

For retailers there are a range of activities underway such as conducting C footprint assessments and running farmers workshops on efficiency and environmental issues (Dairy Roadmap, 2013).



Proportion of GHG emissions associated with each life cycle stage of liquid milk production (based on data from Defra (2007). The Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production. London, Defra.)

[14] http://dairyroadmap.com/wp-content/uploads/Dairy_Roadmap_2013b.pdf

4.3.2 Beef & lamb post-farmgate emissions

In its third roadmap for the beef and lamb industry, Down to Earth, EBLEX showed that over 90% of emissions were accounted for on farm. Quantifying post-farm gate emissions was incredibly challenging because the journey each animal took varied. The HCC Roadmap[15] acknowledges the need to reduce GHG emissions to meet the Welsh agriculture and land use targets. To play its part in ensuring that Welsh farming meets this target, beef and sheep production needs to reduce its annual GHG emissions by at least 8% by 2020, with the 2009/10 financial year being the baseline.The roadmap suggests how to reduce GHG emissions both on farm and in processing and suggests there is potential to reduce energy in the meat processing sector. Other ways to improve supply chain efficiency include reducing meat waste by increasing input into byproducts and increasing shelf life. On retail it suggests the promotion of the “food miles” concept to consumers can help reduce carbon footprint.

As major multiple retailers (i.e. supermarkets) sell the majority of meat consumed, they have the most potential to influence practices. Supermarkets are adopting strategies to reduce the C footprint of food and ensure its sustainability (e.g. Sainsburys carbon footprint of over 600 beef and sheep farms in Wales).

4.3.3 Consumer food waste

Consumer household waste offers an opportunity to increase efficiency in the supply chain. An estimated 400,000 tonnes of household waste per year[16] is produced in Wales with the majority of this sent to landfill. Each tonne of food waste produces 1,090 kgCO_2e. Given this, food waste creates 436 ktCO_2e. In the UK a 15% reduction was achieved between 2007 and 2012. A 15% reduction in Wales would equate to 65.4 ktCO_2e saved.

15 http://hccmpw.org.uk/medialibrary/publications/HCC%20Sustainable%20Red%20Meat%20Roadmap%20English%20LR_1.pdf

16 http://www.wasteawarenesswales.org.uk/foodwaste/love-food-hate-waste#.VBBwzHmYbIU

5. Greenhouse gas inventory issues

The Greenhouse Gas (GHG) Inventory contains the UK's official reported greenhouse gas emission estimates and is used by government to help formulate policies to mitigate emissions. Emissions are reported in nine National Communication (NC) sectors, which include Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Energy Supply. Each year, the UK greenhouse gas inventory is extended (to add another year) and updated to include:

i. Emission estimates for any new sources identified in the UK;
ii. Revised estimates for sources where there is an improved understanding of existing emission sources, e.g. where research identifies that new data are available, or a new, more accurate estimation methodology is developed;
iii. Data revisions, for example to energy statistics or updates.

This analysis is concerned with the second point and is focused on the Agriculture and LULUCF inventories.

Agricultural GHG inventory improvements

The current Agricultural GHG Inventory does not provide a detailed representation of the agricultural practices and influencing environmental factors for Wales and therefore would not reflect many potential changes in practice that follow delivery of the 2010 LUCGG recommendations. Thus implementation of the recommended actions will not always contribute to meeting the targets set by WG, although they may reduce emissions in practice. As such, the analysis is focused on informing decisions on actions to support to meet targets and providing a focus for improvements in the inventory to be more sensitive to Welsh policy.

The improved inventory being developed under the Agricultural Greenhouse Gas Research Platform (Defra projects AC0114, AC0115 and AC0116) will provide a greatly improved spatial, temporal and sectoral representation of the agricultural sector. It has specifically developed a large UK evidence base on the effects of soil and climate on N_2O emission factors, which will be used with extent measurements to develop a statistical model to predict EFs specific to the Welsh environment. The Platform has also developed a large UK evidence base on enteric CH_4 emissions, from which it has been established that feed dry matter or gross energy intake overwhelm any effects of livestock breed or management that might be specific to Wales. Therefore, inventory enteric CH_4 emissions will depend on a calculation of the metabolisable energy requirements of livestock, and a general assessment of the digestibility of accessible forage on Welsh farm systems.

The emphasis placed in the 2010 LUCGG on research on dietary manipulation and animal genetics to improve rumen function, and on provision of support to exploit biogas potential through AD of manures and CH_4 capture in zero-grazed systems, is adequately supported by the improved inventory. Uptake of these aspects is negligible at present, so providing Welsh Government tracks change in uptake, it can be represented.

The recommendations of direct relevance to the current and improved Agriculture Inventory are assessed at annex 10 in terms of how and whether the Inventories can reflect the impact of policy delivery. Recommendations not relevant to the Agriculture Inventory are concerned with C stocks, afforestation, renewables or life-cycle assessment. The most critical of the 2010 LUCCG recommendations (**No. 29**) requires the WG to collaborate with Defra and other Devolved Administrations in a research programme to develop an improved inventory methodology for the United Kingdom. The delivery of an improved inventory embodies within it the separate recommendations to research the key factors affecting N_2O emissions (**No. 36**), improve the statistics on fertiliser use in Wales (**No. 30**), and to capture the effects of different feeds and pasture on CH_4 emissions (**No's 35 and 35**).

LULUCF Inventory improvements

The current assessment of land use change within the LULUCF Inventory has used a model based on land use change matrices which apply rules on possible transition to data on land use change obtained from Countryside Surveys. This approach is not spatially explicit, and assumes that land is in C equilibrium but in practice rotation between grass and crop take place frequently, and therefore C equilibrium is unlikely to be reached in these systems.

As part of the Defra SP1113 project (Moxley et al, 2014) it was possible to map transitions between land use types for land eligible for CAP payments. Using this approach for successive years allows vectors of land use change for given land parcels to be built up. It is proposed to use this vector approach to mapping land use change from the 1990-2014 LULUCF (which will be published in 2016), to allow time for further refinement of the methodology. In particular, the vector approach will be developed further to include consideration of change in crop type within Cropland, as this effects residue returns to soil and hence soil C stocks.

A major advantage of moving to a spatially referenced vector approach to LULUCF reporting is that it will be possible to overlay these maps with other spatial data such as soil or climate maps, and in future, it will be possible to develop LULUCF reporting to take better account of the effect which local geographical conditions have on GHG emissions. From 2016, an improved methodology will be used which will give more detailed tracking of land use. This change will reduce the emissions reported from Grassland conversion to Cropland and removals from conversion of Cropland to Grassland will reduce. When Grassland is converted to Cropland loss of soil C is quick compared to the gradual accumulation of carbon when cropland is converted to Grassland. The LULUCF inventory calculations use a time period of 100 years for soil stocks to reach a new equilibrium after land use changes causing carbon loss and 200 years for new equilibrium stocks to be reached after land use changes which increase carbon accumulation.   As soil C is lost faster than it is gained the net effect of the more accurate tracking of Grassland/Cropland rotations is likely to be an increase in emissions.

To be credited for reducing GHG emissions, Glastir measures must be reflected in the emissions reported in the LULUCF Inventory. At present the Inventory is not spatially referenced and does not capture the past history of land use at a given site. In addition, the Inventory has historically focused on the effect of land use change rather than land managed outwith forests. New reporting requirements mean that the Inventory will need to be improved to be able to capture the effects of key management practices on Cropland and Grassland. This should improve its ability to capture the effects of Glastir measures on reported emissions. In addition, new Guidance has recently been issued on estimating emissions from wetland drainage and restoration. Although the UK has not yet elected to report on these emissions, there is ongoing work to develop a framework for this reporting. This will also improve the ability of the Inventory to capture the effects of Glastir measures.

If the effect of Glastir measures cannot be captured in the LULUCF methodology, some other means of assessing the effectiveness will be necessary (see Table 31 in annex 11).

6. Climate change adaptation

The aim of this exercise was to provide a review and assessment of the evidence to support climate change adaptation interventions in the agriculture and land-use sectors. The scope was to bring together the evidence on the particular impacts that are likely to arise in Wales from a changing climate and extreme weather events. Opportunities are identified where these relate to the risks presented but we have not undertaken a comprehensive analysis of all opportunities that may arise for Wales from climate change. Our analysis has suggested methods that could be employed to adapt to the risks identified, and whether these are likely to be cost-effective.

The summary below details the main risks for each of the sectors focussed on, and gives an overview of priority actions which should be addressed by the Sector Adaptation Plan (SAP) to build resilience and detail adaptation interventions. In order to provide consistency with the climate change mitigation analysis, where appropriate the same themes have been used to present the analysis.

6.1 Rural communities and businesses

Around one in three of the Welsh population live in an area classed as rural. Certain rural communities can face challenges such as less access to public transport and public services. The assessment and prioritisation of risks for rural communities in Wales from climate change identified four key impacts and one opportunity for prioritisation in risk management and adaptation strategies.

Table 13: Climate change risk assessment for rural communities in Wales

Risks	
1.	Flooding due to an increase in winter mean precipitation and extreme rainfall events
2.	Coastal erosion and flooding due to sea level rise and storm events
3.	Decreased water availability due to a decrease in summer mean precipitation and drought events
4.	Landslides associated with heavy rainfall events exhibiting isolated but potentially severe impacts
Opportunities	
1.	Milder winters may reduce winter heating bills and cold-related deaths

Flooding is ranked as the highest risk to rural communities, with around 1 in 6 properties (357,000 dwellings) in Wales (not just rural communities) worth an estimated £55.3 Billion[17] deemed at risk. The second priority risk is coastal erosion and flooding due to sea level rise and storm events. In the flooding of December 2013, 155 properties were flooded and a further 150 affected in the following month but this represents less than 1% of the properties and agricultural land that were at potential risk (Davies, 2014). Decreased water availability, principally caused by a decrease in summer mean precipitation ranks third in priority of risk. Over 90% of the Welsh population may be affected by water shortages by the 2080s, although there are large uncertainties in the projection (Defra, 2012). Landslips, caused by heavy rainfall events ranks as the fourth risk; while they can have devastating impacts to the communities they affect, they are likely to be isolated.

[17] Based on an average house price in North, West and South Wales of £155k (RightMove.co.uk, 2014), and a total number of properties at risk of 357,000.

Climate change also presents some opportunities for rural communities, notably from the increased likelihood of milder winters, which should lead to (relatively) lower heating bills and cold-related deaths in the winter.

In terms of adaptation actions, the agriculture and land use sectors can play an important part in reducing the risk to rural communities from flooding. Cost effective interventions include planting trees to provide a natural flood defence. This may have multiple benefits in terms of preventing against landslides and benefits in terms of climate change mitigation and biodiversity. To reduce the impact of drought, relatively cost effective actions are available to harvest rainwater, from domestic customers recycling “grey” water[18] to construction of reservoirs for wider use. Significant benefits may be gained by encouraging greater stewardship of water, and the promotion of relatively cheap water-saving tools.

Rural businesses includes those in the agriculture and forestry sectors (see other sections of this report), but also other businesses such as manufacturing, construction and those in the service sector (e.g. hotels) amongst others.

Table 14: Climate change risk assessment for rural businesses in Wales

Risks
1. Flooding due to an increase in winter mean precipitation and extreme rainfall events
2. Coastal erosion and flooding
3. Decrease in water availability due to a decrease in summer mean precipitation and increased frequency and duration of drought events
4. Transport disruptions
Opportunities
1. Tourism expansion due to a warming climate
2. Warmer winters

Flooding is ranked as the highest risk to rural businesses. In Wales non-residential properties at a significant risk of river or tidal flooding (in all areas) are estimated to be between 30,000 and 65,000 by the 2050s, against a current figure of 24,000 in 2012 (Defra, 2012). Rural businesses in coastal areas may be at particular risk from flooding through a combination of sea level rise and storm events. Coastal flooding as seen in the 2013/14 winter can destroy sea defences and leave coastal towns such as Aberystwyth vulnerable to further erosion and flooding. By the 2050s drier summers are likely to lead to a decrease in water availability for rural businesses in Wales. Rural businesses, other than those in agriculture or forestry may have to compete with other uses for water which could lead to higher prices, or lack of availability. Transport disruption, especially that caused by snow in the winter can adversely affect rural businesses if rural roads become impassable. Rail services can be adversely affected by snowfall, as well as hot temperatures in the summer.

Adaptation actions for flooding are similar to those for rural communities, and the agriculture and land use sectors have an important role to play with the potential for providing cost-effective adaptation actions. For water stress, small scale adaptation measures such as the creation of ponds/reservoirs and rainwater harvesting systems could be encouraged. This water could be used for ‘grey’ uses and provide an alternative to mains drinking water for some agricultural practices. For rural businesses relying on the tourism sector a warming

[18] Grey water is the wastewater that comes from the laundry, kitchen, and bathroom use and represents an estimated 50 to 80% of all wastewater a residence generates. Recycling grey water reduces the demand on sewage treatment plants as well as water treatment plants.

climate is more likely than not to encourage expansion leading to better revenues. Milder winters will also provide an opportunity to save on heating bills and provide better welfare conditions for staff.

6.2 Productive agriculture

In 2013 the livestock sector in Wales comprised of 13,160 beef and sheep holdings (the majority in Less Favoured Areas), 1,788 dairy farms, 109 specialist pig farms and 471 specialist poultry farms. The area of grassland equates to roughly 1 million ha of permanent grass and 444,000 ha of rough grazing (Welsh Government 2014).

Table 15: Climate change risk assessment for livestock and grasslands in Wales

Risks
1. Increase in liver fluke and other diseases
2. Increase risk of wildfires and conditions for wildfire development
3. Heat stress
4. Availability of animal feed
Opportunities
1. Improved grass yields
2. Farm diversification
3. Livestock performance improvements

The largest impact on the sector from climate change is an increase in liver fluke and other disease impacts, which have always been a problem during the late autumn and winter in western areas of the UK. Wales is forecast to experience high levels of infection, with serious epidemics expected to be the norm by 2050, leading to potential economic losses from delayed time to finishing and damaged livers at the abattoir. Simple adaptation actions involve keeping livestock out of wetter areas of fields (where the snail vector of the disease inhabits), and methods to achieve this can include planting trees which convey multiple benefits. Wildfires are a persistent, widespread, costly and dangerous issue in Wales (particularly South Wales). A decrease in precipitation and temperature increases will make for better conditions for spread of fires. Adaptation actions include raising awareness amongst the public and creation of sector breaks in fields.

Heatstroke and sunburn can cause animal welfare issues and loss in production of all major livestock species in Wales. Estimates at the UK level suggest production losses of £5.8m and mortality losses of £34m by 2080 from gradual temperature increases (excluding any heatwave conditions) (Wall et al 2010). Providing shade for grazing livestock is the simplest way to avoid heat stress. This may consist of manufactured shelters, or planting of trees. The livestock sector in Wales is highly reliant on imported animal feed, largely in the form of soya. With a changing climate, soya yields are predicted to increase in some areas and decrease in others. The sector will need to become resilient to spikes in feed prices through more use of home grown feed, or alternative sources. Opportunities for the sector from climate change include improved grass yields, projected between 20-50% by the 2050s if other conditions are not limiting. In addition farm diversification opportunities, either tourism related or converting land where geographical constraints are not present to crops. Warmer temperatures may in theory provide more favourable temperatures for extended duration of outdoor grazing of livestock, and thus reduced feed cost, however this is dependent on other impacts, such as flooding, not occurring.

The arable and horticulture sectors in Wales are comparatively small when compared with livestock, accounting for only a 4.8% share in total gross output of Welsh agricultural production. Wales has a productive arable area of approximately 79,000ha and 1,500ha of horticulture, against productive grazing land of approximately 1.5m ha (Welsh Government, 2013).

Table 16: Climate change risk assessment for arable/horticulture in Wales

Risks
1. Flooding due to an increase in winter mean precipitation and extreme rainfall events leading to soil erosion and loss of crops
2. Decrease in water availability for crops due to a decrease in summer mean precipitation and increase in severe drought events
3. Physiological impacts on crops from temperature extremes (e.g. heatwaves)
4. Increased pest and disease pressure
Opportunities
1. Improved opportunities for horticulture and changes in crop ranges
2. Longer growing season
3. Diversification of enterprises

Flooding, both coastal and inland has the potential to cause waterlogging of crops and soil erosion. These can lead to physiological impacts through loss of nutrients, and depending on the flood tolerance of the crop through prolonged waterlogging. Flooded soil is not passable by machinery which can in turn affect management of the crop at crucial growth stages. The first adaptation action to consider where possible is good field drainage.

Water stress through a lack of rainfall is a lower risk than flooding due to the relatively high rainfall in Wales. However, for high value crops where available water is essential for yield and quality, restrictions on use for agricultural crops (in the form of irrigation) could be a major problem. The most effective adaptation methods are likely to be on-farm storage of water, either from rainfall or water abstraction in peak periods. Conversely, whilst this presents a risk, in the context of the wider UK, Wales is not as water stressed as eastern regions (or other areas globally), giving rise to an opportunity from expansion of sectors such as horticulture. If water stress becomes a problem that severely limits the yield of crops grown in Wales, land use change to crops which require less, or no irrigation water is likely.

The third risk is the physiological impact on crops associated with high temperatures in summer and includes reproductive (flower) development which can be impaired in some arable and horticultural crops. The probability of heat stress around flowering that might result in considerable yield losses is predicted to increase. Adaptation actions may include the introduction of new varieties of crop that have a greater resilience to heat stress.

Whilst the interactions between crops, pests and pathogens are complex and currently poorly understood in the context of climate change, pests that can survive overwinter e.g. aphids, spider mites and thrips, are a risk to the sector.

6.3 Food Chain

The Welsh food and drink industry employs around 230,000 people, representing 18% of the Welsh workforce. The industry generates around £6.5 billion sales revenue each year (WFDSP, 2014). The scope of this review was on the food chain for food derived from primary products produced in Wales.

Table 17: Climate change risk assessment for the food chain in Wales

Risks
1. Transport disruptions
2. Market price of livestock products
3. Market price of crop products
4. Supply planning
5. Food safety

Given the scope of this review many of the climate change impacts on the food chain exist at the production end and are included in other sections (e.g. arable/horticulture and livestock). Transport disruptions from extreme weather events such as heavy snow or fog will likely close roads or rail connections and coastal flooding can close sea ports which will have an impact on the availability of products and cause economic impacts to the sector. The market price of livestock and crop products will likely rise as a result of climate change impacts and price spikes could make everyday products such as bread or meat unaffordable. As result of changing availability and prices of products, supply planning to meet demand will become more difficult, and whilst this impact is very uncertain if realised could hamper the availability of food retailers to satisfy consumer demand leading to economic losses.

As a result of changes in temperature and precipitation, food safety issues such as occurrence of contaminants could become more of a challenge to control. This can lead to economic losses through recalls of products and consumer health issues if food safety issues are not identified in the food chain. For all impacts identified there are no straightforward adaptation actions, however good supply planning and risk management strategies by those in the food supply chain are likely to make the sector more prepared to respond to impacts. Whilst opportunities may occur for the wider food supply chain (including other products), for products derived from primary production in Wales the opportunities largely rest at the production end of the supply chain.

6.4 Forestry

The area of woodland in Wales covers 306,000 ha or 15% of the land, with approximately 150,000 ha of conifers and 156,000 ha of broadleaves (Forestry Commission, 2014). The Welsh forest sector is made up of woodland-based businesses and traditional forest industries, which contributes more than £340 m per annum to the Welsh economy and employs over 16,000 people in hundreds of small to medium rural businesses.

Table 18: Climate change risk assessment for forestry in Wales

Risks
1. Pest and disease pressures
2. Water stress and drought crack
3. Soil degradation and erosion
4. Waterlogging and flood events
5. Wind throw (trees uprooted or broken)
Opportunities
1. Improved timber yields
2. Forest diversification

Soil degradation and erosion are likely to have a significant impact on the productivity of forests through a decline in aggregate stability, susceptibility to compaction, slower infiltration rates and increased run-off. Waterlogging and flood events, predominantly from wetter winters can impact on root depth of trees, leaving species which are unsuited to fluctuating water tables (such as Douglas fir and Beech) vulnerable. Ensuring adequate drainage is the key adaptation method, however this may only be possible on new plantations. Wind throw severely damages trees and decreases the forests' resilience to further weather damage. Production (single species) forestry is much less resilient to wind damage than that of natural, diverse forest and losses are likely to be much greater when woodland has been thinned. As such, adaptation largely rests in species variety to ensure forests are less susceptible. The main opportunities for the sector include improved timber yields, forecast at 2-4 m^3 per ha per year, and forest diversification from an increase in summer tourism due to warmer weather, however there is great uncertainty in the likelihood.

6.5 Summary of priority actions

Across all sectors, the climate change related risks to the Welsh land use sector that scored the highest were those related to flooding. This includes the risks to domestic and business property, impacts on livestock from grazing and availability of feed, and potential yield impacts in arable/horticulture and forestry. The agriculture and land use sectors have an important role to play in adapting to flooding impacts. In particular planting of trees in specific areas may reduce risk of flooding to land and communities/businesses, whilst also minimising effects of disease in livestock such as liver fluke by restricting access to wetter areas. The increase in pest and disease pressure in both forestry and livestock sectors is a significant risk, largely due to milder and wetter winters. For forestry, ensuring species diversity is key to minimising impacts, which can also have multiple benefits by adapting to water stress and wind throw. For livestock, adaptation depends on the particular disease or pest pressure; however good planning and awareness of best practice may be the best adaptation action.

Whilst less of an impact for Wales when considering the UK as a whole, water stress in times of drought can affect most agriculture and land use sectors. The largest affect is on forestry, rural communities/businesses and livestock. Much of Wales receives comparatively more rainfall than the majority of the UK, and as such the impact of water stress will be less severe. Relatively cost effective actions to harness rainwater can be taken to ease impacts. This is most straightforward on livestock farms in the form of troughs, or ponds. For domestic customers grey water can be harnessed, using rainwater harvesting systems. On a larger scale reservoirs can be built to meet demand, however the cost of doing so needs to be judged against benefit. Wildfires, both affecting grassland and forestry areas, and in some cases rural communities are increasing in Wales as drier conditions in the summer become more favourable for their development. Given the high cost implications, adaptation measures can be cost effective and include raised awareness amongst the general public and partnership working to reduce arson related crime, as well as fire breaks.

7. Opportunities for multiple benefits from climate change actions

The policy landscape for farming, land use and the food chain in Wales is complex and reflects country, UK and EU priorities for economic growth, food and energy security, environmental sustainability and support for rural communities. The concept that sectors and policies can deliver across a number of policy areas has been described variously as multifunctional agriculture or land use. This approach is well represented in the 2007-2013 EU policy framework for rural development which has three policy-focused axes[19] as follows:

1. Improving the competitiveness of the agricultural and forestry sectors
2. Improving the environment and countryside
3. Improving the quality of life in rural areas and encouraging diversification of the rural economy

The same policy objectives lie at the heart of the 2014-2020 EU Rural Development Programme but the architecture has been changed to six priority areas, namely:

i. Fostering knowledge transfer and innovation in agriculture, forestry, and rural areas
ii. Enhancing competitiveness of all types of agriculture and enhancing farm viability
iii. Promoting food chain organisation and risk management in agriculture
iv. Restoring, preserving and enhancing ecosystems dependent on agriculture and forestry
v. Promoting resource efficiency and supporting the shift towards a low carbon and climate resilient economy in agriculture, food and forestry sectors
vi. Promoting social inclusion, poverty reduction and economic development in rural areas.

It is notable that climate change is a cross-cutting priority for the forthcoming RDP. However, responding to environmental pressures has to coexist with socio-economic priorities as evident in the Kevin Robert's independent "Review into the Resilience of Welsh Farming" published in January 2014, which asserted that:

"The next Rural Development Programme for Wales needs to have an economic focus at its heart and its aims and objectives need to work towards an enduring change to the viability of agriculture and the sustained development of the Welsh food industry. "

It is against this backdrop along with growth targets in the new Food Strategy for Wales[20] and the WG policy for energy (Energy Wales: A low carbon transition)[21], that the review of the evidence for climate change action in the agriculture and land use sector is undertaken. We have aimed to identify the necessary trade-offs between different priorities as well as the possible synergies, and be clear and objective about the evidence.

A long-established basis for choosing between options by reference to an explicit set of objectives is multi-criteria analysis (MCA). A key feature of MCA is its emphasis on the judgement of the decision making team, in establishing objectives and criteria, estimating relative importance weights and, to some extent, in judging the contribution of each option to each performance criterion. While this degree of subjectivity can be seen as a risk, in practice it is key that while 'objective' evidence is used, it is important that the decision making team 'own' the outcomes. MCA, however, can bring a degree of structure, analysis and openness to decision-making (CLG, 2009), something which is urgently needed in addressing the climate change agenda.

[19] A fourth cross-cutting axis - The Leader approach – is based on the mechanism for delivery.
[20] Food for Wales, Food from Wales 2010:2020: Food Strategy for Wales. http://wales.gov.uk/docs/drah/publications/101207foodforwalesfoodfromwalesen.pdf
[21] http://wales.gov.uk/docs/desh/publications/120314energywalesen.pdf

7.1 Climate change mitigation measures – wider impacts

A number of studies, notably Moran et al (2012) have considered the extent to which action targeted at mitigating climate change can impact on other ecosystem services. An assessment of the broad mitigation themes considered in this study is shown below.

Table 19: Mapping of broad climate change actions against ecosystem services

	Food / fibre	Timber	Biofuels / Fuelwood	Erosion control	Species diversity	Climate regulation	Flood regulation	Air & water quality	Soil quality	Disease and pest control	Recreation & Tourism	Employment
Productive Agriculture												
Livestock productivity	Increase provision				Potential to reduce provision but not in all cases	Increase provision		Potential to reduce provision but not in all cases		Increase OR reduce provision		Increase provision
Nitrogen use efficiency						Increase provision		Increase provision	Increase provision			
New crops and tillage	Increase OR reduce provision			Increase provision	Increase OR reduce provision	Increase provision	Increase provision	Increase provision	Increase OR reduce provision	Increase OR reduce provision		
Land Use and Management												
Woodland creation	Reduce provision	Increase provision	Increase provision	Increase provision	Increase provision	Increase provision	Increase provision	Increase provision		Increase OR reduce provision	Increase provision	Increase provision
Hedges/ riparian buffers	Increase OR reduce provision	Increase provision		Increase provision	Increase provision	Increase provision	Increase provision	Increase provision			Increase provision	
Peatland restoration	Potential to reduce provision but not in all cases			Increase provision	Increase provision	Increase provision	Increase provision	Increase provision	Increase provision		Increase provision	
Renewable energy												
Biomass	Reduce provision	Increase provision	Increase provision		Increase OR reduce provision	Increase provision		Increase OR reduce provision				Increase provision
Biogas	Potential to reduce provision but not in all cases		Increase provision		Increase OR reduce provision	Increase provision		Increase provision	Increase provision			Increase provision
Wind			Increase provision			Increase provision					Potential to reduce provision but not in all cases	Increase provision
Solar/PV			Increase provision			Increase provision						Increase provision
Hydro			Increase provision		Increase OR reduce provision	Increase provision						Increase provision

Note: provisioning services are shown in green; regulation services in blue and cultural services in brown.

Key:

- Increase provision (green)
- Increase OR reduce provision (salmon)
- Reduce provision (red)
- Potential to reduce provision but not in all cases (amber)

The analysis suggests that there are many opportunities for achieving multiple outcomes from mitigation actions, notably provisioning services from creating woodland and restoring peatland. However these can compete for land with food production on productive land[22]. This is also the case for biomass energy and potentially with biogas, where crops are used as feedstock. Other conflicts include a potentially negative effect of the intensification of livestock on biodiversity and air and water quality; animal health and welfare may increase or

[22] This is not necessarily the case for drained blanket bog or for some abandoned poor condition fens and is not the case for eroded areas. In these areas, drain-blocking restoration should not reduce sheep grazing conditions beyond their current relatively poor state (Wilson *et al*, 2010; LIFE, 2011).

decrease depending on the degree of investment/management. The potentially negative impact of wind farm development on tourism is also noted.

7.2 Mitigation and adaptation - synergies and conflicts

Productive agriculture

There are potentially many synergies between adaptation and mitigation in agriculture, as well as some potential conflicts. It will be important to acknowledge any increased risks associated with productivity measures and adopt appropriate risk mitigation.

Table 20: Synergies and conflicts – productive agriculture

Opportunities for synergy	**Risks of conflict and/or trade-offs**
• Improving livestock health will have benefits for both mitigation and adaptation, as healthy animals will be more productive and more resilient to climate change. • Reductions in fertiliser use from improved nitrogen use efficiency may have beneficial effects on biodiversity, potentially increasing resilience to climate change. • Reduced tillage techniques can improve the stability of soils and improve resilience to flooding, drought and soil erosion.	• Measures to reduce emissions from livestock through intensification of farming systems may involve the use of larger animals and/or higher stocking densities but these systems may be vulnerable to the impacts of climate change and extreme weather. However, increased housing of livestock may offset some of these risks. • Increased risk of livestock and crop diseases would offset productivity and would need to be managed. • A warmer climate may lead to changes in land use and farming practices that increase emissions e.g. conversion of grassland to cropping would increase cultivations and potential for higher yields could increase fertiliser use with an increase in emissions.

Land use and management

Restoring land use to natural systems such as woodland or bog would generally increase resilience against a changing climate. However, there are associated risks.

Table 21: Synergies and conflicts – land use and management

Opportunities for synergy	**Risks of conflict and/or trade-offs**
• Woodland planting alongside waterways and floodplains can help reduce erosion and improve flood control as well as providing shade and shelter for livestock. • Woodland planting on agricultural land diversifies forest structure and ownership, creating greater resilience. • Afforestation allows an adjustment of the species mix as climate changes become apparent, and increases diversity. • Woodland can act as a corridor to link habitats, allowing species space to move to more suitable climates over time. • Rewetted peatland would reduce water run-off during heavy rainfall, reducing flood risk downstream.	• The main trade-off is the loss of agricultural land to woodland or peat restoration which may impact on the output and resilience of some upland farming systems. • There may be some loss of habitats due to afforestation, which will reduce the overall resilience of species dependent on them. • Greater pest and disease prevalence in a warmer, wetter climate might threaten large tracts of woodland and associated ecosystem services.

Renewable energy

While renewable energy offers clear mitigation gains and can improve resilience to climate change, there may also be conflicts with land-use priorities for adaptation.

Table 22: Synergies and conflicts – renewable energy

Opportunities for synergy	Risks of conflict and/or trade-offs
• The increased involvement of farmers in the supply of renewables may provide economic opportunities, increasing their resilience. • Biomass crops in flood-prone areas can enhance flood control, providing they are managed appropriately. • Dams constructed for water supply resilience purposes can be harnessed to provide hydroelectric power (and vice versa). Dams might also be designed to capture excess water in periods of more intense rainfall. • Energy from on-farm renewables can help pump water or provide heating/cooling for livestock.	• The often remote location of many renewable energy sources may make them vulnerable to extreme weather, potentially affecting supply. • There may be an adverse impact of renewables (particularly hydropower) on some species e.g. salmon which may affect their ability to adapt to changes. • Increased demand for renewable heat may lead to planting of fast-growing species which are not well suited to native ecosystems and reduce their resilience.

7.3 A coherent strategy for climate change

It is clear from the above analysis that while there are opportunities for synergy between climate mitigation and adaptation actions, it is not always possible to secure progress across all policy priority areas and that trade-offs are required. In order to provide a basis for making these decisions, which will by definition not meet the needs of all stakeholders, it is helpful to have a framework which is grounded in an objective set of principles. These might for example be based on the three foundations of sustainable development, namely economy, environment and society and hierarchy of priorities within each.

There are multiple ways to achieve net GHG emissions reduction e.g. reduced direct emissions, increased carbon sinks, fossil fuel displacement or displaced GHG emissions (from higher emission sources overseas). This provides a degree of flexibility which should mean that a combination of some or all of the above approaches can help deliver the aggregate GHG emissions reduction that policy seeks.

	Reduced direct GHGe	Increased carbon sinks	Fossil fuel displacement	Displaced GHGe
More productive livestock	(+)	+/-	(-)	++
Increased nitrogen use efficiency	++	Nil	(+)	Nil
Increased woodland planting	+	++	(+)	(-)
Restoration of peatland	+	++	Nil	(-)
Renewable energy generation	(+)	Nil	++	(-)

(“+” = positive; “-“ = negative; “++” = strongly positive; “-” = no impact & brackets denotes uncertain impact)

Given this context, a basket of key measures can be selected which allow specific criteria to be prioritised in a particular context e.g. intensive livestock production can be avoided where there are significant risks from pollutants or animal welfare concerns; renewables can be avoided in sensitive landscapes or built-up areas; woodland can be planted where this is not in conflict with other ecosystem services such as food production or biodiversity. That is not to say that trade-offs can be avoided but that there should be an objective basis for judging measures against economic, environmental and societal criteria (scoring) and a further stage of weighting the criteria according to any given context.

Indeed, the limited progress made on implementing the 2010 LUCC recommendations reflects the extent to which there is lack of consensus or joining up of priorities and programmes. Key examples are:

- suitably located woodland planting can deliver against multiple criteria but there is a lack of consensus about where to plant and mixed incentives to do so;
- peatland restoration is widely acknowledged as an important mitigation measure but there are mixed signals to land managers to take up the option;
- the planning system appears to stymie the development of renewables despite policy and industry enthusiasm.

An ecosystem service modelling framework and GIS decision support tool, the LUCI model[23], is being used as part of the GMEP project for mapping and quantifying effects from a range of Glastir intervention scenarios, and also identifying strategic locations where interventions might better be targeted. This provides a basis for presenting evidence on which policymakers can set priorities. Additional datasets which reflect social and economic priorities could be used alongside the environmental maps to help policymakers and planners to make judgements on where best to place the necessary developments that are a key component of the climate change response.

[23] http://unstats.un.org/unsd/envaccounting/seeaRev/meeting2013/EG13-BG-9.pdf

8. Summary and priorities for action

This section brings together the analysis from the earlier chapters to set out a number of explicit priorities for addressing climate change – both mitigation and adaptation – in Wales. The primary focus is on actions in the period of the next Rural Development Programme (2014-2020) but necessarily takes a much longer perspective in terms of anticipating the risks from a changing climate and the need to meet increasingly challenging GHG emission reduction targets over the coming decades. For the latter we draw attention to the evidence gaps that need to be addressed in the short term to support ongoing policy decisions and develop new technologies, and strategies that are relevant to agriculture and land use in Wales.

The extent and pace of uptake of actions and the profile of abatement over time associated with these is highly uncertain but the emphasis in this report is on what the priority actions should be. Estimates are provided for the scale of abatement and the timescales for accounting in the GHG Inventories but these should be revisited and updated on a regular basis.

8.1 Policy actions on climate change

On the basis of this evidence review, a number of policy recommendations are made which are necessary to support and facilitate the implementation of the action-based recommendations which will actually deliver emissions reductions and help improve the climate change resilience of the agriculture and land use sector. These target the issues which seem to limit progress on this policy agenda.

Policy priority PP1: Develop a decision-making hierarchy which allows policy owners within Welsh Government to consider the possible synergies and conflicts of their programmes with the climate change priorities for Wales. This should be undertaken with active participation of policy leads but owned by the policy lead for climate change. The Land Use Climate Change Sub-group should inform the judgements.

Recommendation 1: Welsh Government to map the policy priorities that relate to agriculture and land use and establish a hierarchy, namely where there is conflict between two options, ensure there is an agreed basis for deciding which takes precedent. This process should engage with government agencies and other bodies such as Local Authorities which have an executive role in implementing climate change policies.

Recommendation 2: Welsh Government and Local Authorities to ensure that the infrastructure to implement climate change policies is in place, including capital and human resources, and is proportionate to task and the timescale.

Policy priority PP2: Ensure that there is an ongoing programme of Wales-based research, development and knowledge transfer on climate change in order to inform policy as priorities, contexts and technologies change. The aim is to help make informed decisions on mitigation and adaptation in the short, medium and long term.

Recommendation 3: Welsh Government and Wales-based research institutes to agree priorities for research on climate change and to draw on available funding and work with external partners to deliver robust evidence for the sector.

Recommendation 4: Welsh Government to ensure there is a framework for policy and programme evaluation which takes account of the climate change impacts of all policies and which secures robust evidence on the uptake and impact of Government's climate change research and programmes. This should avoid looking at programmes in isolation and where possible evaluate programmes which are linked in a holistic way.

Policy priority PP3: Agree a framework for land use priorities in Wales, to include key ecosystem service provision. This will identify areas of conflict and overlap (possible synergy) and help target programmes to where they can deliver the best aggregate outcome. Targeting should be informed by on-the-ground knowledge where possible.

Recommendation 5: NRW to establish a spatial mapping exercise to prioritise land use across Wales, building on existing maps of protected habitats, areas suitable for wind farm development, soil quality, pollution risk etc. The aim is to provide a framework within which NRW, local planning authorities and others can make decisions on land use e.g. where best to plant trees or allow renewables development etc.

8.2 Climate change mitigation actions

The priorities for action on climate change mitigation are considered across the three themes that have been used throughout this report. As these do not exist in isolation, there are cross-references as appropriate.

Productive agriculture

Livestock represents the mainstay of Welsh agriculture for good reason – topography and climate are suited to grassland and this is best used by ruminants to produce food. Given the high emissions associated with meat and milk production, the most direct approach would be to reduce animal numbers and this might indeed create space for other land uses e.g. woodland which would be consistent with reducing GHG emissions. However, in the absence of productivity gains, this would incur leakage[24] of emissions. Any reduction in food production in Wales may also be at odds with wider policies on growing the economic value of the Welsh food sector and maintaining rural communities. In any case, markets will dictate how many livestock are kept (within the constraints of regulation) and the focus should be on how best to reduce emissions of these cattle and sheep.

In terms of priorities for the livestock sector, there are three components to drive reduced GHG emissions intensity[25], namely:

i. Optimal animal genetics – a productive animal, suitable for the farming geography and system e.g. high output relative to the emissions associated with maintaining a breeding animal (covers both extensive and intensive systems).

ii. Optimal animal management – a healthy animal which has low mortality and morbidity and appropriate nutrition e.g. avoidance of excess protein in the diet. New technologies might include high sugar grasses and feed additives to reduce methane production.

iii. Alignment with market requirements – avoidance of waste through unnecessary inputs or unwanted product by ensuring animals are not kept for longer than necessary and meet the buyers' specification. For example, avoidance of low solids milk for cheese manufacture or over-fat cattle or lamb carcasses.

It is difficult to estimate with any accuracy how much abatement is available through these approaches as efficiencies in production are often realised as additional output, rather than reduced input or livestock numbers. As such, the gain is largely in emissions intensity rather

[24] Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country.

[25] A wider set of detailed measures which can be used to reduce GHGE in agriculture systems is available from an EU project (OSCAR http://www.oscar-project.eu/) and from other decision-support tools such as FARMSCOPER https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69615/greenhouse-gas-agriculture-analysis-20121122.pdf.

than absolute emissions. The high variation in emissions between livestock farms (see Table 1) highlights the scale of the opportunity to improve productivity and this should be a priority action. There are strong commercial pressures which drive efficiency in the dairy sector but less so in the long supply chains for beef and lamb. The emphasis should therefore be on supporting farmers to achieve the twin aim of reduced emissions intensity through productivity improvements and increased business resilience.

Priority PA1: Reduce the average emissions intensity and absolute emissions associated with livestock farms by improving the average productivity of production systems in Wales through attention to using the right animal, adopting best practice in herd health and nutrition and ensuring a high proportion of output meets market requirements. Sufficient attention should be paid to meeting regulatory safeguards for the environment and animal welfare and opportunities to deliver other services such as environmental goods or renewable energy.

Recommendation 6: Establish an initiative to promote livestock productivity actions through RDP 2014-2020 funding for knowledge exchange and incentives for investment in skills and technology. Agree targets and establish a basis for monitoring progress. This should link to the Defra Sustainable Intensification Platform (SIP) research and the UK Agri-Tech Strategy.

Recommendation 7: Ensure that research institutes and advisory programmes serving Wales have the capacity and tools to support productivity growth and develop/trial new technologies relevant to the country to help farmers realise step change.

Priority PA2: Improve nitrogen use efficiency of fertilisers and organic resources through the adoption of nutrient planning and new technologies. This should be supported by research to improve understanding of the factors controlling fluxes of nitrogen compounds from soils and to monitor fluxes under a range of management conditions in Wales.

Recommendation 8: Research and support best practice management of fertilisers, manures and biosolids to improve nitrogen use efficiency and consequently reduce N_2O emissions. Key components are nutrient planning (including basic soil management), calibration of equipment and effective use of new technologies for application.

Recommendation 9: Research and support the adoption of new technologies such as nitrification inhibitors for fertilisers and manures, controlled release fertilisers and precision application of fertiliser for high-value crops. Continue to develop the evidence base on practices such as clover in pastures and crop varieties with improved nitrogen use efficiency.

Land use and management

The main opportunities in this theme relate to protecting and building carbon stores via sequestration of carbon through woodland creation, expansion of carbon in hedges and woody linear features and avoiding GHG emissions from degraded peatland. Unlike productive agriculture, the main driver for implementation is public funding to incentivise changes to land use and management e.g. through Glastir. While there is a traded market for carbon this cannot be readily applied to farm-level actions so climate change mitigation is treated as a non-market public good in the same way as biodiversity or air quality.

Some developments are ongoing in developing a market for carbon sequestered through the principle of Payment for Ecosystem Services (PES), notably the Woodland Carbon Code[26]

[26] Forestry Commission (2014) UK Woodland Carbon Code. Accessed at http://www.forestry.gov.uk/carboncode

and the Peatland Carbon Code[27]. While it is important to develop these approaches to bring additional funding to woodland creation and peatland management, in the short term action relies heavily on public funding through Glastir.

A common issue for both planting woodland and restoring peatland is competing pressures for land use and it will be necessary to progress on the basis of good science and stakeholder consensus.

Priority LU1: Agree a strategy and plan for increasing the area of woodland in Wales by at least 50,000 ha over the next 25 years. This will require clear guidance for government agencies, landowners and other local stakeholders on the basis for prioritising land use and will also need to secure adequate public and/or private funding to increase uptake of a woodland creation option and support natural regeneration of woodland where appropriate (see Recommendation 6).

Recommendation 10: Increase the area of new woodland in Wales by at least 50,000 ha by 2040 through methodical identification of the best land to plant and by offering appropriate incentives to landowners in these areas through the Glastir scheme. This should allow sufficient flexibility to plant outside these priority areas where there is good evidence of net positive impact e.g. flood mitigation or recreation and also provide support for natural regeneration of woodland and expansion of hedges and other linear woody features.

Recommendation 11: Agree a basis for quantifying the carbon mitigation available from establishment or management of hedgerows and linear woody features and reporting this in carbon stocks along with small woods (0.1-0.5 ha). Aim to capture this in the Inventory and monitor the contribution to emissions reduction and other ecosystem services.

Priority LU2: Agree a strategy and plan for restoration of all degraded peatland in Wales over the next 25 years. This will require clear guidance for government agencies, landowners and other local stakeholders on the basis for deciding on the priority land use for peatland and will also need to secure adequate public and/or private funding to support a restoration agreement (see Recommendation 6).

Recommendation 12: Implement a programme of restoration and rewetting of drained peatland across Wales in order to protect the carbon stock, avoid emissions and provide wider benefits for biodiversity and flood management (where applicable). This should include a programme of research and monitoring to estimate emissions factors for drainage and rewetting of peatlands in Wales.

Recommendation 13: Monitor the fluxes of all GHGs and dissolved carbon losses simultaneously in the same locations so that the net global warming potential of a range of land uses and management can be determined.

Renewable energy

In terms of renewables, there are two key issues. Firstly, what is the optimal balance of technologies that can be best used to deliver the Government's commitments in this area and where can these be best placed to limit impacts and access the grid (as necessary). Secondly, how can investment in renewables be increased through enhanced targeting and a more timely process for gaining planning consent. Other barriers, including connection to the grid, support for community renewables etc. should also be addressed.

[27] IUCN (2014) Pilot UK Peatland Code. Accessed at http://www.iucn-uk-peatlandprogramme.org/peatland-gateway/uk/peatland-code

Priority RE1: Reconcile the Government's commitments to developing renewable energy and the uncertainty over the balance of technologies required and where these can be developed.

Recommendation 14: Expand the renewables sector through utilising the high cost effectiveness of wind and solar where possible and through hydro, biomass and anaerobic digestion where these bring socio-economic benefits and do not impinge unduly on the environment. Policy priorities for a balance of technologies should be broadly agreed and communicated to Local Authorities and other stakeholders.

Recommendation 15: Ensure the planning system is working effectively and efficiently in implementing the development of renewables in keeping with policy priorities while safeguarding the environment and wider public interest locally. This will require a degree of consensus on the strategic priorities for land use to ensure planning consent is not a barrier to expansion of this important mitigating technology.

Priority RE2: Put in place an infrastructure for supporting the development of renewables which is fit for purpose and allows expansion of the sector. This will include investment in the grid as necessary and advice to farmers and landowners on which technologies are appropriate for their situation and are cost effective, including community renewables.

Recommendation 16: Government and industry to work together to scope and agree the priorities for investment in hard and soft infrastructure to facilitate rapid development of renewables in Wales to 2020 in line with policy commitments.

Recommendation 17: Government and industry to work together to facilitate climate change actions based on synergies between the agriculture and land use sector and the renewables sector. This might include links between biomass processing and miscanthus/willow or forestry, on-farm anaerobic digestion and food waste or utilising heat from renewables.

Recommendation 18: Research the efficacy and impacts of the main renewable technologies, including anaerobic digestion and biomass, across a variety of contexts in Wales to improve knowledge on mitigation potential but also on co-benefits (socio-economic and environmental) and unintended consequences.

8.3 Climate change adaptation actions

The agriculture and land use sector is becoming used to the effects of climate change in terms of changing weather patterns and extreme weather events but the case for action on climate change adaptation is not widely acknowledged. Individual businesses – farm and rural – will put in place some adaptation measures where they have been individually impacted e.g. through flood or pest/disease incidence but a wider initiative is needed so that rural businesses and rural population commit to implementing adaptation measures.

The analysis at Chapter 6 and supporting annexes 12 and 13 focus on establishing the key risks and mapping their degree of likelihood of occurrence and severity of impact. It was beyond the scope of this work to develop detailed adaptation measures but it is evident that many of these will involve changes to land management e.g. to slow down water run-off or store water for flood mitigation, or to reduce the risk of new pests and diseases by planting mixed species etc. There are multiple opportunities for synergy with climate mitigation which should be mapped, researched and promoted to the industry.

Priority AD1: Use the assessment of risks for the agri-food, land and rural sectors in this work to set out a sector adaptation plan. Develop a suite of adaptation responses for each risk and consider how these can be integrated with other policy priorities to ensure coherence and secure synergies where possible.

Recommendation 19: Prepare a sector adaptation plan (SAP) for the agriculture and land use sector and develop a suite of adaptation responses which can be promoted to industry and rural communities. Map the adaptation actions against other policy areas to understand the scope for synergies and conflicts and address these as necessary.

Recommendation 20: Private businesses and public institutions in Wales to establish a climate change risk register and put in place adaptation actions as necessary.

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Annex 2: LUCCG 2010 recommendations and review criteria

2010 recommendations

1. Economic Assessment: to supplement this report by undertaking urgently an examination of the costs and benefits of adopting (or not adopting) these proposals, detailing their contributions to the rural economy and to renewable electricity and heat energy targets as well as to social viability and all ecosystem services.

2. Public awareness and involvement: to institute a major dialogue throughout rural Wales to improve understanding of climate change issues and to show how every individual, community and business can assist in responding to the global challenge, especially by lifestyle changes to increase resource-use efficiency and avoid waste. One avenue is through the Farming Connect Climate Change Development Centre.

3. Forestry: to develop urgently detailed plans with a view to expanding current woodland / forest cover by about 100,000 ha over the next 20 years by planting a range of native deciduous trees, that are well adapted to the mean climate change scenario, and conifers, together with some natural regeneration. These should be grown on both acid upland soils and bracken land, but avoiding peats.

4. Forestry: to ensure that the current public - Forestry Commission (FC) - and private forest holdings are managed to optimise their greenhouse gas (GHG) sink potentials as well as providing a sustainable source of fuelwood and other timber products that form long term “carbon sinks” and/or substituting for fossil fuels.

5. Soils / peat: to ensure that no steps are taken which might undermine the carbon stores in upland peats and lowland fens and mires.

6. Agri-environment: to ensure that Glastir prescriptions are consistent with the needs to reduce GHG emissions.

7. Animal husbandry: to provide support for all manure/slurry from the dairy herd and attendant beef/veal systems to be processed through anaerobic digestion (AD) and to exploit the biogas potential.

8. Animal husbandry: to explore with the dairy and beef industry the adoption of zero-grazed systems to minimise methane (CH_4) and nitrous oxide (N_2O) emissions and to exploit the compressed biogas potential. The impacts of zero-grazing on biodiversity and other ecosystem services need to be assessed.

9. Animal husbandry / food waste: to promote the maximum synergy between AD of slurry/manure and other wastes (that can’t be utilised more efficiently) from the food chain – process, distribution and consumer wastes - through co-operation with food processors, major retailers and local authorities.

10. Animal husbandry: to encourage increased efficiency within dairy, beef and sheep sectors to decrease GHG emission per unit of productive output and to ensure cuts in emissions.

11. Agronomy: to encourage maximising nitrogen (N) use efficiency through best practice management of fertilisers, manures and biosolids.

12. Agronomy: to encourage an increase in the horticultural / glasshouse sector taking advantage of renewable heat sources.

13. Food chain efficiency: to harness the resources of the Food and Drink Advisory Partnership and the Land Use Climate Change Group (LUCCG) to identify and implement resource efficiency improvements between farmer and consumer, through reduction of waste and energy use in the processing and distribution chain and via better consumer education.

14. Renewable energy: to promote all elements of the renewable energy potential of (rural) Wales in appropriate locations and to ensure the obstructions to uptake and grid connectivity are minimised with all speed.

15. Renewable energy: to promote a range of woodland (biomass) planting to create a source of renewable heat energy as a significant contribution to renewable energy from the rural sector.

16. Renewable energy: to work with industry to ensure as rapid as possible take-up of compressed biogas (CBG) and electric plug-in/hybrid vehicles and machinery in rural Wales and the food chain.

17. Research capacity: to work with relevant organisations and research providers to ensure that the research agenda is implemented, and allows it to fulfil its obligations and aspirations in relation to climate change and land use.

18. Governmental capacity: to ensure it has the capacity, expertise, finance and influence to fulfil its obligations and aspirations in relation to climate change and sustainable development and that it “climate-proofs” its policies.

19. Governmental capacity: to ensure that planning regulations are designed to facilitate installation of rural renewable energy generation, subject to essential environmental protection and respect for listed buildings.

20. Governmental responsibility: to commission a report on climate adaptation mechanisms likely to be required in the land use sector by and beyond 2040.

21. Integration of estimates: CEH and NW Research to integrate their methods and estimates more closely, for example on N_2O emissions from soils.

22. Land use change statistics: Welsh Assembly Government and CEH to refine current estimates of land use change in Wales by integrating the outputs of the Countryside Survey (CS) model with actual land use change statistics in order to track land use changes over time – using agricultural statistics data, National Forest Inventory data and settlement data.

23. Land use change reversal: CEH to develop the land use change model so that it is able to take account of reverse transitions and is able to assess net impacts for emissions.

24. Crop rotation land use statistics: CEH to investigate classifying as a separate land use type instead of the inclusion of frequent transitions between land uses.

25. Management practices within land use categories: CEH to assess ways to include agri-environment practices aimed at increasing soil organic matter, or innovations in forest management, and the use of harvested wood products that substitute for fossil fuel use.

26. Soil carbon: CEH and its sub-contractor Forest Research to resolve the best ways for modelling forest soils from the models currently available.

27. Settlements: CEH to test its current assumptions for soil carbon changes for land converted to settlement, on the basis of improving its data on soil carbon changes.

28. Emission projections: CEH to ensure that it bases its emission projections out to 2050 on Welsh Assembly Government policy scenarios for land use change, and compares with historical trends.

29. Agricultural emissions: Welsh Assembly Government to collaborate with the Department for Environment, Food and Rural Affairs and other Devolved Administrations on the research project: "Agriculture GHGI Enhancement" to develop the methods for tracking emissions as new methods for managing farm systems are introduced to reduce emissions –in particular:

    - developing a more accurate range of emission factors for CH_4 and N_2O;
    - developing CH_4 emission factors for a range of ruminant farming systems, breeds, diets and additives (e.g. effects of upland diets for ruminants);
    - developing N_2O emission factors for range of climatic and soil conditions, soil type, crop type, and farm/land management (e.g. upland vs lowland livestock systems).

30. Fertiliser use: Welsh Assembly Government to collect statistics for Wales to provide a more accurate estimate to replace extrapolated statistics from UK.

31. Validating experimental studies: to carry out large-scale trials on farms to test how well dietary manipulation reduces both direct and indirect GHG emissions from ruminants compared with laboratory conditions.

32. Rumen function: to research further the basic science on rumen function and modification, in particular to decrease loss of feed energy.

33. Animal genetics: to research further the varying traits for reducing GHG emissions between and within breeds.

34. Animal feeds: to improve the understanding of potential CH_4 production from different feeds and transfer of this knowledge to the farmer.

35. Upland farming systems: to assess the effects of hill and upland environments on CH_4 emissions where indigenous plants in the diet may alter rumen fermentation to reduce the amount of CH_4 that is produced.

36. N_2O emissions in soils: to research the key factors that influence the fluxes of N compounds in soils and to monitor emission fluxes under a variety of management conditions including organic and conventional farming systems and identify new mitigation options.

37. CH_4 capture and housed systems: to research the technical feasibility of a housed dairy/beef herd with a CH_4 capture system – taking account of animal health and welfare,

controlled environment requirements, lifecycle GHG savings, resource efficiency and practical gas capture techniques.

38. AD digestate: to assess the fertiliser value and the N_2O emissions from its application to land.

39. Livestock and ecosystem services: to develop a clearer analysis of the value (positive or negative) of ruminant livestock for delivery of ecosystem services – food, fibre, soil carbon, water, biodiversity, and landscape.

40. Life Cycle Analysis (LCA): to develop the approach of analysing the effect of interventions on LCA by extending to other foods including processed foods, so as to build up a picture of the GHG emissions on a whole diet basis, and to identify the interventions that will lead to emission reduction.

41. LCA: to develop a more sophisticated analysis of the nutritional value of different foodstuffs relative to their GHG emissions, instead of assessing by unit weight of product.

42. Organic Farming Systems: to undertake comprehensive GHG flux analysis of organic and conventional production systems to determine overall LCAs for Welsh farm products.

43. Soil carbon stocks: improve estimates of the impact of moving from one land use to another (e.g. grassland to forestry) on soil carbon storage, particularly in relation to soil type, by a targeted field survey approach.

44. Grassland management: to quantify the effects of grazing intensity and type, and re-seeding of lowland pastures (an important mechanism to improve productivity), and the impacts of tillage methods on GHG emissions.

45. Grassland management: to breed new grass varieties that enhance carbon storage below ground.

46. Tillage methods: to assess whether the increase in soil organic matter from reduced tillage is offset by the increase in N_2O emissions, and the effect of drainage in reducing N_2O emissions by maintaining aerobic conditions in the soil.

47. Peat re-wetting: to monitor the fluxes of all GHGs and dissolved-carbon losses simultaneously in the same locations so that the net global warming potential can be determined (i.e. all the inputs and outputs required to complete a full GHG budget).

48. Afforestation: to assess the effects on soil carbon stocks in organic soils throughout the life cycle, with a particular need to assess newer forest management methods such as continuous cover management and harvesting.

49. Soil carbon modelling: to develop the soil carbon model, ECOSSE, for representative catchments using finer vegetation categories and underpinning soil data, coupled with better estimates for vegetation net primary production to allow independent testing of changes in soil carbon sequestration rates. Future expansion of ECOSSE-2 should link the model with an LCA model that allows the whole “cradle to grave” GHG emission values to be calculated (e.g. from transport, waste etc.).

Review criteria

Sharpening:

- Is the recommendation still relevant?
- Can it be clearly understood and put into action?
- Is there a clear owner for each recommendation?
- How should recommendations be amended so that they are SMART?
- Can recommendations be combined and/or simplified so that there is a simpler, sharper, focussed plan for action?

Progress:

- What progress has been made to date?
- What have been the main drivers for change?
- What measures should be put in place (either new measures or strengthening/adapting existing measures) to address areas of under-achievement?
- What will such measures achieve and how can progress and success be monitored and evaluated?
- What is the gap between current rates of achievement and what is potentially achievable?
- If the recommendation were fully implemented what would be the potential emissions' cuts, and what costs and timescales are involved?

Note: not all of the above points will be relevant to every recommendation.

Annex 3: Statistics for Wales

Agricultural Land Use in Wales 2004 to 2013 (ha)

	item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
ARABLE CROPS & BARE FALLOW	Wheat	15,423	14,812	15,524	12,989	19,600	19,646	24,347	25,843	25,614	15,133
	Winter barley	8,643	7,570	6,985	6,750	6,748	6,352	7,279	8,097	7,731	4,966
	Spring barley	15,623	14,196	12,144	12,765	14,801	17,923	13,158	14,683	14,094	15,428
	Other cereals for combining	4,705	4,937	6,278	6,863	6,317	6,030	7,418	6,443	5,998	4,870
	Potatoes	2,139	2,190	2,026	2,208	2,192	2,554	2,056	2,539	2,935	2,586
	Maize	7,298	9,099	9,239	9,911	11,278	12,701	12,995	12,805	10,802	9,599
	Crops for stockfeeding	7,462	6,133	5,472	8,721	7,689	9,463	8,608	9,011	8,737	19,396
	Oil seed rape (winter & spring)	3,388	2,959	2,614	2,820	3,145	4,013	5,439	5,215	5,628	4,679
	Other crops	2,883	1,906	1,670	1,753	1,788	2,847	3,062	2,753	2,098	2,126
	Bare fallow	856	750	782	939	826	796	867	766	609	678
	Section sub-total	**68,420**	**64,552**	**62,734**	**65,719**	**74,384**	**82,325**	**85,229**	**88,155**	**84,246**	**79,461**
HORTICULTURE	Vegetables & Salad grown in the open	462	324	420	410	318	346	394	456	437	407
	Commercial orchards	252	526	260	296	298	295	314	358	365	350
	Other orchards & small fruit	311		257	253	277	308	320	342	408	365
	TOTAL HARDY CROPS	286	299	233	319	99	262	235	279	281	297
	Glasshouse	38	37	41	45	53	48	38	38	34	30
	Section sub-total	**1,349**	**1,186**	**1,211**	**1,323**	**1,045**	**1,259**	**1,301**	**1,473**	**1,525**	**1,449**
GRAZING	Grassland under 5 years old	107,628	115,056	99,661	95,034	86,934	88,052	103,247	116,681	138,001	143,720
	Grassland over 5 years old	1,009,657	982,386	1,037,585	1,001,081	1,016,601	1,026,867	1,020,506	1,044,697	1,049,087	997,620
	Sole-rights rough grazing	201,971	220,756	228,879	209,503	199,824	213,372	229,614	224,170	222,972	263,816
	Section sub-total	1,319,256	1,318,198	1,366,125	1,305,618	1,303,359	1,328,291	1,353,367	1,385,548	1,410,060	1,405,156
	UTILISED AGRICULTURAL AREA	1,389,025	1,383,936	1,430,070	1,372,660	1,378,788	1,411,875	1,439,897	1,475,176	1,495,831	1,486,066
OTHER LAND	Set-aside - total	4,471	4,657	4,527	3,945	756	n/a	n/a	n/a	n/a	n/a
	Woodland	41,723	44,934	51,271	67,859	59,198	60,831	69,128	44,190	62,616	63,366
	All other land	17,930	15,156	13,738	15,476	15,931	16,727	20,384	13,174	10,201	10,126
	Section sub-total	64,124	64,747	69,536	87,280	75,885	77,558	89,512	57,364	72,817	73,492
	TOTAL AREA ON FARMS	1,453,149	1,448,683	1,499,606	1,459,940	1,454,673	1,489,433	1,529,409	1,532,540	1,568,648	1,559,558
	Common rough grazing	180,305	180,305	180,305	180,305	180,305	180,305	180,305	180,305	180,305	180,305
	TOTAL AGRICULTURAL AREA	1,633,454	1,628,988	1,679,911	1,640,245	1,634,978	1,669,738	1,709,714	1,712,845	1,748,953	1,739,863

Livestock on Agricultural Holdings in Wales 2004 to 2013 (number)											
	description	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
CATTLE (FROM C.T.S. SINCE 2004)	Male under 1 year	169,860	156,741	150,655	139,984	143,041	141,259	143,165	138,581	141,778	133,095
	Beef female under 1 year	135,184	131,798	128,575	121,236	116,598	109,634	105,844	108,941	109,731	101,114
	Dairy female under 1 year	56,776	54,785	52,486	55,080	54,826	61,643	63,499	65,724	67,674	67,663
	Male aged 1-2 years	126,901	126,727	117,021	111,394	104,748	108,862	106,903	103,816	98,423	102,210
	Beef female aged 1-2 years	105,143	109,183	104,179	100,946	97,995	95,492	91,567	85,932	88,188	88,738
	Dairy female aged 1-2 years	59,121	55,627	53,568	51,228	53,393	53,443	60,121	61,809	63,963	65,640
	Male aged 2+ years	47,601	52,634	53,268	49,027	48,196	48,533	50,795	46,570	42,548	42,602
	Beef Female 2+ no offspring	51,858	53,419	54,234	51,272	52,845	54,126	56,196	50,009	42,799	45,871
	Dairy Female 2+ no offspring	58,616	60,851	60,900	55,053	53,443	52,972	52,879	54,921	51,129	50,403
	Beef Female 2+ w/offspring	210,699	210,821	204,788	195,126	189,519	182,564	185,818	186,824	183,351	174,100
	Dairy Female 2+ w/offspring	244,776	238,386	236,822	234,081	228,614	221,440	221,340	220,322	223,557	223,208
	Total cattle & calves	**1,266,535**	**1,250,972**	**1,216,496**	**1,164,427**	**1,143,218**	**1,129,968**	**1,138,127**	**1,123,449**	**1,113,141**	**1,094,644**
SHEEP & LAMBS	Ewes for further/future breeding	4,720,640	4,472,043	4,401,709	4,258,699	3,951,765	3,775,651	3,876,116	3,722,872	3,681,216	4,003,581
	Ewes for cull/slaughter	237,231	260,168	299,110	270,599	243,735	220,220	233,490	394,977	488,063	271,786
	Rams for service	100,771	103,107	112,985	100,747	92,266	89,429	90,146	96,630	101,017	139,988
	Other sheep (aged 1+)	153,438	117,779	144,081	130,432	96,532	114,699	106,302	64,822	75,222	157,447
	Lambs (aged under 1)	4,524,756	4,557,287	4,392,814	4,226,558	4,133,297	4,037,738	3,938,108	4,340,113	4,552,665	4,887,890
	TOTAL SHEEP AND LAMBS	**9,736,836**	**9,510,384**	**9,350,699**	**8,987,035**	**8,517,595**	**8,237,737**	**8,244,162**	**8,619,414**	**8,898,183**	**9,460,692**
PIGS	Breeding pigs	4,281	3,853	3,704	3,728	3,260	3,658	4,458	4,525	4,889	4,382
	Fattening pigs	26,376	24,510	21,462	20,084	17,548	18,645	22,516	21,284	23,776	20,508
	Total pigs	**30,657**	**28,363**	**25,166**	**23,812**	**20,808**	**22,303**	**26,974**	**25,809**	**28,665**	**24,890**
POULTRY	Chicken used for egg production	1,548,876	1,507,493	1,532,725	1,246,414	1,193,260	1,254,953	1,289,205	1,640,787	1,911,862	2,018,062
	Table chicken (broilers)	6,483,950	4,998,651	4,029,955	3,327,884	5,427,435	5,568,433	5,850,469	5,872,847	5,752,630	6,079,114
	Chicken used for breeding	318,577	273,644	273,756	2,671,622	438,843	298,751	224,077	357,083	408,699	358,296
	Turkeys	299,459	369,989	241,268	215,390	59,302	56,744	58,504	56,301	129,310	110,180
	All other birds	37,566	42,008	45,096	49,024	50,820	71,717	148,424	183,961	45,724	170,895
	Total poultry	**8,688,428**	**7,191,785**	**6,122,800**	**7,510,334**	**7,169,660**	**7,250,598**	**7,570,679**	**8,110,979**	**8,248,225**	**8,736,547**
OTHER	Total Horses	37,009	41,790	49,209	45,859	42,965	45,455	48,530	47,244	51,055	50,381
	Total goats	5,493	6,667	8,106	8,635	7,174	6,801	7,446	8,040	6,948	10,475
	Farmed deer	1,448	1,401	1,047	886	695	755	880	884	1,000	1,007

Source: Survey of agricultural and horticulture http://wales.gov.uk/statistics-and-research/survey-agricultural-horticulture/?lang=en

Components of livestock-based GHG emissions

	$ktCO_2e/yr$
4A1a_Enteric_Fermentation_Dairy	519.77
4A1b_Enteric_Fermentation_Non-Dairy	804.63
4A3_Enteric_Fermentation_Sheep	930.82
4B12_Liquid_Systems	6.65
4B13_Solid_Storage_and_Drylot	192.77
4B14_Other	32.59
4B1a_Manure_Management_Dairy	197.79
4B1b_Manure_Management_Non-Dairy	281.18
4B3_Manure_Management_Sheep	56.41
4B9_Manure_Management_Poultry	20.14

Source: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990-2012

Total annual agriculture GHG emissions Wales (GHGI-modified)

Year	Agriculture emissions $ktCO_2e$	Total emissions $ktCO_2e$	Agriculture as % of total
2005	6,487	48,735	13%
2006	6,400	50,208	13%
2007	5,831	47,204	12%
2008	5,518	49,128	11%
2009	5,467	42,811	13%
2010	5,642	46,370	12%
2011	5,644	43,844	13%

https://view.officeapps.live.com/op/view.aspx?src=http%3A%2F%2Fuk-air.defra.gov.uk%2Fassets%2Fdocuments%2Freports%2Fcat07%2F1312120858_Welsh_Government_CC_Strategy_traded_nontraded_GHGI.xls

DECC and Ricardo-AEA have compiled data on the number, installed capacity and generation comparable to that shown in the tables below (available at: https://restats.decc.gov.uk/cms/historic-regional-statistics/)

Table 1: Number of sites generating electricity from renewable sources, 2013[1]

	Hydro	Wind[2]	Wave and tidal	Landfill gas	Sewage gas	Other bioenergy[3]	Total excluding PV	Solar PV	Total
England	**228**	**3,032**	**1**	**358**	**160**	**252**	**4,031**	**390,650**	**394,681**
East Midlands	22	305	-	39	13	27	406	45,769	46,175
East	5	760	-	69	13	31	878	50,618	51,496
North East	9	205	-	20	8	11	253	21,194	21,447
North West	43	353	-	54	24	42	516	41,279	41,795
London	-	27	-	1	4	12	44	12,759	12,803
South East	15	101	-	69	34	29	248	64,695	64,943
South West	89	562	-	39	20	33	743	74,604	75,347
West Midlands	16	136	-	29	20	37	238	36,191	36,429
Yorkshire and the Humber	29	583	1	38	24	30	705	43,541	44,246
Wales	**129**	**388**	**-**	**24**	**16**	**11**	**568**	**33,065**	**33,633**
Scotland	**358**	**2,398**	**8**	**45**	**7**	**27**	**2,843**	**31,427**	**34,270**
Northern Ireland	**55**	**541**	**1**	**8**	**2**	**22**	**629**	**5,046**	**5,675**
Other Sites	-	291	-	-	-	4	295	48,128	48,423
UK Total	**770**	**6,650**	**10**	**435**	**185**	**312**	**8,366**	**508,316**	**516,682**

Table 2: Installed capacity of sites generating electricity from renewable sources, 2013[1]

	Hydro	Wind[2]	Wave and tidal	Landfill gas	Sewage gas	Other bioenergy	Solar PV	**MW** Total
England	**31.7**	**5,154.6**	**0.1**	**869.5**	**179.1**	**2,565.9**	**2,336.7**	**11,137.7**
East Midlands	4.6	678.0	-	65.4	17.3	57.1	266.3	**1,088.6**
East	0.1	1,361.9	-	201.6	26.3	125.6	338.9	**2,054.3**
North East	7.6	403.1	-	43.9	11.6	118.6	69.4	**654.1**
North West	6.3	981.8	-	149.6	25.5	99.9	152.6	**1,415.7**
London	-	4.4	-	0.3	23.4	169.5	49.1	**246.8**
South East	0.7	1,104.4	-	171.7	28.5	230.2	423.7	**1,959.2**
South West	9.5	194.4	-	96.1	14.0	33.3	698.2	**1,045.5**
West Midlands	0.8	3.5	-	60.3	23.1	1,011.4	165.8	**1,264.9**
Yorkshire and the Humber	2.3	423.2	0.1	80.5	9.5	720.3	172.7	**1,408.5**
Wales	**151.3**	**771.0**	**-**	**45.5**	**13.1**	**38.4**	**143.6**	**1,162.9**
Scotland	**1,501.0**	**4,701.2**	**5.9**	**114.3**	**5.6**	**143.1**	**119.1**	**6,590.1**
Northern Ireland	**8.5**	**579.3**	**1.2**	**12.4**	**0.2**	**14.5**	**28.2**	**644.3**
Other Sites	0.0	2.9	0.0	0.0	0.0	0.0	152.3	**155.2**
Total	**1,692.6**	**11,209.0**	**7.2**	**1,041.7**	**198.0**	**2,761.9**	**2,779.8**	**19,690.2**
UK Total	**1,692.6**	**11,209.0**	**7.2**	**1,041.7**	**198.0**	**2,761.9**	**2,779.8**	**19,690.2**
Co-firing[4]						35.2		**35.2**

Table 3: Generation of electricity from renewable sources, 2013[1]

	Hydro	Wind[2]	Wave and tidal	Landfill gas	Sewage gas	Other bioenergy[5]	Solar PV	GWh Total
England	**83.5**	**14,233.9**	**0.2**	**4,344.8**	**685.3**	**11,349.1**	**1,720.6**	**32,417.4**
East Midlands	12.4	1,551.4	-	319.5	70.8	289.0	191.9	**2,435.0**
East	0.2	4,126.6	-	1,031.9	56.1	3,878.1	225.8	**9,318.9**
North East	24.5	785.1	-	172.5	52.2	418.2	50.1	**1,502.5**
North West	15.1	3,201.7	-	658.3	115.5	317.5	118.1	**4,426.2**
London	-	11.5	-	2.3	60.2	706.3	39.7	**820.1**
South East	1.4	3,335.7	-	965.2	115.8	813.7	317.9	**5,549.7**
South West	20.9	405.0	-	465.8	64.3	151.9	521.2	**1,629.0**
West Midlands	2.5	7.2	-	331.3	118.4	1,125.6	124.5	**1,709.6**
Yorkshire and the Humber	6.4	809.7	0.2	397.9	31.9	3,648.8	131.4	**5,026.4**
Wales	**227.5**	**1,702.0**	**-**	**200.5**	**45.1**	**373.4**	**115.3**	**2,663.8**
Scotland	**4,366.0**	**11,145.3**	**2.5**	**562.8**	**30.2**	**768.2**	**92.4**	**16,967.4**
Northern Ireland	**21.1**	**1,345.2**	**3.1**	**60.5**	**0.7**	**73.3**	**26.9**	**1,530.7**
Other Sites	-	7.2	-	-	-	-	80.5	**87.7**
Total	**4,698.1**	**28,433.6**	**5.9**	**5,168.5**	**761.2**	**12,564.1**	**2,035.6**	**53,666.9**
UK Total	**4,698.1**	**28,433.6**	**5.9**	**5,168.5**	**761.2**	**12,564.1**	**2,035.6**	**53,666.9**

Notes to Tables 1 to 3

- Nil or less than half the final digit shown.

1 At 31 December 2013.

2 Offshore wind is allocated to regions/countries according to where the cabling comes ashore. Wave and Tidal has been separated out from wind for the first time this year.

3 Eight of these sites are sites that co-fire renewables with fossil fuels (see also note 4, below).

4 This is the proportion of non-fossil fuelled capacity used for co-firing of renewables based on the proportion of generation accounted for by the renewable source. This estimate has not been disaggregated into region values because to do so could disclose data that relate to individual companies.

5 Includes bioenergy sources co-fired with fossil fuels.

6 Generation data for wave and tidal schemes are from publically available monthly Renewables Obligation Certificates data (or DECC estimates where this is not available); therefore, where there are regions with less than three sites, no company data are being disclosed.

Annex 4: Climate change mitigation measures for the livestock sector

Anaerobic digestion of manures

Anaerobic digestion of manures (**Recommendation 7**) offers the potential to capture methane emissions from livestock farms, and through combined heat and power (CHP) equipment generate useful energy while reducing the global warming potential of gaseous emissions (i.e. by releasing CO_2 rather than CH_4). This is most relevant to cattle farms because sheep are typically housed for very short periods, if at all, and so there is little opportunity to collect manures on sheep farms. However, not all cattle farms would be able to implement AD. Digestion of slurry alone is inefficient, since most of the methane production has occurred enterically, and therefore other feedstocks for AD would be required. This could be energy crops grown locally, or the use of waste products from other industries (Recommendation 9). Both of these issues raise questions – the use of energy crops for direct use in AD, as opposed to use as human or animal feed, and the proximity of farms with AD plants to sources of other feedstocks.

A recent report (Rural Futures (North West) Ltd, 2010) suggested AD is not economically viable on a single farm with less than 300 animals, and also required 30% of inputs as an energy crop. In Wales (2011), 31% of dairy farms, and 3% of non-dairy cattle had more than 100 animals – information on herd sizes above 100 head was not provided. In any case, this recommendation would therefore be applicable to relatively few current Welsh cattle farms. To date there are only 3 AD agricultural plants in Wales, although this implies potential to increase numbers in the future. The ha Wales Centre of Excellence for Anaerobic Digestion[28] has been providing support and technical services to the AD industry, industry stakeholders, policy developers and regulators since 2008.

The addition of other (non-slurry) materials to slurry in AD, either grown specifically for the purpose, or municipal or industrial waste material collections (**Recommendation 9**), can significantly improve biogas production. About 7.0 Mt of domestic food waste are estimated to be created in the UK each year (approximately 0.3 Mt in Wales). An additional 6.5 Mt of grocery waste is estimated to be produced annually in the UK (1.6Mt from retail, 4.9 Mt from manufacturing), of which 0.02 Mt is food waste that is currently processed by AD, and more that is currently composted or landspread/landfill could be used in AD. The 'Hub and PoD [Point of Digestion]' model would pasteurise food and other waste material before delivery to a farm AD plant to be digested with slurry (WRAP 2013). This may offer a mechanism for increasing biogas production on-farm, at the same time as diverting domestic and retail waste materials from landfill. However, this would depend on the creation of appropriate infrastructure and having on-farm AD located close of sources of municipal waste.

For the most efficient capture of GHG (methane and nitrous oxide) from manures, these gases must be captured from the livestock. This happens during housing periods in most cattle systems, and could be extended to 365 days of each year. This already happens in some dairy systems, particularly those using robotic milking systems, although the current rates of all-year housing of cattle in Wales are unknown. **Recommendation 8** suggests the adoption of zero-grazing systems (which could be taken to mean cut-and-carry fresh forage, or feeding of a conserved forage-based diet) to maximise the collection, storage and processing (AD) of manures to minimise GHG emissions. Approximately 53% of nitrous oxide emissions in Wales come from grazing returns, and removing animals from grazing land would give greater control to reduce these emissions. Estimating the number of Welsh cattle farms that would be able to house all their animals year round without significant investment in housing, and slurry storage and processing equipment, is challenging. However, since grazed grass is generally seen as the cheapest source of feed for ruminants,

[28] http://www.walesadcentre.org.uk/Technologies/DigestateProcessing.aspx

and because Wales has an abundance of this natural resource, feed costs are likely to be increased by year-round housing.

Digestion of slurry with CHP in a large dairy can achieve GHG reductions of 495 kgCO_2e/tonne slurry, leading to a lifecycle GHG reduction of 15% for milk production (Styles et al., 2014). On a medium-sized dairy farm where biogas is used only for heating, GHG reductions of 240 kgCO_2e/tonne of slurry can be achieved, leading to a lifecycle GHG reduction of 5% for milk production. Avoided fossil resource depletion over the lifecycle of milk production translates to 56% and 6% for large and medium sized dairy farms, respectively. Digestion of food waste can achieve GHG reductions of 637 kgCO_2e/tonne digested in a <200 kW AD-CHP unit on a large dairy farm, or 1021 kgCO_2e/tonne in a >500 kW AD-CHP unit (compost counterfactual). However, there is the risk of increased NH_3 emissions from digestate storage and spreading, especially for smaller (dairy) units where digestate storage is unlikely to be covered. This may require regulation. Economically, AD could increase rural economic activity, but is currently only financially viable for larger farms (about 500 dairy cows).

Animal Husbandry

Improved technical efficiency of livestock (**Recommendation 10**) has the potential to reduce GHG emissions intensity (i.e. g CO_2e/unit productive output) by making use of improved breeds, feeds and husbandry practices. Even though methane and N excretion rates (g/d per animal) increase as feed intake increases, faster growing and higher yielding animals tend to reduce GHG emissions intensities by reducing the Ym (proportion of gross energy intake that is excreted as methane energy) as feed intake increases. Similarly, g N excretion per unit milk output decreases as milk yield increases in dairy cows. For sheep meat production, increasing the lambing percentage of the Welsh sheep flock would reduce the number of ewes required to maintain lamb output, and this will affect the GHG emissions intensity from the system. Therefore, use of modern livestock genetics is important, with improved reproduction characteristics and which can achieve high feed intakes and high productive outputs; artificial insemination in beef herds and sheep flocks would increase the rate of genetic progression. Animal breeding programmes have led to milk production by dairy cows continuing to creep up, and (some) beef cattle and (some) sheep breeds becoming more efficient. Greater progress has been achieved in the dairy sector which has a more limited number of breeds in use – B&W dairy cows predominate here. The average rate of N use efficiency (NUE) in dairy cows for milk production is about 25%, and average efficiency of about 35% should be achievable. Average efficiency of N use for beef meat production is similar to that of dairy cows.

There are 224 thousand dairy cows in Wales, annually producing an average (UK) of 7,500 litres of milk each. At 3.2% protein (0.5% N), this gives an annual output of 8.4M kg milk N. At 25% NUE, this means 25.2M kg N is excreted each year. Increasing the herd average NUE to 35% while maintaining milk N output could reduce annual N excretion to 15.6M kg in addition to requiring less N to be used in dairy cow rations. This will help lead to reductions in N emissions, both as nitrous oxide, and also as ammonia, but also leaching of nitrate.

Increasing growth rate and therefore achieving maturation and slaughter at an earlier age will reduce total lifetime emissions, and therefore reduce emissions intensity of beef production. Increasing milk yield per cow, through breeding programmes, and reducing cow numbers to maintain milk production, would also reduce methane emission intensity. This is happening in Wales to some extent, as changes to farm size/structure have led to fewer/bigger dairy farms, although dairy cow numbers have been relatively stable in Wales since 2009. Beef cattle numbers continue to decline, and although the breeding sheep flock in Wales has declined steadily since 2000, there has been a small increase in the last 3 years.

Recommendation 33 suggests further research on animal traits that may reduce GHG emissions between and within breeds. Livestock agriculture in Wales is dominated by ruminant animals; non-ruminant species (i.e. pigs and poultry) are currently of relatively minor importance to Wales. 97% of Welsh agricultural methane emissions come from ruminant species – 63% from dairy and beef cattle, and 34% from sheep. Therefore, specific targets should focus on ruminant animals. One trait that has been the focus of breeding research is residual feed intake (RFI). This is the difference between what an animal would be expected to eat for a given growth rate or milk yield, and what it actually eats. It is a moderately heritable trait, and a number of programmes have bred divergent breeding lines of cattle. Cattle selected for low RFI tend to produce less methane than do high RFI cattle, because feed intake is lower for a given body weight or live weight gain. However, there could be an issue with selecting for cattle with low feed intake, because this may eventually lead to less productive animals. This would increase the emissions intensity of production, not reduce it. Data on reduction potential is scarce; an example of work in Australia with beef cattle has shown variation in feed intake between individuals of more nearly 6 kg DM/d with no difference in average daily gain. This led to differences in methane emissions intensities: 132 versus 173 g methane/kg live weight gain for low RFI and high RFI breeding lines respectively; lowest emitting cows being about 76% methane emissions of the highest emitters. A 16% reduction in methane emissions from individual beef herds (3% reduction nationally) has been calculated as possible over a 25 year period by breeding for lower RFI (in Australia).

A major stumbling block to breeding animals with reduced methane emissions is the lack of an easy and automatic way of monitoring methane production. This has meant progress to date has been slow. Monitoring the effectiveness of such programmes would be affected by the same limitations. There is potential to monitor methane emissions from dairy cows at milking (Garnsworthy et al, 2012), although the robustness of this method for animal ranking or selection is not proven.

Improving animal fertility and reducing the consequences of disease are regularly cited as ways of improving the technical efficiency of livestock and reducing the GHG emissions intensity of meat and milk production. Marginal abatement cost curve (MACC) analysis by Elliott *et a*l (2014) suggests that for the dairy sector, mitigation measures exist for most of the diseases considered which simultaneously deliver GHG abatement and financial benefits to farmers. The combination of reduced dairy animal numbers and lower GHG emissions per dairy animal produced a GHG abatement potential of 266-669 $ktCO_2e$ respectively at UK level, under a fixed output constraint. The economic gain from these improvements in the technical efficiency of the dairy sector are slightly diluted by downward price pressures caused mainly by production expansion, based on a Cochrane technological treadmill (Levins and Cochrane, 1996) where technological improvements drive prices downwards.

Increasing the longevity of individual dairy cows, for example, would mean fewer replacement heifers would be required, and more calves could be used for beef production. Breeding targets in dairy cow improvement programmes have changed in recent years to address this; cross-breeding of B&W dairy cows with other breeds that improve longevity can affect milk yield, although the carcass of the cull cow often has a higher value for meat than that of a pure-bred Holstein.

Increasing the lambing percentage of ewes is another general breeding target that is currently being carried out for economic reasons, although it also has the benefit of reducing emissions intensity of lamb production. Research by Jones (2014) on mitigation of greenhouse gas emissions in sheep farming systems highlighted the importance of productivity and efficiency as influential drivers of emissions' abatement in the sector. In particular, cost-effective measures aimed at *improving ewe nutrition to increase lamb survival* and *lambing as yearlings* offer considerable relative abatement potential per kg of lamb produced.

Livestock nutrition is important, as feed use efficiency is heavily influenced by the quality of feeds and quality of ration formulation, particularly to reduce the crude protein concentration of livestock diets. Use of modern forage plant breeds can improve livestock feed use efficiency, particularly at grazing when other methods of diet manipulation are difficult to implement. **Recommendation 34** aims to improve the understanding of potential methane production from different feeds and transfer of this knowledge to the farmer. As with animal breeding, focus should be the ruminant sector. However, 'animal feeds' covers a very wide range of materials including imported feedstuffs, by-products, locally grown crops, and grazed pastures (from natural grassland on poor soils to highly improved crops on excellent soils). It also includes compound feeds and feed additives that may influence methane emissions in various ways. There is reasonably good understanding of which feeds and feed components contribute to reducing methane emissions from ruminant animals through diet manipulation. For example, high starch (low fibre) diets and high lipid diets tend to decrease methane emissions through modification of rumen fermentation and the rumen microbial population.

A number of plant secondary compounds (e.g. condensed tannins, saponins, allicin) are known to have at least transient effects on reducing methane emissions from ruminants in some cases. For full reviews on historic and recent progress see Hristov et al. (2013a) and Knapp et al. (2014). Large areas of Welsh upland cannot be used for agricultural purposes other than livestock production, and this is generally viewed as problematic because of the GHG emissions from animals grazing there. Very little is known about methane emissions from animals grazing upland pastures, so further work to challenge or confirm these assumptions is required, as specified by **Recommendation 35**. The biodiversity of some upland pastures (semi-natural rough grazing) means that grazing cattle and sheep may consume secondary compounds as part of their diet (e.g. condensed tannins in heather). However, very little research has been done on this to date. Some work has been carried out recently as part of Defra project AC0115, albeit with limited numbers of animals and in limited situations. More work would be required to supplement this initial work, and to study the effects of specific plants (as opposed to plant communities, in which the grazing animal had a choice of diet). Some in vitro analysis of upland plants has shown different rates of methane emission (Doran et al., 2013), although the precise cause of this has not been established. The relatively harsh environments and relatively poor quality pastures mean that smaller and hardier animal breeds are used in the hills and uplands, which do not produce prime beef and lamb. However, they are important to the overall system of food and livestock production in Wales, and also contribute to other ecosystems services.

Recommendation 32 suggests further research on rumen function to better understand methane production, the microbes that produce methane, and dietary additives that might modify the process. Methane production appears to be a largely inevitable by-product of rumen fermentation, particularly of that associated with feeding foods that are not consumable by humans (i.e. high fibre feeds). However, as little as 2 or 3% and up to about 12% (average about 6.5%) of feed gross energy may be converted to methane energy. This range of variability indicates that there is a potential to manipulate the system to the bottom end. However, it is difficult to predict the scale of benefits of such research on Welsh GHG emissions because even though this area has been a topic of investigation for decades, it continues to be researched today.

When animals are housed, there is potential to manage enteric GHG emissions as well as manures. **Recommendation 37** was to research the feasibility of capturing methane from housed cattle. Some dairy and beef farms house their animals year round, so there is knowledge of the implications of this part of the recommendation. However, large-scale capture of methane in relatively low concentrations from naturally ventilated buildings is not really feasible, and would need significant technical development for efficient on-farm use. The flammability of methane in air is between 5% and 15% v/v, whereas the range of methane concentration in ruminant expired air is between approximately 10 and 200 ppmv (0.001% to 0.02%) depending on whether it emanates from the lungs (breath) or the rumen (eructation). Therefore methane must be concentrated from collected air before it could be burned. An alternative use could be the catalytic conversion of methane to hydrogen or other hydrocarbons as chemical feedstocks. The collection and use of methane from landfill sites is becoming more commonplace, but is aided by the composition of landfill gas being approximately 50:50 CO_2:CH_4. The technological challenge for this recommendation is the concentration of methane from air collected in the livestock housing to levels that become flammable or useful for other processes, assuming that existing housing is appropriate for collection of expired gases, which is unlikely to the case on any current farms. Potentially nearly 100% of current methane emissions could be captured in fully housed systems, compared to 0% on most individual farms now.

Grassland Management

Recommendation 44 was to quantify the effects of grazing intensity and type, re-seeding of lowland pastures, and the impacts of tillage methods of GHG emissions. There is currently a lack of data on rotation practices – how often soils are cultivated, and what is sown (Defra project SP1113). Therefore, there is a need to improve not only the information about the impacts of grassland (and crop land) management on GHG emissions, but also on land use reporting. While this would not directly reduce emissions, a better understanding of management practices affecting GHG emissions from grassland management would enable advice to farmers to be better targeted. This is currently limited by the lack of field data.

Carbon sequestration in soils could be increased using plants specifically bred for the purpose (**Recommendation 45**). As far as is known, no plants are currently being bred specifically for soil C sequestration, but this trait could become part of the panel of targets for any future plant breeding programme, not just for grasses. Current plant breeding programmes exist to breed new plant varieties that could be important to both agriculture and amenity uses. One example is *Festulolium*, which is an intergeneric hybrid between species of *Festuca* (fescue) and *Lolium* (ryegrass), which occur naturally as well as synthetically. Breeding targets in the current *Festulolium* breeding programme at IBERS, for example, include increased root mass, primarily as a way of increase plant tolerance to both drought and flooding, but a secondary benefit of this is increased underground plant mass and C sequestration. Similarly, red clover breeding programmes at IBERS are targeting root mass as a way of increasing plant resilience, and this could also have a role in increasing below-ground plant biomass. A relatively small proportion of Welsh agricultural land (about 13% - 'arable', which includes grass leys < 5 year old) is directly targeted by this approach. 57% of Welsh agricultural land is classified as permanent pasture, which is also potentially relevant. However, producing a new plant variety takes a long time, approximately 15 years from inception to getting the variety onto the market. In addition for a new agricultural plant variety to be sold in Europe, it must be listed on an EU national list following testing for agronomic characteristics. New varieties of grass (or other forages) that partition nutrients away from above-ground parts into roots may have lower crop yields than existing varieties, and therefore although may appear on a national list, they are unlikely to become part of the Recommended List, which would most likely limit their use unless some other intervention was imposed (e.g. as part of an agri-environment scheme).

Annex 5: Climate change mitigation measures for soils, crops and fertilisers

Improved Nitrogen Use Efficiency of fertilisers, manures and biosolids

From Table 23, it is evident that after grazing returns (urine), fertiliser N and manure applications are the largest sources of N_2O from Welsh soils. What is also clear is that indirect losses of N_2O are significant, so any management practice to reduce nitrate leaching and ammonia volatilisation should reduce total N_2O emissions.

Table 23: Sources of N_2O emissions from fertiliser and organic sources in Wales (2012)

Annual N_2O emission (t)			
Manure management	748.4		
Soil	**Direct**	**Indirect**	
		Nitrate	**N deposition**
Fertiliser applications	1302.5	868.3	115.8
Manure applications	613.7	460.3	122.7
Grazing returns	2896.5	1086.2	289.7
Crop residues	98.4		
Biological fixation	0.0		
Improved grassland	93.3		
Histosols	0.0		
Sewage sludge applications	44.4	33.3	8.9
Total	**5797.2**	**2448.1**	**537.0**

Source: UK Agriculture Greenhouse Gas Emissions Inventory

A key recommendation in the LUCC Report to the Welsh Assembly Government (LUCC, 2010) was to encourage maximising nitrogen (N) use efficiency (NUE) through best practice management of fertilisers, manures and biosolids (Recommendation 11). This remains an important strategy to reduce direct and indirect N_2O emissions from soil, as well as reducing the wider environmental effects of nitrate leaching, and ammonia volatilisation and N deposition on aquatic and terrestrial systems. Improved NUE also offers potential economic gains to farm businesses.

Fertiliser N use

Since the LUCC2010 report, Defra published the Eighth Edition of the Fertiliser Manual (RB209) (Anon, 2010). In this version, the approach for fertiliser recommendations for grassland were changed significantly, moving away from an N*opt* approach to maximise yields, to an approach that provided sufficient forage to maintain a given level of production, based on milk yield for dairy, as well as stocking rate and concentrate use for all ruminants. This approach should result in a reduction in excess use of fertiliser N, when not required – resulting in subsequent reductions in N_2O emissions from soil, and reduced GHG emissions associated with the manufacture of N fertilisers.

There is no specific information yet to know if farmers in Wales have adopted this new recommendation system, and if it has resulted in more efficient use of fertiliser N. However, a survey by Exeter University, as part of Defra project Validation of fertiliser manual (RB209) recommendations for grasslands (IF01121)[29], is assessing to what extent farmers and advisors are adopting the new recommendations and what barriers there may be to its use. Of the 600 respondents to this survey, 101 are Welsh farmers, of which 76 use manufactured N – this is a very small sample from which to make any claims, but could be explored (only one Welsh contractor responded to the survey).

The degree to which Welsh farmers are utilising N more efficiently can be implied using national statistics. For Wales, data used in the UKGHGEI for the year 2012 indicate an overall reduction in fertiliser N use between 2010 and 2012, although during 2008 to 2010 fertiliser use increased (see Figure 2). Hence, Recommendation 30, to collect statistics for Wales to provide a more accurate estimate (and replace extrapolated statistics from UK) has started to be delivered in terms of fertiliser N use, although the British Survey of Fertiliser Practice (BSFP, e.g. 2014) does not disaggregate application rates for Wales only (the category is still England & Wales). Further breakdown of fertiliser data is being sought via the GHG Platform project, AC0114, which is delivering the appropriate level of disaggregated activity data (spatial and temporal) to drive the new agricultural GHG inventory[30].

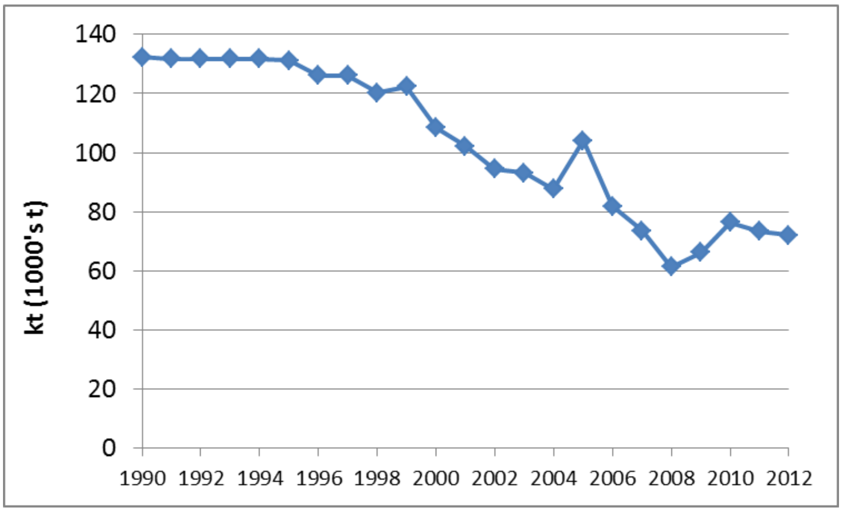


Figure 8: Trends in fertiliser nitrogen use in Wales (1990 – 2012).

Some Glastir measures will impact on fertiliser and manure management on farms, and so potentially reduce N_2O emissions from soil, e.g. (Option AWE 15) Grazed Permanent Pasture with No Inputs. This management option requires that no manufactured fertiliser or organic manures be spread to permanent pasture. The pasture must continue to be grazed to maintain a sward with a range of heights during the growing season. The aim is to increase plant diversity, reduce nutrient leaching and contribute to carbon capture, but it will also reduce direct soil N_2O emissions.

Current modelling in the WG funded Glastir Monitoring and Evaluation Project (GMEP), based on the assumption that the measure is implemented fully across the entire relevant land area on a farm, suggests that this 'No Inputs' measure could result in *ca*. 4.8 – 7.2% (417 - 628 t N_2O = 129,292 - 194,629 tCO_2e) reductions in N_2O emissions from agricultural land, depending on the level of uptake (Emmett et al., 2014). But the potential size of the mitigation impact is likely to be less than these modelled values, because although the option

29 http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17803
30 www.ghgplatform.org.uk

potentially applies to 620,900 ha of permanent grassland receiving some manufactured nitrogen fertiliser, the area of land currently under this Glastir option is only 22,364 ha, with the average area per farm that has adopted this measure being ca. 18 ha/farm. Analyses of scheme uptake statistics indicate that uptake is unlikely to be more than 50% of the maximum relevant land area. Modelling the effects of Glastir options on N_2O (and CH_4) emissions will continue in 2014 and 2015, via the GMEP project.

Organic Resources

There is a strong European pressure to increase the nutrient use efficiencies of organic resources, particularly those with a high available N content. This is evidenced in Nitrate Vulnerable Zone Acton Plans, which farmers are required to follow if they farm in zones designated as vulnerable (in terms of potable water supplies). Although the EU Nitrates Directive and subsequent Action Plans only apply to a small area of Wales, even after the revised designations in 2013, the Action Plans can be regarded as best practice to improve NUE from organic resources through:

- Improved knowledge of manures/digestate nutrient content and availability
- Optimising application rate and timing to meet crop demand
- Using application and cultivation techniques to conserve available N and reduce losses of e.g. ammonia, using shallow injection, trailing hose/shoe for slurry and digestate, and/or incorporation into arable soils.

The principal considerations are provision of sufficient slurry storage capacity to provide flexibility to apply these resources at correct agronomic rates at times of the growing season, using appropriate application methodologies.

The Eighth Edition of the Fertiliser Manual (RB209) published in 2010, now includes a greater number of organic resources (including composts), and provides information on how nitrogen availability to crops can be improved by optimising timing and method of applying organic resources. Unfortunately, there were insufficient data to include digestates in this version of the Fertiliser Manual (RB209). To assess the fertiliser value of digestates, there is a need to benchmark against other known organic manures, e.g. farm yard manure (FYM), cattle and pig slurry, where there is already a great deal of information (e.g. Anon, 2010). The recently completed WRAP funded project (Digestate and Compost in Agriculture - DC-Agri; WRAP, 2014a,b,c,d), will provide some of this information, and the expectation is that ADAS Decision Support Software, MANNER-NPK (Nicholson et al., 2013) can be further validated with the experimental results from DC-Agri, and the ninth Edition of the Fertiliser Manual (RB209) updated to include this guidance to farmers and advisors.

Increased N availability of all organic resources, including digestate would reduce reliance on inorganic N fertiliser use, and hence fertiliser manufacturing (Zhang et al., 2013). Both the use and manufacture of inorganic fertilisers result in significant GHG emissions, so environmental savings would be accrued, especially if the digestate was managed carefully and the increased ammoniacal-N content was not allowed to escape into the environment. Specialist spreading equipment may be required, and whilst some farmers may be able to purchase their own e.g. trailing hose or shallow injection slurry spreader, perhaps with support from Glastir Efficiency Grants, others may turn to contractors to assess the nutrient content of the digestate/manure and apply at using these techniques at agronomic rates. [Note: moving to trailing hose/shoe or shallow injection, whichever is the most appropriate for the farm, would future-proof Welsh farmers for any future potential requirement to spread slurries in this way to reduce ammonia volatilisation, as required in much of mainland Europe].

We estimate that if the plant N availability of manure applied to Welsh soils was improved e.g. for cattle and pig FYM from 5 to 10%; for cattle slurry from 25 to 30%; for pig slurry from 35 to 40%; and from poultry manures from 35% to 40% (there is no evidence for these manure values of N availabilities in Wales, they are illustrative and taken from the Fertiliser Manual (RB209), the estimated reduction in N fertiliser requirement would be ca. 1,500 t per year resulting in a reduction in direct and indirect soil N_2O emissions from reduced fertiliser applications of *ca*. 2% (48.8 t N_2O = 15,116 tCO_2e)

There is conflicting evidence that direct N_2O emissions are reduced (or not) following digestion of livestock slurries as a result of decreased demand for O_2 and consequently heterotrophic denitrification[31] (Chantigny et al., 2007; Thomsen et al., 2010). During anaerobic digestion a significant proportion of the total N is mineralised to the ammonium-N form, which is then at risk of ammonia volatilisation if unchecked. So the high ammonium-N content of digestate can increase the risk of N_2O production via nitrification and denitrification, especially if the denitrifier population is not carbon limited. So there is still ambiguity regarding the effect of digestion on N_2O emission from organic resources applied to soil, suggesting that soil and environmental conditions may influence N_2O emissions more than the digestion process itself following the application of digested slurries.

<u>Nitrification inhibition</u>

There is great potential for the use of nitrification inhibitors (NIs) to improve NUE (Abalos et al., 2014) by slowing the rate of microbial conversion of NH_4 to NO_3, thus reducing the N_2O production during nitrification, but also reducing the pool of NO_3 at risk of partial denitrification to N_2O production and emission, and improving the potential for plant uptake of applied N. Since the LUCC2010 report, there has been significant UK R&D on the potential of nitrification inhibitors (NIs) to reduce direct N_2O emissions from soils receiving fertiliser N, livestock slurries and urine (e.g. Defra projects AC0116 and AC0213). There is growing evidence that NIs can significantly reduce direct soil N_2O emissions from all these N sources, but mitigation efficacies are variable in the field, e.g. ranging from 0 – 80% in the case of the AC0116 urine experiments. The controlling factors appear to be temperature (NIs such as dicyandiamide, DCD, are mineralised much quicker at high temperatures), clay and organic matter content and rainfall (these factors appear to control the co-location or dis-location of the NI with the NH_4.

Within the next 1-2 years there may be sufficient evidence from which to base guidelines to optimise the use of NIs to significantly reduce N_2O emissions from Welsh soils. But before then, R&D providers need to address three key areas: i) an improved understanding of what factors control the current variability in efficacy, ii) cost-effective delivery mechanisms for applying NIs to farmland, and iii) public perception of another chemical in the environment.

Since NIs have the clear potential to mitigate this major greenhouse gas (e.g. an average reduction in emissions from fertiliser and slurries of perhaps 40% should be possible), and to increase NUE, thus reducing the N_2O intensity of production, there is much policy and industry interest in understanding the factors that control its efficacy. But whilst NIs can be incorporated in fertiliser prills (as coatings or in the mix, and some fertiliser products have been commercially available for some time now), or mixed with slurries prior to spreading, controlling N_2O emissions from grazed grassland, particularly upland systems using NIs presents a challenge. However, New Zealand researchers are trialling DCD diffusion into the

[31] Denitrification is a microbially facilitated process of nitrate reduction (performed by a large group of heterotrophic facultative anaerobic bacteria) that may ultimately produce molecular nitrogen (N_2) through a series of intermediate gaseous nitrogen oxide products.

rumen (Ledgard et al., 2008) and potential delivery via boluses, and dosing water troughs with NIs (Welten et al., 2013) to specifically target the urine patch source of N_2O.

Public perception of NI use needs careful thought, particularly since the temporary voluntary withdrawal of NI fertiliser products from the New Zealand market following the finding of trace quantities in milk products (MPI, 2013). The delivery of natural / biological inhibitory compounds via plants may also alleviate some of the concerns about use of more chemicals in the farmed environment, but this will require significant R&D and plant breeding investment by Government and Industry.

Cropping and crop management

Minimum Tillage

Minimum tillage (min till) could apply to some of the 225,000 ha of cropping land in Wales. The benefits of min till are mainly thought to be the enhanced carbon storage in soil and water conservation, with inconsistent effects on N_2O emissions. However, effects on soil carbon storage appear to be over-estimated according to Powlson et al (2014), as many studies have compared the effects of different cultivation techniques on the soil carbon within the upper soil layers, e.g. 0-15 cm, and the absence of mixing with deeper soil exaggerates the claims. Reports have concluded that there is little difference in soil carbon content between tilled and reduced till soils once variation with depth and differences in bulk density have been taken into account (Powlson et al., 2014). Min till can improve water conservation, which can indirectly increase soil carbon levels in dry regions of the world.

Rochette (2008) reviewed the effects of min till on N_2O fluxes from soils, and concluded that the outcome is controlled by soil aeration status: so wet sites with high rainfall and poor drainage tended to show increased emissions under reduced tillage, whilst those in drier soils showed decreased emissions or no change.

Low emission crops

There has been little progress on the use of crop varieties with improved N use efficiency since the 2010 report. Research is underway worldwide to identify genes that improve the NUE of a range of crop types, especially those relating to primary N metabolism (N uptake, assimilation, amino acid biosynthesis, translocation, remobilization and senescence).

The use of high sugar grasses in Wales has probably increased over this period, which should have resulted in improved energy: protein balances, and reduced N excretion by ruminants. Dietary manipulation and effects on both enteric CH_4 emissions and N excretion, could contribute to reductions in subsequent NH_3 and N_2O emissions from urine deposited on grassland.

Clover and other legumes could be considered as ‘low emission crops’, as there use results in reduced fertiliser N requirement with reduced GHG emissions associated with fertiliser manufacturing and use. The integrated carbon balances of grazed systems with more home grown protein sources and greater legume content of pastures need to be assessed (see section Improved Emission Factors for Welsh Conditions).

Precision agriculture

The spatial and temporal optimisation of N inputs, especially via fertilisers, can be achieved using tractor mounted sensor systems, e.g. the Yara N-sensor, particularly in arable crops. In grazed pastures, it is not clear how useful precision application technologies could operate and account for spatial distribution of urine and dung patches. There do not appear to be any specific data to track Welsh farmer adoption of these techniques. But ultimately, adoption should result in reduced national fertiliser N use.

Regular (annual) calibration of fertiliser and manure spreaders would improve NUE from fertiliser N and organic resource use by more uniform distribution. Data for British farmers (2012-2013) suggest that ca. 40% of farmers with a fertiliser spreader check the calibration of their fertiliser spreaders annually using catch trays, 10% check less than once per year, and 25% have never checked spread patterns in this way (BSFP, 2013). Moreover, this appears to be a consistent story, i.e. similar data for 2009-2013. Hence, WG could promote the simple measure of regular calibration of fertiliser and manure spreaders further, as it should improve NUE and reduce N_2O emissions from N loading 'overlap', which are likely to be proportionally greater if localised N loadings are greater than crop demand.

Improved Emission Factors for Welsh Conditions

A general recommendation from the LUCC2010 report was to research factors controlling fluxes of N compounds from soils and to monitor fluxes under a range of management conditions, including organic and conventional systems and identify new mitigation options (Recommendation 36). Significant investment has been provided by the UK Department for Environment, Food and Rural Affairs (Defra), the Department of Agriculture and Rural Development in Northern Ireland, the Scottish Government and the Welsh Government, to generate country specific N_2O emission factors for typical combinations of N sources, soil types and agro-climatic zones using a combination of modelling and measurements (via project AC0116, the *InveN₂Ory* project to Improve the agricultural inventory: nitrous oxide[32]. [Note: a similar project, AC0115 (Improve the agricultural inventory: methane)]. Information from this and associated projects will be of relevance to both organic and conventional farming systems, although key omissions still remain, especially in relation to N_2O emissions from upland farming systems typical of Welsh agriculture:

Urine N_2O EFs for upland pastures

Table 23 shows that urine deposition by grazing livestock are the major source of direct and indirect N_2O emissions from Welsh soils. Research is required to better understand the influence of the grazing animal on N_2O emissions from upland soils. The current IPCC Tier 1 approach to estimating N_2O fluxes from grazing livestock assumes 2% of N deposited in excreta is emitted as N_2O for cattle, and 1% for sheep, with no differentiation between livestock grazing e.g. lowland *Lolium perenne* dominated swards in lowland pastures compared with livestock grazing upland mixed vegetation.

A large proportion of the Welsh beef and sheep population spend time grazing in upland pastures and on common grazing land in the mountains, where mixed vegetation will result in a very different urine composition compared to those animals grazing on lowland pastures. Urine composition reflects the composition of the grazed herbage, and some metabolites in urine such as hippuric acid are influenced by diet (Dijkstra et al., 2013), and are known to effect denitrification rates in soils. Moreover, the urine deposited by livestock grazing in the uplands will be deposited on acidic podzols and peats compared to the brown earths of the lowlands. So the N_2O emission factor for livestock excreta (urine especially) deposited in the uplands could be much lower than for the lowlands, and could be lower than the current IPCC defaults emission factors used in the UK inventory, and reduce the C footprint of Welsh red meat products.

Project AC0116 in the UK GHG Platform is conducting field experiments to provide separate country specific emission factors for urine and dung. But the experiments are being conducted with cattle urine (fed *Lolium* dominated swards) because of the quantities required for each experiment, and experiments are being conducted on mineral soils. So, although extremely useful for providing data for generating N_2O emission factors for cattle in lowland

[32] www.ghgplatform.org.uk

systems – these data will not be applicable to the majority of sheep and cattle urine deposited in Wales.

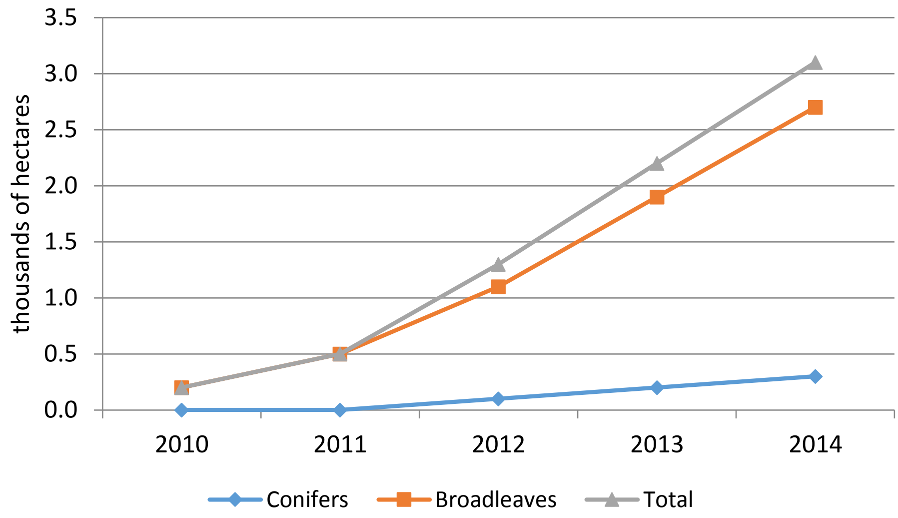
N_2O emission factors from clover-based pastures

There is a dearth of information on N_2O emissions from soil where high proportions of clover are used to provide N inputs to swards. High clover content pastures, e.g. in organic systems, avoid the GHG emissions associated with fertiliser production and from soil after use on land. But the fate of fixed N (by clover) is not clear, especially in swards with high clover contents. Direct emission from the soil *per se*, may not be high – but once the sward is grazed, the high protein content of the clover intake will affect the N content of the livestock urine, and subsequent emissions may be greater than from an equivalent fertiliser N (loaded) sward.

Clover will also impact on the enteric methane emissions. At the end of the growing season, excess N in the soil profile in swards with high clover contents may be at risk of loss via leaching (an indirect soil N_2O loss). Hence an integrated assessment of GHG emissions (direct soil N_2O, indirect N_2O associated with nitrate leaching and ammonia emissions, enteric methane emissions and soil carbon stocks) on grazed swards with high clover content is required. Emissions need to be integrated with livestock production to enable yield-scaled (GHG intensity of production) emissions to be estimated.

Annex 6: Climate change mitigation measures for forestry

The area of woodland in Wales has increased by 3,100 ha since 2010 which is substantially below, only 16%, of the 20,000 ha target required by 2014. The afforestation of 3,100 ha can be broken down into coniferous forest (300 ha) and broadleaved forest (2700 ha). Rates of coniferous tree afforestation has remained constant for the last three years, whilst the rate of broadleaved forest creation was eight times faster but remained constant for the last two years (Figure 4). The expansion of woodland within Wales and been triggered mainly by Glastir woodland creation grants, but also recently encouraged by the potential benefits of afforestation to prevent flooding.



Source: Forestry Commission, 2014.

Figure 9: Cumulative new woodland area since 2010.

Table 24: Area of woodland in thousands of hectares and percentage change between 2010 and 2014 for coniferous and broadleaved forests separated by ownership

	Woodland Type	2010	2014	Change (%)
NRW	Conifer	90	98	9
	Broadleaved	15	19	27
¥Other	Conifer	65	53	-18
	Broadleaved	114	137	20
Total	Conifer	155	151	-3
	Broadleaved	129	156	21
Total		284	307	8
**Total	**Revised	304	307	1

¥Other: all other woodland. Includes woodland previously owned by Countryside Council for Wales, and the Environment Agency in Wales, other publicly owned woodland and privately owned woodland.
**Revised: disparity between the FC estimates of the woodland area in Wales existed for the reference date of March 2010. Forestry Statistics (2010) published 284 thousand hectares as the total woodland area, but the National Forest Inventory (NFI, 2010) published 303.5 thousand hectares at the same time point. The disparity is believed to be due to methodological differences between the National Inventory of Woodland and Trees (NIWT) and NFI, and the classification of unmapped areas.

Following the Countryside Survey in 2007, the condition of Welsh Woodlands was brought into question following identification of reduced light penetration correlated with the Ellenberg scores of ground flora. Light is a major driver in the ecosystem dynamics and ultimately affects woodland health, regeneration, recruitment and the diversity and abundance of ground flora. Appropriate woodland management is an essential practice to maintain ecosystem diversity, resilience and ecosystem service provision.

Sustainable management of woodland in Wales can only reliably be determined by identifying areas audited against the UK Woodland Assurance Standard (UKWAS). It is possible, however, that woodlands exist that are managed sustainably but are not certified under UKWAS and are not accounted for in the figures presented below. As Glastir woodland management is not required to be accredited by UKWAS, it is not possible to accurately determine if Glastir schemes have had an impact on sustainable woodland management in Wales. The total area of woodland certified in Wales at the end of March 2014 was 141,000 hectares which equates to 46% of the woodland area and a 2% increase since 2010 (Table 25) suggesting that accreditation is occurring beyond uptake of Glastir funded forestry schemes.

Table 25: Area of woodland under sustainable management determined through certification by the UK Woodland Assurance Standard.

	2010	**2014**	**Change (%)**
NRW	105	117	11
¥Other	18	24	33
Total	124	141	14
% of woodland area	44%	46%	2

¥Other: all other woodland. Includes woodland previously owned by Countryside Council for Wales, and the Environment Agency in Wales, other publicly owned woodland and privately owned woodland.

Source: Forestry Commission, 2014.

Expansion of Forest Cover

The LUCCG report sets an ambitious target for woodland creation with the aim of afforesting 100,000 ha in Wales by 2030, creating a net sink of 1,600 ktCO_2e/yr from a combination of increased carbon storage in biomass and replacement of fossil fuels with wood fuel. Expanding woodland cover to 19% of Wales' land area offers the potential to sequester between 44 MtCO_2 and 82 MtCO_2 over the suggested 100 year period (Valatin and Saraev, 2012). However, a full life cycle assessment[33] of the GHG balance of British forestry conducted by Morison *et al*. (2012) using the CSORT model concluded that afforestation with Sitka spruce (YC12) on a peaty gley and a 50 year rotation would produce an average sequestration of 224 tCO_2e/ha with thinning management interventions, and a subsequent 50 year rotation would sequester approximately 196 tCO_2e/ha a total of 420 tCO_2e/ha for a 100 year period. Native broadleaved species such as oak (YC6) grown on brown earth might expect to sequester 694 tCO_2e/ha with minimal interventions during the same period. This supports and potentially reduces the estimated C sequestration determined by Valatin and Saraev, (2012) and suggests that an additional 100,000 ha of forest in Wales would actually provide a net C sink somewhere between 644 and 694 ktCO_2e/yr or a total of 64-69 MCO_2e.

Using the C sequestration potential data of Valatin and Saraev, (2012) the cost of Glastir Woodland Creation would be between £5 and £10 per tCO_2 and the predicted associated climate change mitigation cost-effectiveness estimates ranged from -£21 to £13 per tCO_2.

[33] Included tree biomass; Debris/Litter; Soil; HWP; Forest Operation; Substitution.

These estimates are substantially lower than the 2012 cost-effectiveness comparators which ranged from £22 to £76 per tCO_2 indicating that woodland creation is a very cost-effective climate change mitigation measure (Valatin and Saraev, 2012), but that the estimated C sequestration data used may be optimistic for the expansion of woodlands containing native broadleaved species on organo-mineral soils in Wales.

Prior to the establishment of the Glastir scheme the rate of woodland creation was approximately 200 ha/yr; subsequently an increase, averaged over 4 years, of 775 ha/yr was achieved and is a positive step forward. Despite this increase it is apparent from the rate of uptake of the Glastir scheme that barriers to woodland creation still exist.

The recent Welsh Government Glastir consultation (January-March, 2014) provided an excellent opportunity to obtain feedback from stakeholders, and has been reviewed in addition to stakeholder meetings conducted for this report. Woodland expansion targets are viewed with scepticism and are seen as being unrealistic. However, in general, there was strong support for woodland creation and management for biodiversity. There was also considerable support for mixed woodland planting with a high conifer mixture component to ensure financial sustainability. It should be noted that although **Recommendation 3** states that “planting a range of native deciduous trees, that are well adapted to the mean climate change scenario, and conifers, together with some natural regeneration” that the current Glastir woodland creation scheme only unambiguously supports the use of conifers in one (Small Simple Woodland) of the five woodland categories, and that natural regeneration is not supported at all.

Stakeholder consultation suggests that Glastir Woodland Creation is being hampered by:

- Pest and disease concerns over initial investment and obligations to establish and maintain woodland;
- A lack of specialist advice and information to woodland owners since the amalgamation of Forestry Commission Wales into NRW;
- The traffic light planting map which identifies areas where planting can be conducted is considered to be too restrictive, inaccurate and out-of-date;
- Land within current agri-environmental schemes cannot be planted until the previous scheme has terminated;
- Financial sustainability of native broadleaved woodland is considered lower than allowing coniferous and broadleaved woodland diversification;
- A return to a paper based system of administering Glastir after the Better Woodland for Wales grant scheme ended is a retrograde step;
- The lack of promotion of natural regeneration as an establishment method;
- Concerns over the continued financial support beyond the seven year timescale of the Rural Development Plan;
- The restriction of controlled grazing within woodland preventing farmers from including woodlands within Glastir where a synergy between animal husbandry and forestry may exist. Promoting farm agroforestry and increasing engagement within agri-environmental schemes may also encourage woodland expansion and improved management of farm woodlands.

The use of natural regeneration to expand existing woodland areas with a low establishment cost has been identified by stakeholder groups as potential improvements to the woodland creation scheme which should be encouraged. Natural regeneration is particularly useful for rapidly establishing forest cover with minimal financial outlay where seed sources are available. Appropriate subsequent management interventions (e.g. gap creation and under planting) can lead to woodland with high structural and species diversity, providing both greater ecosystem service provision and improved ecosystem resilience to pressures such as pests and diseases. However, it is recommended that native woodland creation by natural regeneration should be combined with some planting of trees from southern provenances to increase genetic diversity and promote adaptive resilience to climate change. The grant rate for establishing woodland with natural regeneration should reflect that costs of establishment are lower, but costs of management (e.g. respacing) and the implementation of low impact silvicultural systems are higher. Establishment of woodland using natural regeneration is recommended and should be seen as an opportunity to increase woodland cover, especially to inaccessible areas, with low initial establishment costs.

Planting maps generated by Welsh Government should attempt to utilise Ffridd, gorse scrub and bracken land that cannot be easily farmed due to frequency of rocky outcrops, scree, and the slope of the terrain as the ideal location for woodland establishment to maximise woodland expansion whilst minimising the impact of existing farming practices.

Historically, where livestock have had access to woodlands for shelter over-browsing and a reduction of woodland regeneration has occurred leading to a decline in woodland structure and species diversity. Light grazing, however, can have a positive effect and reduce the abundance of vigorously growing species that may reduce diversity and yield. Recent research on this subject is sparse, but Linhart and Whelan (1980) conducted a study on the impact of grazing on oak regeneration in the Clwyd, Denbighshire and demonstrated that protection from grazing did not enhance oak regeneration. Oak regeneration requirements such as periodic ground disturbance by large animals and burial of acorns were lacking, and colonising brambles, as a result of stock exclusion, were inhibiting growth of shade tolerant oak seedlings.

Inclusion of livestock into woodland area can also be beneficial for control of invasive species. Trampling of bracken by cattle, for example, is a useful tool to prevent *Rhododendron* and bracken encroachment, and can also create soil disturbance to promote the recruitment of tree seedlings. However, a simple overarching recommendation for grazing in woodlands is confounded by the selectivity of grazing between different livestock species, and there impact on of invasive species control. For example, when considering ground disturbance as a mechanism for bracken control the hoof pressure of cattle is about 3.4 kg cm^{-2} whilst a sheep hoof pressure is only 1.5 kg cm^{-2}, about 44% of that applied by cattle suggesting that sheep would have little disturbance impact on bracken during summer but maybe suitable for selected winter grazing on wetter sites to improve ground flora. Conversely, winter grazing by cattle on wet sites should be avoided to prevent soil compaction and damage.

Potential benefits exist in permitting controlled grazing during woodland establishment and management, low intensity grazing and an appropriate choice of livestock for environmental conditions. Introducing grazing regimes that can ensure a positive influence on woodland would likely be difficult but not impossible. The potential benefit of promoting limited and controlled grazing would be greater engagement within the GWC and GWM schemes which is likely to have a positive overall impact on woodland creation rates.

<u>Opportunities to increase Wales' wooded areas</u>

The current NFI methodology is restricted to identifying woodland with a minimum area of 0.5 ha under stands of trees with the potential to achieve tree crown cover of more than 20%, and with a minimum width of 20 m (FC, 2011). Woody linear features (hedgerows, riparian buffers and lines of trees) and smaller point features (small clumps of trees) are important components of Wales' landscape and make up over half of all boundaries in Wales. The

National Inventory of Woodland and Trees (1997) identified 14,568 km of linear woody features that were comprised of 15.3 million trees outside of the woodland inventory. These linear woody features are not currently included in the National Forest Inventory, but a comparison of the 2007 land cover map (LCM2007) and spatial data collected during the countryside survey 2007 revealed that the UK has 527,000 ha of linear features, which when scaled to Wales' land area equates to 2.2% of Wales' or 45,000 hectares (Morton *et al*. 2011).

Data on the carbon sequestration potential of linear features is limited but making the pessimistic assumption that this land area would store 1/10th of the carbon stored in a traditional woodland would effectively add between 2.4 and 4.0 Mt CO_2 equivalents of sequestered carbon. Forest Research are investigating methodology to increase the resolution of woodland accounting by using a minimum woodland area of 0.1 ha that can be used in the LULUCF inventory. However, this would still not capture hedgerows as these do not meet the canopy cover and width threshold. CEH have recently been asked by DECC to investigate how the effects of Grassland and Cropland management on carbon stocks in living biomass might be incorporated in the LULUCF inventory. This could include consideration of woody biomass in hedgerows if suitable activity data and stock change factors are available.

During the first year of the Glastir Monitoring and Evaluation Programme (GMEP) 790 km of linear features (hedgerows, riparian buffers, etc.) were surveyed (Emmett *et al.*, 2014). Data has indicated that not only would significant increases to the total woodland area of Wales be achieved if these areas were included in the woodland cover estimate, but that a significant carbon sink of between 2.4 and 4.0 Mt CO_2 e exists that is not currently accounted for. Furthermore, Emmett *et al.* (2014) modelled the potential impact of Glastir Woodland Edge Expansion (option AWE 24) and Streamside Corridor Planting (option AWE 9b) scheme participation and found that under both Low and High participation scenarios between 8,000 ha and 12,000 ha of woodland habitat could be created through this mechanism. This represents approximately 10% of the increased area that the Welsh Government commitment to achieve in woodland cover in Wales and as a currently unaccounted carbon sink could contribute to between 6 and 11 $MtCO_2$ equivalents by 2100.

Optional inclusion of Glastir woodland creation schemes within the UK Woodland Carbon Code provides an additional financial incentive to create woodland by certifying woodland creation projects and accounting for capture and storage of CO_2 in standing woody biomass. The value of long-term sequestered carbon in standing wood needs to be balanced with the potential short-term green economy benefits (e.g. wood fuel harvesting) land owners may wish to exploit which will be influenced by the carbon accounting methodology and Certified Emission Reduction (CER) market price[34]. The volatility of the CER price which peaked in 2008 at £12.50 a tonne CO_2 equivalents but fell to a value of only a few pence during the global financial crisis and is currently valued at around £6 is certainly a factor influencing take up of the scheme but is an excellent first step towards Payment for Ecosystem Services (PES). The discipline of registering schemes with the code and calculating the project lifetime (50 – 100 year) carbon sequestration is a useful check on the data claims for woodland creation.

The Welsh Government, in conjunction with the NRW and Coed Cadw (The Woodland Trust) support the Plant! Scheme where a tree is planted for every child born, or adopted, in Wales. Since 2007 an additional 200,000 native broadleaved trees (80 ha) have been planted through this scheme. Community engagement schemes should be encouraged and expanded as a mechanism for establishing woodland, but offer potential to develop

[34] It is still possible to produce timber while registering with the carbon code, albeit less CO_2 would be sequestered and so the credits available would be lower.

additional avenues for woodland creation through the promotion of the value of woodland ecosystems in schools and local community groups.

Synergies with other objectives and ecosystem services

The GMEP project considered the potential additional benefits to ecosystem services if broadleaved tree species establishment increased by between 3 to 12% using the Glastir Entry Scheme woodland edge expansion and streamside corridor planting options. They found that as a result of reduced land run-off that flooding potential was reduced by between 1 to 9%, and carbon storage was increased by 0.4% (Emmett et al. 2014).

Increasing the woodland cover of Wales has potential benefits for hydrological processes, and flooding. Hydrological studies at Pont Bren in Wales showed that infiltration rates were up to 60 times faster in native woodland shelterbelts compared to grazed pasture. Modelling of the impact of shelterbelts planted on grazed grassland revealed that peak flows could be reduced by between 14 and 48% (Nisbet et al. 2011). However, the current evidence base is not conclusive and studies conducted in England have shown no effect or a reduction of only 1-2% of 1-in-100 year flood event and produce only a 15 minute delay in the flood peak. Forestry may provide its greatest potential benefits when considered at the catchment scale where forest cover can increase hydraulic roughness and reduce the water velocity by 50%, and increase water retention by 71%. These changes resulted in a flood peak that was delayed by 140 minutes (Thomas and Nisbet, 2006).

Modelled data suggest that significant reductions in flood risk could be achieved through the afforestation of floodplain and riparian areas upstream of towns and cities but this would only represent part of a wider set of flood prevention measures. Currently there is a lack of evidence in this area, particularly on the impact of tree species specific traits, soil type and depth profile which requires further research to accurately determine the interactions between Wales' unique soil and geology and flood alleviation.

Sustainable forestry

Forestry practice is covered by the UK Forestry Standard (UKFS) and guidelines for Wales are still provided by the UK Forestry Commission, whilst advice on sustainable forestry can be obtained by the Forestry Commission. Additionally, the UK Woodland Assurance Standard (UKWAS, 2006) contains explicit commitments to low impact silvicultural systems (LISS) which may include, but is not exclusively restricted to, continuous cover forestry operations. Glastir management plans are intended to promote sustainable management practices by requiring adherence to the UKFS, and these requirements should assist in owners in becoming accredited by UKWAS. Certification bodies such as the Forestry Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC) provide independent certification of sustainable forest management in the UK.

Some of the biggest threats to forestry in Wales are the outbreak and transmission of pests and disease. In addition to being unproductive and sequestering little C, woodland in poor condition can promote host susceptibility to pests and diseases. Single species stands with trees of a similar age class and genetic heritage are vulnerable to the same infestations. Microclimatic conditions (temperature, precipitation, humidity) found in unmanaged woodlands are factors that can contribute to an environment that may propagate pests and diseases. The fungus *Dothistroma septosporum* (red band needle blight), for example, could impact circa. 9,000 ha of conifer trees in Wales reducing both yield and CO_2 sequestration potential. Thinning interventions improve air flow through the canopy and create a less suitable habitat for the disease. Additionally, creating woodlands of greater diversity, through improvement to the age class structure, species composition, and provenance of woodlands would not only maintain forest health and yield but would also have an added benefit of increasing resilience to storm damage (wind throw and wind snap). Indeed, 85% of unmanaged woodland surveyed for the Woodland for Wales Indicators Report (2011) showed no recruitment of seedlings and saplings highlighting the need for management interventions that create light and space with either the appropriate seed source to favour the recruitment and establishment of seedlings and saplings, or under planting, to maintain stand productivity, diversity and health.

Existing woodlands being bought into management are generally in poor condition and often with limited accessibility. Woodland management interventions currently supported in GWM are for thinning, restocking, infrastructure provision, boundary fencing, conservation of priority species, vegetation management, pest control and public access. A perception exists that the application process is too complex and that the costs of these activities are insufficiently covered by the current grant system. This could be due to disparity between standard reference rates used by Welsh Government or that these rates do not accurately reflect higher prices required for forestry operations on land of limited accessibility. Public communication about Glastir should be improved and the wide variety of funding options available to manage woodlands without individual outlay should be disseminated.

Improvements to the sustainable management of forests and GHGs can be achieved through:

- Promoting the benefits of management in reducing pest and disease pressure;
- Improvement in communication and the dissemination of grant rate calculations;
- Improved grant rates for early management interventions (e.g. gap creation and under planting) to diversify stand age, structure, species composition and genetic diversity;
- Advocating afforested deep peatland restoration (see annex 8);
- Restricting planting on organo-mineral soils[35] with a deep organic layer and high soil moisture regime;
- Provision of advocacy services and workshops to remove perceived barriers to using LISS practices such as CCF;
- Promoting the benefits of management to increase recruitment of seedlings and saplings;
- Promoting woodland diversification to increase ecosystem resilience.

Assessing the GHG balance of forests

Data on factors of the carbon balance of forests is necessary in order to assess the effect of afforesting and deforesting land.

The LULUCF inventory has recently moved to use Forest Research's CARBINE model to assess change in biomass and soil carbon stocks in forests. This model gives a more complete reflection of the carbon balance of forestry, as it includes a full range of tree species, and improved modelling of forest management practices compared to the previous C-Flow model. However, in both CARBINE and the previous C-Flow model, the ability to accurately model change in soil organic carbon (SOC) stocks in organic soils is limited by the scarcity of UK-relevant field data to parameterise the model. For the 1990-2012 LULUCF inventory, CARBINE was parameterised using the same data as had been used in C-Flow which was based on a small number of sites in Scotland (Hargreaves et al, 2003). However, new, more extensive data on the carbon stocks of forest soils has recently become available

[35] Organo-mineral soils include peaty gleys, peaty podzols and peaty rankers and contain approximately double the C as truly mineral soils

(Vanguelova et al, 2013), and modelling of SOC stocks in afforested organic soils is being reviewed.

A full lifecycle assessment (LCA) of the emissions reduction benefits of wood fuel as a replacement for fossil fuel requires information from the LULUCF inventory to be combined with information on fuel emissions from the energy sector inventory. When wood is harvested for fuel, the carbon in it is released as CO_2, however this may be recaptured in new tree growth. To obtain a full GHG balance for this process the CO_2 released from wood fuel per unit of energy needs to be compared with that released from fossil fuels. More work is required to quantify the life cycle benefits of wood fuel compared to fossil fuel.

Net carbon stock changes from Harvested Wood Products are reported under an additional category 5G of the LULUCF inventory. In the 2013 submission -3401.78 Gg C was submitted but was substantially revised to 99.7.12 Gg C for the 2014 submission, a change of -70.7% following a switch to the CARBINE model. Work is proceeding to ensure the approach for estimating removals and emissions due to HWP are consistent with methodologies agreed at Cancun and Durban and that underpinning data on UK wood production are reported so as to support implementation of these methodologies (Webb et al. 2014).

Annex 7: Land management options for climate change mitigation

Protecting carbon stocks in upland peats and lowland mires and fens.

Wetlands such as bogs, mires and fens store large amounts of carbon as peat in their soils. It is estimated that 121.3 Mt of carbon are stored peats in Wales (Smith et al, 2007). It is important to protect wetlands so that this carbon is not released. In addition some peatland areas have been damaged by activities such as drainage and erosion, and may be losing carbon. If these sites can restored then these carbon losses can be reduced or possibly even reversed.

The original recommendation only considers protecting existing carbon stores, which could largely be achieved with a business as usual scenario with the possible exception of offering protection from wind-farm development on peatlands.

A more ambitious plan to place all degraded peatlands under restoration actions, in line with Welsh Government policy in this area, will have more wide-ranging impacts. Economic impacts may include reduction or cessation of intensive agricultural activities in drained peatlands, reduction or cessation of forestry on deep peat. Peat restoration actions supported by Glastir may however be economically neutral if Pillar II payments for restoration and ongoing peatland management substitute for Pillar I production payments. Actions to re-wet and restore degraded peatlands are likely to have broader environmental benefits including enhancement of biodiversity, and possible benefits for water quality and flood regulation, and may also provide social benefits such as recreational value of restored peatlands. Publication of the IPCC Wetland Supplement in 2014 will provide a basis to account for GHG emissions from drained and re-wetted peatlands in the LULUCF inventory and Kyoto Protocol reporting.

Welsh Government has committed to place all degraded Welsh peatlands under restoration actions within seven years, with financial support via Glastir, and a plan for delivery being developed via the Peatland Action Group. BGS are producing a new map the extent of peat in Wales which is likely to be quite different from the National Soil Survey Maps of Wales because of its more detailed treatment of small areas of peat. The total area of degraded peatland in Wales is currently being mapped and comparison of this area with the current extent of peat restoration (via Glastir and otherwise) will be assessed later in 2014. Large areas of Welsh blanket bog have become dominated by Molinia in recent years, and the effect of this on carbon stocks is unknown.

DECC are currently tendering a project to implement the Wetland Supplement guidance in the UK's LULUCF inventory, which will include developing emission factors for peatland drainage and rewetting which are appropriate to the UK. This work will give a better understanding of the potential to reduce emissions from degraded peatland in Wales through initiatives to encourage rewetting and restoration.

Management of grassland

Management of grazing land can affect the GHG emissions from it. Defra project SP1113 (Moxley et al, 2014) attempted to assess how Grassland management affected soil carbon stocks. Some literature reports suggested that intensification of grazing on improved grassland on mineral soils can increase soil carbon stocks as the increases grass yields needed to support great numbers of livestock lead to increases inputs of crop residues and root exudates to soil. However, there was a lack of evidence on the effect of intensification of rough grazing on organic or organo-mineral soils. There is a risk that measures such as drainage, liming, and cultivation on these soils could lead to loss of soil carbon. More data on the effect of these practices on rough grazing and high carbon soils needs to be collected before full recommendations on intensification can be made for all Grassland types.

If even if intensification does increase soil carbon stocks, this has to be balanced against increased emissions of nitrous oxide due to soil compaction, increased nitrogen inputs from urine and increased methane emissions from increased ruminant numbers. Further, intensification can be associated with increased use of feed supplementation, which can have a high embedded GHG footprint.

The potential benefits of re-seeding lowland pasture as a result of increased carbon inputs to soil need to be assessed against the possibility that carbon losses increase as a results of soil disturbance during cultivation. More field data is needed to assess the effects of reseeding on GHG emissions.

It will be difficult to assess for the LULUCF inventory to assess the area of lowland pasture reseeded each year as this activity does not result in a change in land cover. If this activity were to be included in the LULUCF inventory activity data would have to be collected from other sources such as the Agricultural Census.

Breeding grass varieties to enhance carbon storage could offer an alternative way of increasing the carbon sequestered by grassland, for example using *Festulolium*, an intergeneric hybrid between species of *Festuca* (fescue) and *Lolium* (ryegrass), which occurs naturally as well as synthetically. Breeding targets in the current *Festulolium* breeding programme at IBERS, include increased root mass, primarily as a way of increase plant tolerance to both drought and flooding, but a secondary benefit of this is increased underground plant mass and C sequestration. Similarly, red clover breeding programmes at IBERS are targeting root mass as a way of increasing plant resilience, and this could also have a role in increasing below-ground plant biomass. As far as is known there are no plant breeding programmes aimed specifically at increasing soil carbon stocks, although improved carbon storage could be set as an objective of a breeding programme.

Increasing carbon storage in grassland soils through the introduction of new grass varieties is a long term aspiration, as it takes approximately 15 years from initial selection to market availability of new plant varieties and then at least years to see tangible amounts of C sequestered. The overall potential for mitigation offered by this action is uncertain, and would depend on the results of the breeding programme and uptake of the new grass variety.

One issue with this recommendation is that for a new agricultural plant variety to be sold in Europe, it must be listed on an EU national list following testing for agronomic characteristics. New varieties of grass (or other forages) that partition nutrients away from above-ground parts into roots may have lower crop yields than existing varieties, and therefore although may appear on a national list, they are unlikely to become part of the Recommended List, which would most likely limit their use unless some other intervention was imposed (e.g. as part of an agri-environment scheme).

Cross cutting issues.

Glastir measures are not all designed to reduce net GHG emissions as their primary role. Measures related to change in land use or management could increase carbon storage in soils or plant biomass. Importantly – no Glastir measures appear to increase net GHG emissions, although in some cases there is a trade-off between different emission sources. When considering measures relating to land use and management, the consequences for emissions from productive agriculture need to be considered to ensure that there are no unintended consequences. This report is part of the process of ensuring that a co-ordinated approach is taken to optimise the GHG reduction of Glastir measures.

LULUCF Inventory improvements.

To be credited for reducing GHG emissions, Glastir measures must be reflected in the emissions reported in the LULUCF inventory. Improvements to some areas of the inventory were identified as being necessary to improved capture of the effect of Glastir measures.

As discussed in the Crop/Soil section above, the LULUCF has modelled land use change using land use change matrices which are not spatially explicit. Because of this, it has not been possible to capture the actual history if land use at a site, which has been particularly problematic for rotational grassland. A spatially explicit vector approach to land use change is being developed which will be developed which will take into account the past history of a site when calculating emissions from land use change.

Defra project SP1113 has recently reported (Moxley et al, 2014) on how the effects of land management might be included in the LULUCF inventory, and the 1990 – 2013 inventory will include the effects of Cropland Management. It has proved more difficult to develop a methodology for reporting on Grassland Management because of a lack of field data on the effect, particularly relating to the effect of improving Grassland on organic and organo-mineral soils.

The LULUCF inventory's reporting of Forest Management has improved with the change to using Forest Research's CARBINE model to assess carbon stocks in forests.

Settlements make up a small part of the land area of Wales. When land is converted to Settlement it is taken that half of the area is covered with hard surfaces and half is greenspace. It is assumed that all soil is lost from land covered by hard surfaces, and that greenspace as similar soil carbon stocks to grassland. All of these assumptions could be improved upon, in particular the fate of soils under hard surfaces is not well understood: top soil may be removed for use elsewhere or remain in situ rather than being lost. Data on the carbon stocks of urban soils is very limited.

A project funding by Welsh Government to use Earth Observation to assess the extent of impervious surfaces within urban areas has recently completed, and its findings could be used to improve modelling of the proportion of urban areas in Wales covered by impervious surfaces (Scott et al, in review)

Effects of rewetting drained peatlands

Peat sites with full carbon and GHG budgets are still very limited in Wales and elsewhere, meaning that it is difficult to draw firm conclusions about the global warming potential of intact or degraded peatlands. Currently these data are being collected on a blanket bog in the Upper Conwy (intact, drained and re-wetted sites) and at a site in the Anglesey Fens (intact and nutrient-enriched sites). There are no data for some important land-use/condition categories including afforested peat, lowland peats converted to grassland, blanket bog affected by *Molinia* encroachment, eroding bog, wind farms on peatland. Sites at which measurements are currently taking place are probably representative of less than half the total Welsh peat area, and there is little or no replication within the land-use/condition categories where measurements are taking place.

Research is needed in order to fill this knowledge gap. Implementation of the Wetlands Supplement guidance will increase the need for this information. A number of organisations are currently involved in this work (e.g. CEH, Bangor University, Leeds University with funding from Defra, NERC and others, but there is no clear co-ordination of work. Funding for additional flux measurements could be targeted at priority land-use categories where there is potential for intervention (land-use change, restoration, implementation of Glastir measures etc.) that may lead to significant reductions in GHG emissions.

Annex 8: Mitigation potential of peatland re-wetting and restoration

The research team undertook a preliminary assessment of the potential climate mitigation that could be provided by re-wetting all modified peatlands in Wales. The assessment was undertaken as follows:

1. The new 'unified' peat map of Wales, which has been developed as part of ongoing work for the Welsh Government by BGS and CEH within the Glastir Monitoring and Evaluation Programme, was used as the base map of peat extent. This map combines peat mapping data from BGS with NRW Phase 1 habitat data, as well as some areas of detailed mapping undertaken by the former Forestry Commission Wales.
2. The CEH Land Cover Map 2007 was overlaid on the peat map, to estimate the overall cover of each land-use class on peat. Land-use classes were aggregated into a smaller number of categories for which emission factors could be derived, as shown in Table 26.
3. Emission factors for CO_2, CH_4 and N_2O were assigned to each aggregated land-use category from comparable land classes in the IPCC Wetland Supplement (IPCC, 2014) and interim data from Defra project NR0165 (Developing peatland carbon metrics and financial modelling to inform the pilot phase of the UK Peatland Code; Smyth et al., 2014).
4. Total present day GHG emissions from peatlands were calculated by multiplying emission factors (in to CO_2/ha/yr) for each land class by the estimated area of Welsh peatland in that class
5. The maximum feasible reduction in GHG emissions was estimated by first converting all peatlands to the most appropriate near-natural category (i.e. near-natural bog or fen), then calculating the theoretical emissions (or removals) associated with that category, and finally calculating the difference in total emissions relative to present-day.

Table 26: Area of Land Cover Map 2007 broad habitats on peat, based on unified Welsh peat map

Aggregated land class	LCM 2007 broad habitat classes (and sub-categories where relevant)	Total area on peat	
		ha	%
Bog – near natural	Bog	7,301	8.0
Bog - modified	Bog, grass dominated	19,767	21.7
Heathland	Dwarf shrub heath, Montane	13,527	14.9
Rough grassland	Acid grassland, rough low-productivity grassland	33,988	37.4
Improved grassland	Improved grassland, neutral grassland	5,453	6.0
Coniferous woodland	Coniferous woodland	6,687	7.6
Broadleaved woodland	Broad leaved, mixed and yew woodland	1,612	1.8
Arable	Arable and horticulture	972	1.1
Fen – near natural	Fen, marsh and swamp	367	0.4
Other	Built up areas, freshwater, rock, coastal habitats	1,117	1.2

Due to the preliminary nature of some of the emission factors currently available, incomplete current information on some key aspects of peat condition (notably the presence of artificial drains on blanket bogs) and the limited information provided by the land cover classification, it was necessary to make a number of important assumptions in order to calculate total emissions, as follows:

i) The area of peat classified as 'heathland' was assumed to be drained, whilst all other areas of bog and fen were assumed to be undrained. This simplistic assumption will be superseded once a new map of drained peat area has been developed as part of the Glastir Monitoring and Evaluation Programme.

ii) All rough grassland was assumed to have the same emissions as modified bog (a Peatland Code category) rather than drained grassland (an IPCC category) since the latter emission factor was derived from more highly drained and modified European grasslands, and no directly applicable emission factor currently exists for rough grassland on upland peat.

iii) An area of 450 ha of eroding blanket bog (based on an estimate provided by NRW) was included in the analysis, and assumed to occur within the 'modified bog' category.

iv) The area of improved grassland was assumed to be 50% on bog peat, and 50% on fen peat, and the appropriate (IPCC) emission factor assigned to each component.

v) All coniferous woodland was assumed to occur on bog peat, and all broadleaf woodland and arable land on fen peat.

vi) All woodland was assumed to be managed. GHG emissions from the peat were derived from the IPCC's 'temperate forest on bog' emission factor, while the net effect of CO_2 uptake into tree biomass in terms of avoided emissions (i.e. accumulation into harvested wood products and substitution of fossil fuels) was estimated from information presented in Broadmeadow and Matthews (2003), which suggests a long-term mitigation value of around 2.7 tCO_2/ha/yr (Figure 10).

vii) The small area of peat (1.2%) classified as 'other land' was assumed to either be the result of misclassification or to have zero net emissions, and was therefore excluded from the assessment.

viii) All areas apart from 'other land' were assumed to be restorable to near-natural bog or near-natural fen.

As shown in Table 26, over one third of the mapped Welsh peatland area is classified by LCM2007 as rough grassland. Areas remaining as bog account for just under 30% of the mapped area, of which the majority is classed as modified (i.e. grass dominated), whilst only 0.4% is mapped as intact fen. Woodland accounts for 10% of the mapped area, heathland (assumed here to be drained bog) for 15%, and intensive agriculture (improved grassland and arable) for just 7%. As noted above, there are many uncertainties within this classification, and it is possible that some areas of more intensive land-use on peat could be due to map classification errors, for example due to 'edge effects' where peat polygons and agricultural land-use polygons overlap within mosaic landscapes.

Some of the emission factors currently available are also considered highly uncertain, either due to the limited number of flux measurement studies used to derive them, or due to the limited transferability of the flux study sites to peat and land-use types that occur in Wales. For example, there are no currently published measurements of GHG fluxes for *Molinia*- or acid grass-dominated blanket bogs, and the (relatively high) IPCC emission factor for temperate forest on bog is derived from a very small number of flux studies, only one of which took place in the UK. Ongoing work should provide more robust data on peat condition, land-use and associated emissions, therefore the data presented here should be considered as indicative estimates of the overall mitigation potential, which will be refined as new data become available.

Overall, the emissions calculations (Table 27) suggest that improved grassland on peat currently represents the largest total GHG emission source from Welsh peatlands, followed by modified and drained bog, coniferous woodland and arable land. Eroding bogs and broadleaf woodland make relatively minor contributions to emissions due to their small overall areas. The total mitigation potential of different land-use classes shows a similar pattern, with the greatest mitigation potential associated with re-wetting and restoration of improved grassland to bog and fen, followed by similar mitigation potential associated with the restoration of conifer forest, modified bog and rough grassland, and drained bog. Restoration of arable land on peat would make a modest contribution to total mitigation, although on a per unit area basis (final column) this would generate the largest emission savings. Similarly, although restoration of eroding bog would provide limited total mitigation potential, this also represents a highly effective measure on a per unit area basis. Overall, the potential climate mitigation that could be attained by fully restoring all Welsh peatlands is estimated to be around 320 ktCO_2e/yr.

Table 27: Estimated present-day GHG emissions, and mitigation potential following restoration to near-natural bog or fen, for aggregated land-use categories on peat in Wales

Aggregated land-use category	Area	2012 emissions	Emissions if restored	Maximum potential emissions reduction	
	ha	ktCO_2e	ktCO_2e	ktCO_2e	tCO_2e/ha/yr
Improved grassland	5,453	134	3	131	24.0
Coniferous woodland	6,887	60	4	56	8.2
Modified bog and rough grassland	53,306	77	28	49	0.9
Heathland (assumed drained)	13,527	55	7	48	3.6
Arable	972	33	7	26	27.3
Eroding bog	450	10	0	10	22.8
Broadleaf woodland	1,612	14	11	3	1.9
Near-natural bog	7,301	4	*Not applicable*		
Near-natural fen	367	2	*Not applicable*		

As emphasised above, this assessment is based on uncertain data and a number of crude assumptions, particularly in relation to the area of Welsh blanket bog that is actually drained, for which more reliable estimates should soon be available. The assessment also assumes that all areas are theoretically restorable. While this may indeed be the case for areas retaining a semi-natural vegetation cover, it may be much more difficult to convert areas that have been subject to major hydrological or structural changes (e.g. afforested bogs) and/or major modification of vegetation, nutrient levels and acidity (e.g. improved grassland and arable land) back to their peatland function. GHG emissions associated with land-use transitions (such as ‘spikes’ of CH_4 or N_2O emission after re-wetting) have also not been factored into the analysis. On this basis, the overall calculated mitigation potential may represent an over-estimate of the degree of emission reduction that is practicably achievable.

On the other hand, it is possible that the amount of GHG reduction that could be obtained by restoring grass-dominated and drained bogs may be under-estimated; these areas occupy a large part of the total Welsh peatland area, but current emission factor estimates suggest that restoring these areas would (on a per unit area basis) deliver only fairly marginal reductions in GHG emissions. Since these emissions estimates are based on a relatively few (and in the case of *Molinia* bog, no) directly relevant flux measurements, these values are highly uncertain and may represent under-estimates of the true emissions. Given the very large areas involved, even small increases in the estimated GHG emissions per unit area for these modified bog categories could greatly increase the total mitigation potential resulting from their restoration.

Annex 9: Climate change mitigation from renewable energy generation

Government policies and targets on renewable energy at all levels are critical to this application. The need to reduce greenhouse gas emissions and the consequent urgent requirement to decarbonise electricity generation is of national and international importance. Relevant policies and strategies include:

- The Climate Change Act (2008)[36]
- The Renewable Energy Strategy (2009)[37]. The targets are now enshrined in SI 243 - Promotion of the Use of Energy from Renewable Sources Regulations which came into force on 14th March 2011
- National Policy Statements[38]
- The Renewable Energy Roadmap 2011 and 2012 and 2013 updates[39]

Welsh Government's Energy Policy Statement, 2010 (EPS) sets out two aims related to renewable electricity and consumption, namely:

1. Wales will renewably generate up to twice as much electricity annually by 2025 as it consumed in 2010; and
2. By 2050, at the latest, all Wales' energy needs for heat, electrical power and transport will be met by low carbon electricity production.

Consequently the target for renewable electricity generation was increased from 7 TWh of electrical output per annum to 48 TWh by 2020/25. In 2013, Wales generated 2.7 TWh (Energy Trends, September 2014) using renewables. This means that Wales would need to increase electricity generated using renewables by 18 times to meet this target. The EPS then sets out how this could be achieved by setting targets for renewable electricity generation and installed capacity. The average annual installation rates would need to increase from approximately 50 MW over the period 2003-2001 to 1,600 MW per year 2013 to 2025 to achieve this potential. The EPS states that 1 GW of capacity could be provided by 'local electricity generation (mainly PV/Wind/Hydro)'

Planning Policy Wales (PPW) Edition 5 sets out the WG's land use planning policies and has been revised in the context of the WG's energy policy. PPW sets out a broad strategic framework which is clear in its support for renewable energy generation. It also sets out the material considerations which should be addressed when determining applications for planning permission. These criteria include:

- Contribution to renewable energy targets
- Wider environmental, economic and social benefits
- Impact on natural and historic environment
- Need to minimise impact on local communities and safeguard quality of life
- Avoid/mitigate/compensate adverse impacts
- Grid connection
- Transportation issues

In this annex we set out the mitigation potential of the main renewable technologies in turn and highlight key issues for uptake.

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[36] HM Government, 2008, Climate Change Act 2008
[37] UK Renewable Energy Strategy 2009
[38] In particular, Overarching National Policy Statement for Energy (EN-1) (July 2011) and the National Policy Statement for Renewable Energy Infrastructure (EN-3) (July 2011)
[39] UK Renewable Energy Roadmap (July 2011); UK Renewable Energy Roadmap Update 2013 (December 2012); UK Renewable Energy Roadmap Update 2013 (November 2013).

Wind energy

Renewable energy generation in Wales is currently dominated by onshore wind, accounting for almost two thirds of the total (NAW, 2013). Offshore wind generation is expected to expand rapidly, but onshore wind retains a significant cost advantage and has considerable potential for further expansion. In order to meet the 2020/2015 targets set in the Welsh Government's Energy Policy Statement (EPS) 2010, onshore wind electricity generation will need to increase by a factor of almost three, and offshore wind electricity generation will need to increase by a factor of over six. Meanwhile, nascent tide and wave electricity generation would need to be installed at an average rate of over 1 GW per year to meet EPS targets. If EPS targets are met, the annual GHG mitigation potential associated with onshore wind, offshore wind and tide/wave generation would amount to over 1, 4 and 8 $MtCO_2e$, respectively, delivering an additional 13.3 $MtCO_2e$ mitigation compared with current operational and approved RE capacity. The major barriers to the EPS targets are the cost and lack of commercial experience with large scale tide/wave electricity generation technologies, and the comparatively high cost of offshore wind electricity generation.

Energy yields per gross hectare are relatively high for wind energy compared with other renewables, and energy yields per net hectare utilised are very high. Annually, wind turbines can displace over 300 MWh of primary energy per gross hectare utilised at typical load factors (RWE, 2014; NREL, 2009), compared with 55 MWh of primary energy per hectare of short rotation coppice. Therefore, each ha of wind farm can avoid 44 tCO_2e annually (>440 tCO_2e/yr per net ha utilised), assuming replacement of NGCCT marginal electricity generation (DECC, 2012; Defra, 2012). Establishing wind turbines on 1% of Welsh land area (i.e. 20,761 ha) could avoid 0.913 $MtCO_2e$ annually. Wind turbine foundations and access tracks occupy less than 10% of the land where they are located, and as little as 1% according to some data (RWE, 2014), leaving the remaining land area available to deliver food production (e.g. sheep/cattle grazing) or other ecosystem services.

There are significant planning barriers to further expansion of onshore wind generation, in particular objections to visual impacts on valued landscapes. Clear guidelines on the weighting that should be placed on visual objections relative to strategic national energy security and climate change objectives could facilitate planning decisions. There are also challenges to integrate wind generation into the national grid network, which will require significant grid upgrades to accommodate.

Biomass energy

Biomass currently comprises approximately 10% of the 760 MW of operational renewable energy generating capacity in Wales, but this is expected to increase dramatically to approximately 30% of the 2900 MW capacity that has been approved to date (NAW, 2013). However, a large quantity of firewood is burned in Wales for domestic heating without being recorded in national statistics (see below), which could amount to 1 TWh of bio-heat and additional bioenergy GHG mitigation of 0.340 Mt CO_2 (Table 29).

There is considerable scope for indigenous bioenergy feedstock production in Wales. Miscanthus breeding work in IBERS has made recent advancements in establishment using seeds, significantly reducing upfront costs for farmers wishing to plant this high-yielding energy grass. Meanwhile, the development of high-sugar grasses offer great promise for more sustainable ethanol production. However, in the near term, the greatest potential for bioenergy generation in Wales is from wood provided by forestry thinnings and dedicated short rotation forestry.

Official statistics on the use of wood heating in Wales do not capture significant quantities of fuel wood gathered or exchanged outside of the formal market. Data on domestic firewood consumption and supply is lacking (DECC, 2013). Biannual surveys across Wales over the period 2005-2011 indicate that around one in 10 households in Wales use wood as a fuel (Forestry Commission Wales; 2005, 2007, 2009, 2011) and there is little evidence of a trend over this period. Wong and Walmsley (2012) undertook a Wales-wide survey in 2012 of 535 households and extrapolated their results up to a nationwide estimate of 576,000 m^3 per year. This is in addition to the official annual cut of around 1.2 million m^3, as more than half of households self-source, and represents 1.00 TWh of bio-heat assuming 70% conversion efficiency in wood stoves (the most common use of heating wood according to Wong and Walmsley, 2013). The magnitude of GHG avoidance achievable through this unrecorded bioenergy generation can be estimated by assuming that oil heating, with a life cycle GHG intensity of 0.34 $kgCO_2e$ per KWh_{heat} (Ecoinvent, 2010), is avoided. Forestry-wood heating has a very low lifecycle GHG intensity equivalent to just 1% of oil heating (Gustavsson and Karlsson, 2002). Thus, the annual quantity of additional GHG mitigation achieved by unrecorded bioenergy is in the region of 0.34 $MtCO_2e$.

Further work currently at Bangor University is attempting to devise robust methods for the characterisation and quantification of domestic firewood usage and discussions are currently being held between the University and the Department of Energy and Climate Change to take this forward. The recently launched domestic Renewable Heat Incentive (RHI) is likely to drive investment in micro-scale wood heating systems, whilst the large areas of woodland creation planned in Wales will offer a greater potential supply of fire wood. The magnitude of additional GHG mitigation achievable through expansion of micro-scale wood heating can be estimated as equivalent to current mitigation - i.e. representing a doubling of current micro-scale wood heating (Table 29).

Life cycle GHG emissions for heat generated from wood produced in dedicated short rotation coppice (SRC) systems are approximately 0.045 $kgCO_2e$, compared with 0.248 and 0.331 $kgCO_2e$ for gas and oil heat, respectively (Styles and Jones, 2008). Thus, shifting from fossil- to SRC-wood-heating could also lead to significant GHG emission reductions. A simple scenario at the national level, assuming 1% of Wales' land area could be used to cultivate short rotation coppice or similarly productive biomass production, could lead to the avoidance of 0.202 $MtCO_2e$ annually (20,800 ha x 8 t dry matter (DM)/ha/yr x 18 GJ/t DM x 1000,000/3600 kWh x 0.85 conversion efficiency x (0.331-0.045) $kgCO_2e$/kWh). This is more than sufficient to meet Wales EPS target for additional mitigation from biomass of 0.071 $MtCO_2e$ and recognises the multiple pressures on land for productive agriculture, managed habitat, forestry etc. It is likely that such quantities of wood could be produced without displacing significant food production. Strategic planting of forestry in areas of lower agricultural productivity avoids significant displacement of food production. Trees planted as shelter belts, buffer strips and runoff/erosion breaks (woody linear features; *Recommendation 3*) have the potential to complement sustainable food production.

Barriers to biomass energy include relatively long payback times and commitment periods for forestry, even short rotation forestry, and relatively few pelleting plants to produce the high-quality (homogenous) pellets required for efficient micro-scale wood heat generation. There are also psychological barriers for some farmers to dedicate land to forestry or other non-food production uses.

Biogas (anaerobic digestion)[40]

As of 2013, there were 223,208 dairy cows in Wales according to DairyCo (2014), producing an estimated 1662 million litres of milk. Assuming a similar size distribution to the overall UK herd, 66% of milk output arises on farms producing more than 1 million litres per year, and 31% on farms producing more than 2 million litres per year. Assuming slurry generation of approximately 0.25 kg dry matter (DM) per litre of milk produced, and that half of milk production on farms producing more than 2 million litres per year occurs in confinement

[40] See also animal husbandry section on the potential and barriers for farm anaerobic digestion (AD).

systems, LCA modelling results for GHG mitigation from Styles et al. (2014) can be extrapolated to estimate the total GHG avoidance that could be achieved if all farms producing more than 1 million litres of milk installed AD systems. GHG avoidance is dependent on the type of slurry management system replaced, being considerably greater where lagoon slurry storage is replaced.

Farm practice survey data (Defra, 2014) indicates that tank and lagoon slurry storage is split approximately 50:50 across dairy farms. The electricity generated by dairy farm AD units accounts for between 13% and 45% of the life cycle GHG avoidance, where tank and lagoon slurry storage is replaced, respectively. For non-confinement dairies, in the absence of significant co-feedstock input (which could be associated with significant carbon leakage in the case of crops), the most economic application of AD is small scale heat-only systems. Table 28 indicates that the maximum GHG avoidance achievable through AD of dairy slurries in wales is approximately 0.349 MtCO_2e/yr. Co-digestion of additional waste feedstocks such as pig and poultry manures and food waste could considerably enhance this GHG mitigation potential, although the Welsh Government is committed to diverting food waste to centralised non-farm AD units. Styles et al. (2014) calculated GHG avoidance of up to 1021 kgCO_2e/t DM food waste digested, assuming substitution of composting.

Experience of on-farm AD in the UK so far shows that FiTs for AD electricity are driving a rapid expansion in crop AD, with crop feedstock often dominating even in situations where large quantities of animal waste are present (NNFCC, 2014). This creates a risk for carbon leakage via intensification and land use change associated with displaced production of food and animal feed. Styles et al. (2014) found that crop-only AD can lead to significant, though not particularly high, GHG mitigation of up to 6.63 tCO_2e/ha/yr under a best-case scenario where all CHP heat and electricity are used, but more typical GHG mitigation of just 1.52 tCO_2e/ha/yr where CHP heat is dumped, assuming no carbon leakage. However, under a worst case assumption of all displaced food production incurring land use change, crop-only AD leads to a net increase in life cycle GHG emissions of almost 5 tCO_2e/ha/yr. Compared with other options reported here and elsewhere, crop-only AD is at best an inefficient use of land for energy generation and GHG mitigation.

Table 28: Potential GHG avoidance via anaerobic digestion of medium to large dairy farms in Wales

Farm size (million litres milk sold/yr)	**Slurry generated (t DM/yr)**	**Slurry handling system**	**Biogas use**	**GHG avoidance (kgCO_2e/t) slurry**	**National GHG avoidance (tCO_2e/yr)**
1– 4	176,588	Tank	Heat only	240	42,381
1– 4	176,588	Lagoon	Heat only	1332	235,215
> 4	31,163	Tank	CHP	495	15,426
> 4	31,163	Lagoon	CHP	1787	55,688
Total					**348,710**

Solar PV

The Feed-in Tariff (FiT) is currently driving expansion of solar PV. A progressively reducing FiT rate is being compensated by falling PV cell manufacturing and installation costs. The GHG mitigation potential of solar PV is comparatively small in the near term, compared with wind and biomass.

Large arrays of solar PV panels may be installed in fields, creating the opportunity to maximise power output by optimising orientation (south) and angle (30-40^0). NFU (2010) note that 2 ha of land are required per MW of installed capacity, similar to capacity outputs quoted in case study statistics for existing and planned field arrays (TGC Renewables, 2014). Based on an electricity yield of 850 MWh per MW installed (optimum angle and orientation, North Wales: Energy Saving Trust, 2014), that would translate into 425 MWh electricity (1063 MWh primary energy) per hectare. This in turn would translate into a GHG saving of 157 tCO_2e/ha/yr. Establishing solar PV arrays on 1% of Welsh land area (i.e. 20,761 ha) could avoid 3.259 $MtCO_2e$ annually.

Although it is claimed that sheep can graze among solar PV cells, food production will be minimal where PV arrays are efficiently arranged to maximise interception of solar radiation, and therefore solar PV fields could be associated with indirect GHG emissions ("carbon leakage") via intensification or land use change elsewhere. However, even under worst case assumptions, this effect will be minor compared with aforementioned GHG mitigation achieved via fossil energy displacement.

Hydro

Hydropower contributed approximately 300 GWh of electricity to the Welsh grid in 2011, representing approximately 14% of renewable electricity generation (WAG, 2013). However, growth in hydropower output is low, and installed hydropower capacity is forecast to increase much more slowly than other RE options such as wind. Although the number of hydropower sites more than doubled between 2003 and 2011, the installed capacity of hydropower installations increased by only three per cent (WAG, 2013).

The FiT is encouraging some small scale hydro, but, as indicated in the previous figures, the cumulative output, and therefore GHG mitigation potential, of these schemes is small. An Environment Agency report (EA, no date) found that small scale hydropower (e.g. on weirs) could contribute at most 1% of the UK's electricity demand by 2020, based on a maximum technical potential of 1200 MW installed capacity across England and Wales. However, that report noted significant ecological barriers to realising this potential, especially detrimental impacts to sensitive fish habitats, and that a high proportion of potential hydropower sites in Wales exhibited high ecological sensitivity. A study by the British Hydropower Association and IT Power on behalf of DECC and WAG (BHA & IT Power, 2010) indicated a much lower realistic potential installed capacity of 146 to 248 MW across potential new hydropower sites in England and Wales, of which 26 to 63 MW were located in Wales. Thus, the potential for hydropower to contribute to further GHG mitigation in Wales appears to be highly limited. Assuming a load factor of 75% over the year, the aforementioned hydropower capacities would lead to GHG avoidance of between 63,203 and 153,147 tCO_2e/yr.

EA (no date) did not evaluate opportunities for large scale hydro generation via new dams, but note the ecological barriers associated with such large scale systems. There does not appear to be much information on large scale hydropower potential in Wales, which may warrant further investigation.

Aggregate mitigation potential from renewables

A summary of the mitigation available from all the land-based renewables is set out in Table 29. This represents a total of around 3 $MtCO_2e$/yr. This needs to be seen in the context of targets for offshore wind of 5.8 $MtCO_2e$/yr and tidal/wave development of 8 $MtCO_2e$/yr, which highlight the overall scale of reliance on renewables and the need to be bold with land-based technologies where possible. In terms of the WG 3% target, they have limited mitigation potential within the sector apart from offsetting end-use consumption in agriculture. More widely, they have an impact of power generation in Wales but any analysis needs to allow for increased exports of renewable electricity (to England) when assessing net mitigation potential for WG targets.

Table 29: GHG mitigation potentials for different options in Wales, with simple indicative scenarios of national additional GHG mitigation potential

Technology	Existing GHG mitigation ($MtCO_2e/yr$)	Estimated GHG mitigation per area ($tCO_2e/ha/yr$)	Indicative scenario	National indicative additional mitigation potential ($MtCO_2e/yr$)	Barriers
Onshore wind	0.537	44	2% Wales area†	1.29	Local objections to planning, and grid connection
Solar PV (roofs)	0.0033*	157	Welsh micro RE target††	0.167	
Solar PV (fields)	0.041*	157	0.1 % wales area	0.285	Local objections to planning, and grid connection
Large hydro	0.111				
Small hydro		NA	Feasible small scale units	0.063 – 0.153	Cost of installing small scale systems, grid connection, property rights
Biomass (official)**	0.142	9.724	Mix of forestry waste, willow etc.	0.869	Lack of developed market for biomass/wood energy
Biomass (unrecorded local use)‡	0.340	NA	Doubling of local use (availability from woodland planting)	0.340	No systematic recording of “casual” wood fuel use
Dairy biogas	Negligible	NA	All dairy farms > 1 M litres milk output	0.238 Mt	Poor economics for slurry-only systems (FiT encourages digestion of crops)
Crop biogas	Negligible	6.63 (best case); 1.52 (typical deployment); -5 (worst case *increase* in GHG emissions)	1% Wales area under maize for AD	0.138 Mt (best case); 0.032 (typical deployment); -0.104 (worst case *increase* in GHG emissions)	

*Based on 2013 micro-RE data, assuming mostly solar PV (NAW, 2013), and 115 GWh solar PV generation in Wales in 2013 (DECC, 2014); ** Based on 76 MW installed capacity for biomass (NAW, 2013), operating at 75% load factor to replace oil heating; †Similar to the implied land take for the 2010 Energy Policy Statement target for onshore wind; ††Referred to in WAG (2008); ‡Wong and Walmsley (2013), assume oil heating avoided.

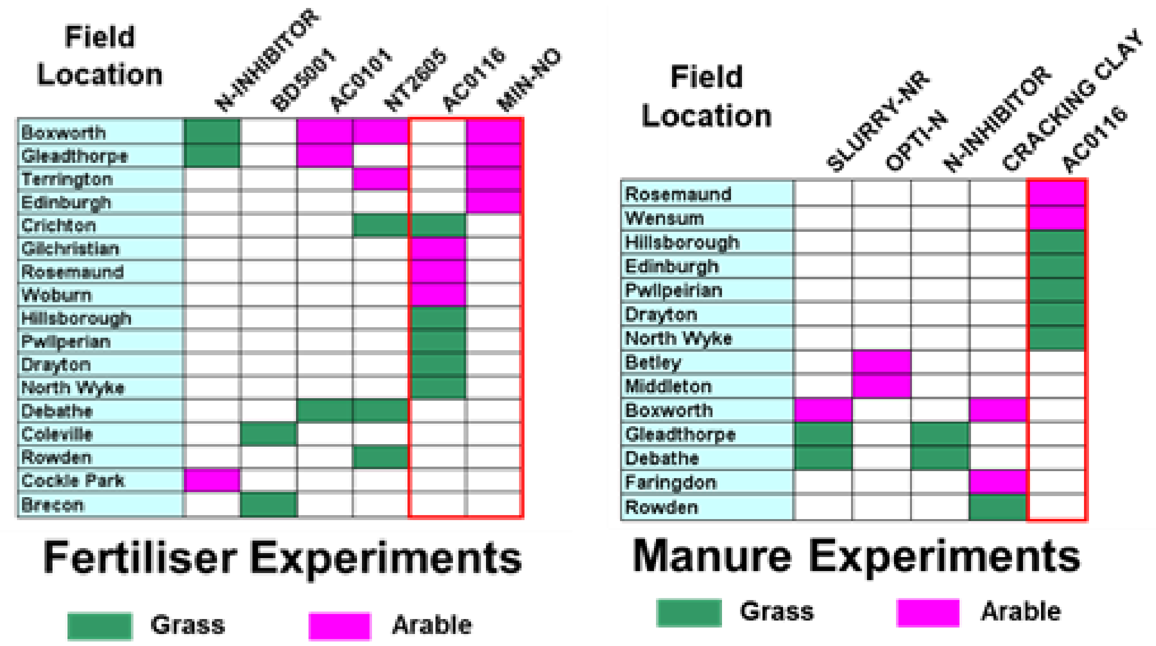
Annex 10: Agricultural greenhouse gas inventory development

The Agricultural Greenhouse Gas Research Platform (Defra projects AC0114, AC0115 and AC0116) was commissioned in November 2010 and is due to complete in June 2015. The programme is tasked only with developing a revised GHG inventory methodology for the Agriculture sector. A follow on project (SCF0102) was commissioned by Defra in October 2013 and is tasked with implementing the revised methodology as an automated calculation and mapping system, and delivering annual inventory reports by March 2016. The inventory method development programme is well developed, and the Welsh Government participates and provides regular feedback to the management and delivery teams at six-monthly Programme Management Group meetings chaired by Defra.

The inventory method development programme seeks to:

a) Develop emission factors based on United Kingdom measurements of nitrous oxide emissions from manufactured and organic nitrogen fertiliser, which explicitly represent variability in environmental risk factors (soil and climate) between countries (England, Wales, Scotland and Northern Ireland).

This is addressed by projects AC0114 and AC0116. The AC0116 project is delivering field measurements of nitrous oxide emission factors for manufactured nitrogen fertiliser, managed manure, dung and urine at nine sites representative of United Kingdom soils and climate, at a range of fertiliser rates that span current practice. Of special relevance to Wales, the AC0116 project is measuring nitrous oxide emissions from pasture at five research sites (including Hillsborough, Crichton and North Wyke) with similar soil and climate conditions. The AC0116 field sites were specifically selected to augment measurements made under previous and parallel research projects, including the NT26 and MIN-NO projects. The AC0114 project is responsible for collating emission factor measurements from all projects (Figure 10), with the aim of developing a statistical model that predicts emission factors as a function of local soil and climate. This will be carried out separately for arable and pasture, and for nitrogen sources (fertiliser, manure, dung, urine) to implicitly account for the effects of application timing.



Source: AC0116 project and other projects that will contribute measurements to the final synthesis.

Figure 10: Field study sites selected for measurement of nitrous oxide emission factors

b) Develop methane conversion factors based on United Kingdom measurements of enteric methane emissions from cattle and sheep of various breeds, ages and physiological state on different diets, which explicitly represent any differences between lowland and upland livestock.

This is addressed by project AC0115 that completed in January 2014. Measurements of enteric methane from dairy cattle, beef cattle and sheep of varying breed, age, body-weight, physiological state were made under controlled conditions in respiration chambers and at grazing. Coupled with measurements of feed intake, this enabled calculation of the proportion of feed gross energy excreted as methane energy. Eight different breeds of sheep and eight breeds of cattle were investigated, and seven different types of forage for sheep and eleven for cattle. A focus of the project was generating conversion factors for beef cattle of all ages, and immature dairy cattle, on contrasting improved and semi-improved pasture types. Statistical analyses of the results emphasised the over-riding importance of dry matter intake in controlling methane emissions, with little or no important additional effects of other potential controlling factors, such as breed or pasture quality.

Project AC0114 has extended this work by a meta-analysis of measurements of emissions from cattle and sheep reported in the literature (McBride et al., [YEAR]) and further statistical modelling incorporating existing large databases of methane emissions from individual animals maintained by research organisations in the United States, Northern Ireland and The Netherlands (Crompton et al., [YEAR]). It is anticipated that the final synthesis model will predict the methane conversion factor from dry matter intake, itself derived from the energy requirements of an animal, and that the conversion factor will decrease with intake, i.e. high producing animals will have a lower GHG emission intensity.

c) Develop a tier-two methodology for calculating potential enteric methane emissions from cattle and sheep, based on feed and product energy balances, that explicitly represents variability in livestock breeding and finishing systems between countries.

This is addressed by project AC0114 that is developing an approach to disaggregating total livestock numbers reported by the June Agricultural Survey between breeding and finishing system types that can be associated with, for example, information on rate of live-weight gain and age at slaughter, and access to different types of feed that will affect the individual animal's emission footprint. For sheep, a specially commissioned survey of lambing practices has enabled disaggregation of the sheep sector between the lowland, upland and hill flocks. For cattle, the focus is on use of the Cattle Tracing System to disaggregate beef cattle between suckler herd and finishing systems, with separation of the finishing systems between those finished at 11 to 14, 15 to 17, 18 to 20 or 21 to 24 months. A proposed inventory structure for representing a range of livestock systems has been documented (Misselbrook et al., 2012).

d) Spatially disaggregate government surveys of agricultural practices, including fertiliser use, to better reflect differences in land and livestock management between countries.

Project AC0114 has led the analysis of existing surveys of manufactured and organic fertiliser nitrogen practices in the United Kingdom, with a focus on the ability to disaggregate survey data by country. The principal source of information on manufactured fertiliser nitrogen is the British Survey of Fertiliser Practice that traditionally reports practice for 'England and Wales' in aggregate. Statistical modelling has demonstrated that production of Wales-specific survey data is feasible for grassland, taking account of the restrictions on sample number to control uncertainty propagation. The survey sample number is inadequate to produce Wales-specific data for arable crops. However, the survey is stratified by Robust

Farm Type and in general, statistical analyses have demonstrated that Robust Farm Type (e.g. specialist Cereal, or Lowland Cattle and Sheep) explains more of the variability in fertiliser use than country or region. Therefore, in the short-term it is proposed that survey data for England, are extrapolated for use in Wales, on the basis of Robust Farm Type.

e) Represent the impact of changing farm practices and adoption of specific mitigation methods to control agricultural GHG emissions.

Project AC0114 has led on the representation of mitigation. To a large extent, the mitigation practices highlighted by the 2010 LUCGG recommendations concern improvements in production efficiency (e.g. reduction in fertiliser use, and increase in productive life of breeding stock) or changes in the farm management system (e.g. adoption of anaerobic digestion). These types of change are termed 'implicit' in the improved inventory, as they affect the mass flow of potential emissions and the effects will be automatically captured by changes in the agricultural practice survey data directly input into the inventory calculations. The challenge is that whilst some survey data are annually updated (e.g. surveyed nitrogen fertiliser rates and animal numbers), others will require commissioning of special surveys or expert consultation to track change (e.g. the proportions of farms adopting various manure management systems).

Project AC0114 has also developed a list of 48 explicit mitigation methods that will be represented by modifications to an emission factor in the inventory calculations (Table 30). The majority of these mitigation methods concern the reduction of ammonia emissions from manure management systems, with indirect consequences for nitrous oxide emissions. The improved inventory model will therefore have the ability to provide a more accurate baseline for GHG emissions from agriculture in Wales and the ability to track changes, but will depend on the continued provision of timely and robust activity data in order to deliver this.

Table 30: Mitigation methods in the improved Agricultural GHG inventory by change to emission factor

No	Sector	Type	Sub-type	Name
1	Livestock	Base Diet Change	Winter Diet	Maize Silage
2			Winter Diet	Whole Crop Silage (Wheat, Barley or Oats)
3			Summer Diet	High Sugar Grasses
4			Winter Diet	Lower Crude Protein Diet Formation (Concentrates)
5		Dietary Supplements	Oils, Fat or Lipid	Fat Supplement
6		Genetic Potential	Breed or Line Specific	Lower Base Enteric Methane Conversion Factor
7	Land	Fertiliser Management	Inhibitors	Urease Inhibitor
8				Nitrification Inhibitor
9		Soil Management	Cultivation	Minimum Tillage
10				Zero Tillage
11			Hydrology	Field Drainage (Working Drains)
12		Crop Management	Soil Nitrogen	Cover Crop
13			Nitrogen Fixation	Clover Rich Pasture
14				Leguminous Forage Crop
15	Manure	Manure in Housing	Broiler and Turkey Litter	Alum Additive
16			Broiler and Turkey Litter	Manure Drying (House Heat Exchange Unit)
17			Layer Manure	Manure Drying (Belt System)
18				Frequent Removal (Belt System)
19			Mechanically Ventilated Housing (Pig and Poultry)	Air Scrubber and Bio-Filters
20			Pig Slurry	Frequent Removal (Vacuum Pump)
21		Manure in Yards	Cattle Collecting Yard	Daily Washing Down
22		Manure in Storage	Slurry Storage	Rigid Store Cover
23				Floating Store Cover
24				Natural Crust
25				Acidification
26				Aeration
27				Cooling
28				Solids Separation
29				Anaerobic Digestion
30			Farm Yard Manure Storage	Store Cover
31				Compaction
32				Active Composting
33			Broiler and Turkey Litter	Incineration
34		Manure in Fields	Slurry Application Technique	Band Spreader (Low Trajectory)
35				Injection
36			Slurry Incorporation Technique	Incorporated within 6 hours by Plough
37				Incorporated within 6 hours by Disc or Tine
38				Incorporated within 24 hours by Plough
39				Incorporated within 24 hours by Disc or Tine
40			Farmyard Manure Incorporation Technique	Incorporated within 6 hours by Plough
41				Incorporated within 6 hours by Disc or Tine
42				Incorporated within 24 hours by Plough
43				Incorporated within 24 hours by Disc or Tine
44			Poultry Manure Incorporation Technique	Incorporated within 6 hours by Plough
45				Incorporated within 6 hours by Disc or Tine
46				Incorporated within 24 hours by Plough
47				Incorporated within 24 hours by Disc or Tine
48	Land	Fertiliser Management	Fertiliser Placement	Percent incorporation or directly placed into soil

Annex 11: Land Use, Land-Use Change and Forestry (LULUCF) inventory

To date the assessment of land use change within the Land Use, Land-Use Change and Forestry (LULUCF) inventory has used a model based on land use change matrices which apply rules on possible transition to data on land use change obtained from Countryside Surveys which take place approximately once every decade. This approach is not spatially explicit, and assumes that land is in carbon equilibrium at the start of a transition. Because soil carbon stocks can take decades to centuries to reach a new equilibrium after a change in land use, this is an oversimplification. Some types of land use change, particularly rotation between grass and crop take place frequently, every few years, and therefore carbon equilibrium is unlikely to be reached in these systems.

As part of the Defra SP1113 project (Moxley et al, 2014) the feasibility of using IACS data to track the use of land parcels was investigated. It was possible to map transitions between land use types for land eligible for CAP payments. The results for Wales between 2008 and 2009 are shown in Figure 11. In upland areas there is little change in land use, while in the lowlands around 5 % of land moves from Cropland to Grassland and vice versa each year.

Using this approach for successive years allows vectors of land use change for given land parcels to be built up. It is proposed to use this vector approach to mapping land use change from the 1990-2014 LULUCF (which will be published in 2016), to allow time for further refine of the methodology. In particular, the vector approach will be developed further to include consideration of change in crop type within Cropland, as this effects residue returns to soil and hence soil carbon stocks. As the IACS data only covers agricultural land it will be supplemented by other spatially referenced data such as maps of afforestation and deforestation and the remotely sensed information from CORINE land cover map which is updated more frequently than the Countryside Survey Land Cover Map.

A major advantage of moving to a spatially referenced vector approach to LULUCF reporting is that it will be possible to overlay these maps with other spatial data such as soil or climate maps, and in future, it will be possible to develop LULUCF reporting to take better account of the effect which local geographical conditions have on GHG emissions. This will need to be given further consideration once the land use change vectors are available, but modelling emissions using the LUCI[41] or ECOSSE[42] models could be options. Although moving to the new methodology will not change actual emissions, it will affect the emissions reported.

[41] CEH (2014) Introduction to the LUCI model: An ecosystem service modelling framework and GIS decision support tool http://unstats.un.org/unsd/envaccounting/seeaRev/meeting2013/EG13-BG-9.pdf
[42] SEERAD (2007) ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions: Final Report http://www.scotland.gov.uk/Resource/Doc/170721/0047848.pdf

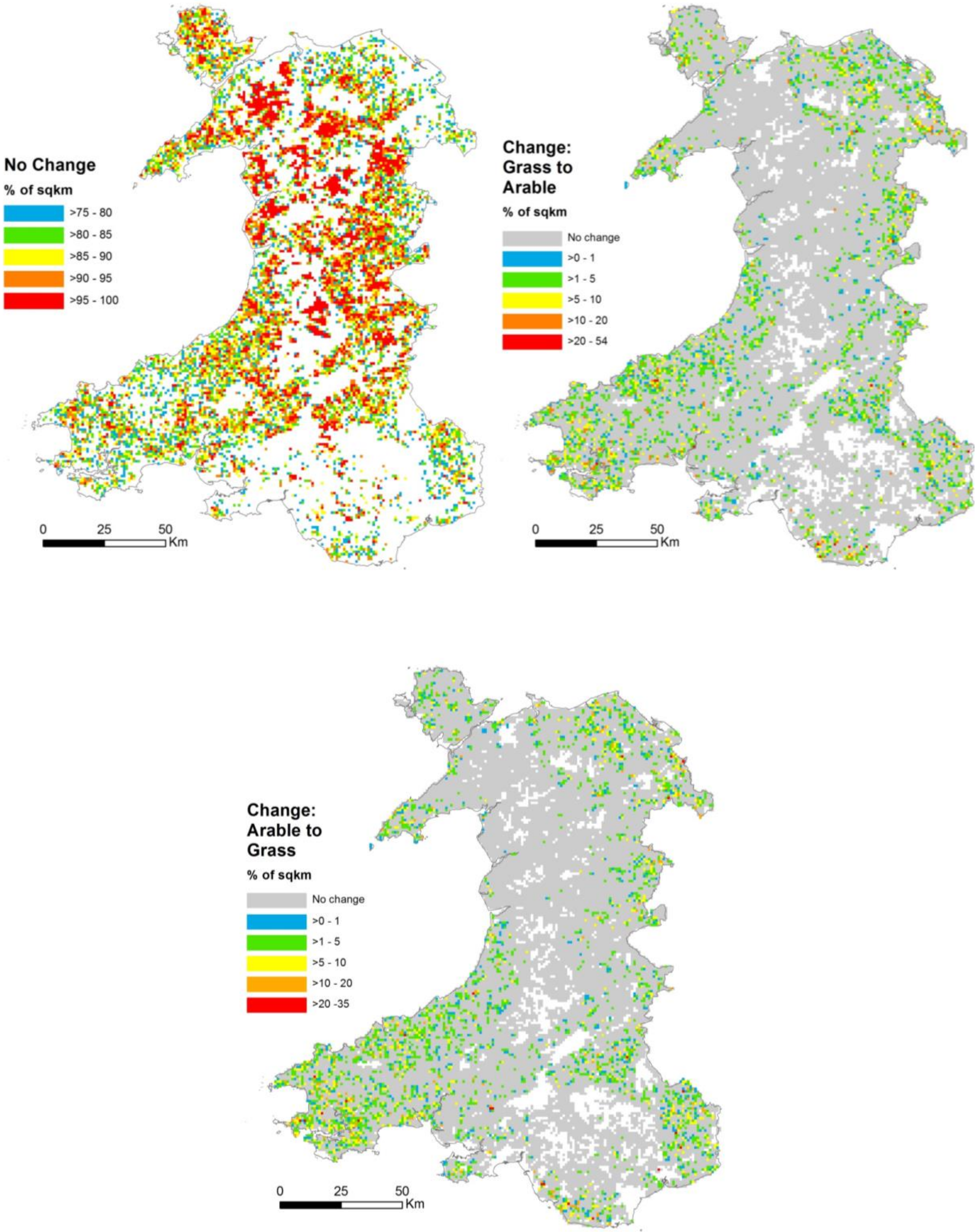


Figure 11: Land Use Change for land eligible CAP payments for in Wales (2008 –2009).

LULUCF inventory reporting does not explicitly consider the effect of the CAP payment regime, but does model projected emissions and removals to 2050 using scenarios supplied by the DA governments. For Wales the projections for land use change to 2050 are:

Low emissions scenario; 2.5 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 7.7-9.5 kha p.a. Grassland-Cropland "churn" each way 5.24 kha p.a.

Mid emissions scenario 5.5 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 8.9-9.6 kha p.a. Grassland-Cropland "churn" each way 5.24 kha p.a.

High emissions scenario 10.0 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 11.6 kha p.a. Grassland-Cropland "churn" each way 5.24 kha p.a.

The emissions and removals modelled for these for the Cropland and Grassland categories are shown in Figures 4 and 5 below. The graphs show the emissions from the land use change alone and with inclusion of a factor allowing for the effect of "churn" between Cropland and Grassland in rotational systems.

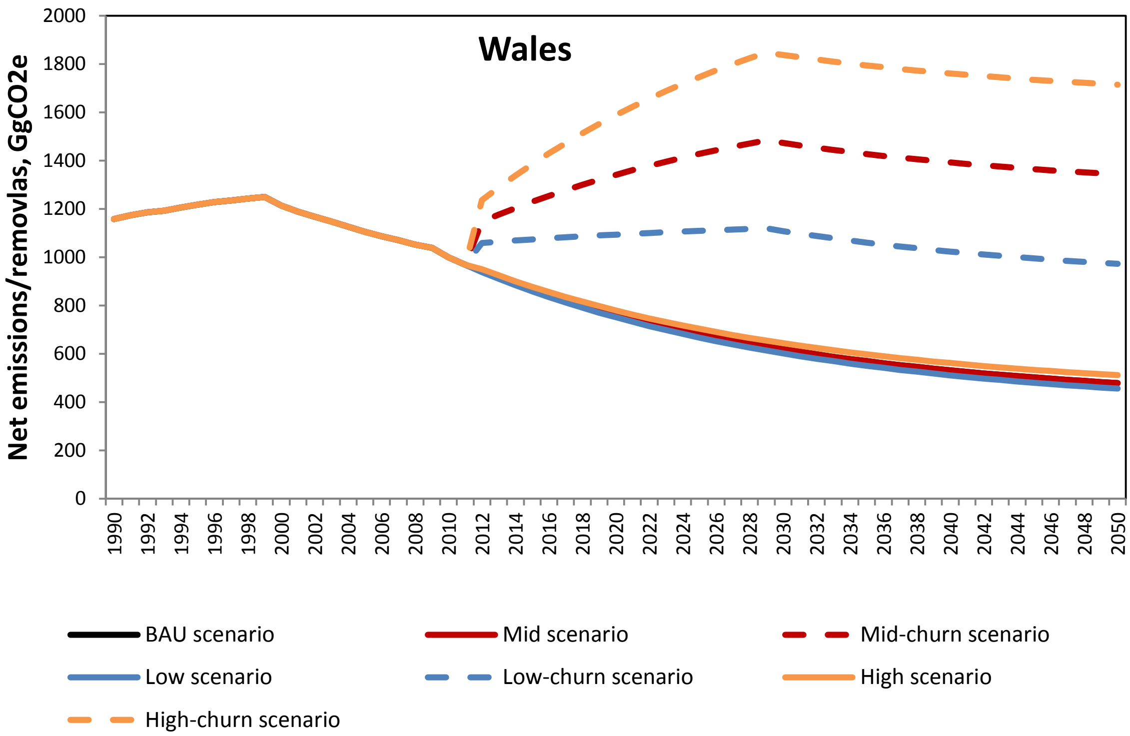


Figure 4: Projected emissions from Cropland in Wales to 2050 and impact of rotational "churn".

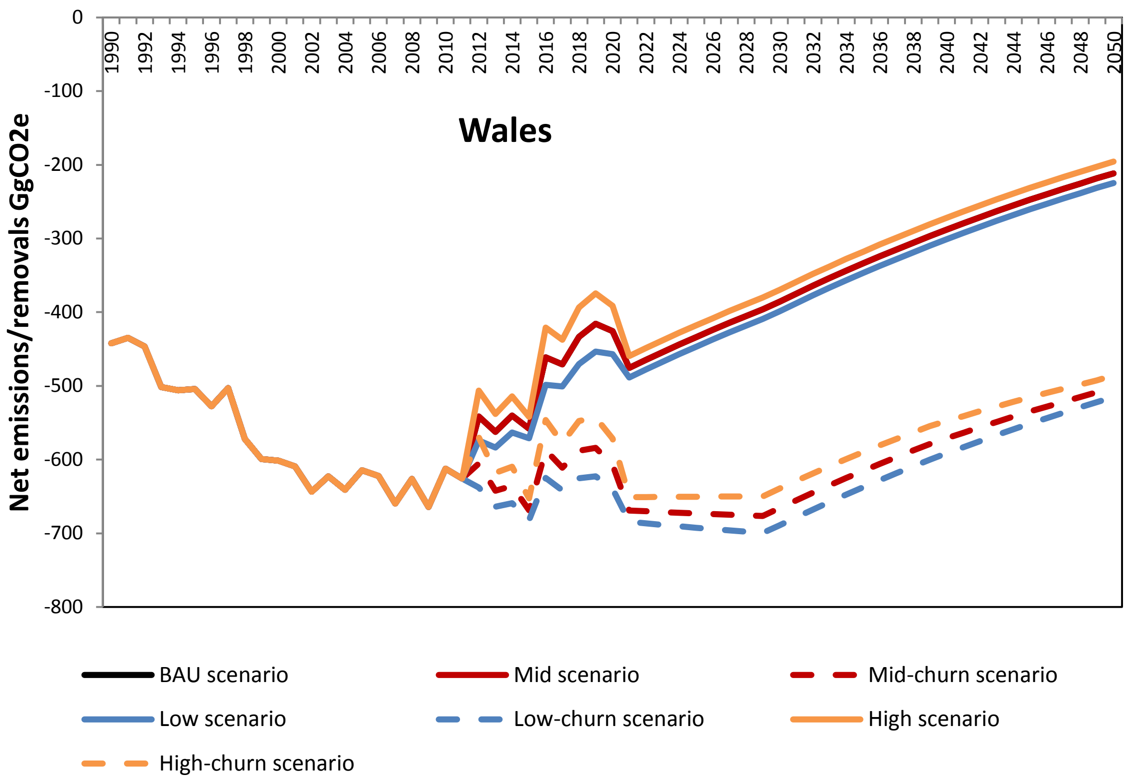


Figure 5: Projected removals from Grassland in Wales to 2050 and impact of rotational "churn".

LULUCF Inventory improvements.

To be credited for reducing GHG emissions, Glastir measures must be reflected in the emissions reported in the LULUCF inventory. At present the inventory is not spatially referenced and does not capture the past history of land use at a given site. In addition, the inventory has historically focused on the effect of land use change rather than land managed outwith forests. New reporting requirements mean that the inventory will need to be improved to be able to capture the effects of key management practices on Cropland and Grassland. This should improve its ability to capture the effects of Glastir measures on reported emissions. In addition, new Guidance has recently been issued on estimating emissions from wetland drainage and restoration. Although the UK has not yet elected to report on these emissions, there is ongoing work to develop a framework for this reporting. This will also improve the ability of the inventory to capture the effects of Glastir measures.

If the effect of Glastir measures cannot be captured in the LULUCF methodology, some other means of assessing the effectiveness will be necessary (see Table 31).

Table 31: representation of land use change and management in the LULUCF inventory

LUCCG Rec.	Summary of Measure	Captured in LULUCF inventory?	Captured by improved LULUCF Inventory?	Comment
3	Expand current woodland / forest cover by about 100,000 ha over the next 20 years	Yes	N/A	This would be captured as a land use change activity.
4	Ensure that forests are managed to optimise their GHG sink potentials as well as providing a sustainable source of fuelwood and other timber products that form long term "carbon sinks" and/or substituting for fossil fuels	Yes	N/A	The move to using the CARBINE model in the 1990 – 2012 to assess emissions and removals from Forestry has improved the ability of the LULUCF inventory to capture the effects of change in forest management, and a full range of management practices are now represented.
5	Ensure that no steps are taken which might undermine the carbon stores in bogs, mires and fens.	No	Yes	The recently published IPCC Wetlands Supplement gives improved guidance on including wetland drainage and restoration. DECC are currently tendering a major project to support implementing this guidance in the UK. This project will run until 2016 after which the LULUCF inventory should be able to capture the effects of these activities
22	Refine current estimates of land use change in Wales	Partially	Yes	The move to a vector based approach to estimating land use change will improve estimate of land use change in Wales. This will be implemented in the 1990-2014 inventory.
23	Develop the LULUCF inventory so that it is able to take account of reverse transitions	No	Yes	The move to a vector based approach to estimating land use change will allow full accounting of reverse transitions. This will be implemented in the 1990-2014 inventory.
24	CEH to investigate classifying rotational grass as a separate land use type instead of the inclusion of frequent transitions between land uses	No	Yes	A new vector approach to modelling land use change using spatially referenced IACS Land Parcel data and CORINE land cover data will be adopted from the 1990 – 2014 inventory which will enable crop-grass rotations to be captured.
25	Assess ways to improve the LULUCF inventory to include agri-environment practices aimed at increasing soil organic matter, or innovations in	Partially	Yes	The change to use of the CARBINE model to estimate emissions from Forestry has already improved capture of forest management practices.

	forest management and the use of harvested wood products that substitute for fossil fuel use.			The new EU requirement for reporting on Cropland and Grassland management is driving improvement to the LULUCF inventory in these areas. Cropland management will be included in the forthcoming 1990 – 2013 inventory. Field work is required to fill knowledge gaps relating to Grassland Management, and it is hoped that work will be commissioned to address this and allow reporting of Grassland Management, although it could take two to three years to develop reporting.
26	Resolve best ways of modelling forest soils	Partially	Yes	The models for mineral soils under forest perform well. There has been a lack of UK-relevant field data to support modelling of the effect of forest on organic soils. New data has recently become available and the models are being improved for the forthcoming 1990 – 2013 inventory.
27	Improve current assumptions for soil carbon changes for land converted to settlement.	No	Partially	This is a not a priority area for inventory improvement because of the small areas involved. However if new data becomes available for inventory improvement e.g. remote sensing data on the proportion of impermeable surfaces within Settlements this will be used. There is no work planned to improve understanding of soil carbon stocks under different land uses within Settlements which would be likely to be costly and time consuming.
39	Develop a clearer analysis of the value of ruminant livestock for delivery of ecosystem services.	Partially	Partially	This is a very broad action. Some of the effects of ruminant livestock on GHG emissions e.g. methane emissions from animals and manure management are captured in the Agricultural Sector inventory rather than the LULUCF inventory. In the 1990 – 2013 inventory these sectors will be amalgamated into a new AFOLU sector. However some ecosystem services delivered by livestock e.g. biodiversity issues related habitat control will not be reflected in any GHG inventory.
43	Improve estimates of the impact of moving from one land use to another on soil carbon storage particularly in relation to soil type.	Partially	Yes	This is an ongoing need as new data becomes available. Use of the vector approach to land use change in the 1990-2014 inventory will allow the interaction of land use and soil type to be modelled in more detail in the inventory.

44	Quantify the effects of grazing intensity and type, re-seeding of lowland pasture and the impacts of tillage methods on GHG emissions	No	Probably	The new EU requirement to report on the effect of Cropland and Grassland management in the LULUCF inventory provides a driver for work on this. Defra project SP1113 attempted to develop a framework for incorporating the effect of these practices in the LULUCF inventory, but failed because of a lack of field data. The SP1113 project team offered proposals on how this knowledge gap might be filled, although the work would take approximately two years. It is hoped that the funding will become available to allow this knowledge gap to be filled.
45	Breed new grass varieties that enhance carbon storage below ground.	No	Yes	If new grass varieties became available, and there was evidence of their efficacy in increasing soil carbon stocks this could be included in the LULUCF inventory as a Grassland Management practice.
48	To assess the effects on soils carbon stocks in organic soils throughout the life cycle particularly newer forest management methods	Partially	Yes	The models for mineral soils under forest perform well. There has been a lack of UK-relevant field data to support modelling of the effect of forest on organic soils. New data has recently become available and the models are being improved for the forthcoming 1990 – 2013 inventory.

As discussed in the Crop/Soil section above, the LULUCF has modelled land use change using land use change matrices which are not spatially explicit and it has not been possible to capture the actual history of land use at a site. This has been particularly problematic for rotational grassland. A spatially explicit vector approach to land use change is being developed which will be developed which will take into account the past history of a site when calculating emissions from land use change.

Defra project SP1113 has recently reported (Moxley et al, 2014) on how the effects of land management might be included in the LULUCF inventory, and the 1990 – 2013 inventory will include the effects of Cropland Management. It has proved more difficult to develop a methodology for reporting on Grassland Management because of a lack of field data on the effect, particularly relating to the effect of improving Grassland on organic and organo-mineral soils.

The LULUCF inventory's reporting of Forest Management has improved with the change to using Forest Research's CARBINE model to assess carbon stocks in forests.

Settlements make up a small part of the land area of Wales. When land is converted to Settlement it is taken that half of the area is covered with hard surfaces and half is greenspace. It is assumed that all soil is lost from land covered by hard surfaces, and that greenspace as similar soil carbon stocks to grassland. All of these assumptions could be improved upon, in particular the fate of soils under hard surfaces is not well understood: top soil may be removed for use elsewhere or remain in situ rather than being lost. Data on the carbon stocks of urban soils is very limited.

A project funding by Welsh Government to use Earth Observation to assess the extent of impervious surfaces within urban areas has recently completed, and its findings could be used to improve modelling of the proportion of urban areas in Wales covered by impervious surfaces (Scott et al, in review)

Effects of rewetting drained peatlands

Peat sites with full carbon and GHG budgets are still very limited in Wales and elsewhere, meaning that it is difficult to draw firm conclusions about the global warming potential of intact or degraded peatlands. Currently these data are being collected on a blanket bog in the Upper Conwy (intact, drained and re-wetted sites) and at a site in the Anglesey Fens (intact and nutrient-enriched sites). There are no data for some important land-use/condition categories including afforested peat, lowland peats converted to grassland, blanket bog affected by *Molinia* encroachment, eroding bog, wind farms on peatland. Sites at which measurements are currently taking place are probably representative of less than half the total Welsh peat area, and there is little or no replication within the land-use/condition categories where measurements are taking place.

Research is needed in order to fill this knowledge gap. Implementation of the Wetlands Supplement guidance will increase the need for this information. A number of organisations are currently involved in this work (e.g. CEH, Bangor University, Leeds University with funding from Defra, NERC and others, but there is no clear co-ordination of work. Funding for additional flux measurements could be targeted at priority land-use categories where there is potential for intervention (land-use change, restoration, implementation of Glastir measures etc.) that may lead to significant reductions in GHG emissions.

Annex 12: Analytical framework for climate change risk assessment

Risk Rating (1-25) = Likelihood (1-5) x Consequence (1-5)

Risk	Opportunity
L = Low Risk (1 to 4)	L = Low Opportunity (1 to 4)
M = Medium Risk (5 to 15)	M = Medium Opportunity (5 to 15)
H = High Risk (16 to 25)	H = High Opportunity 16 to 25)

LIKELIHOOD

Likelihood rating		Recurring event	Single event
5	**Very Likely**	Could occur several times a year	More likely than not – probability greater than 50%
4	**Likely**	May arise about once per year	As likely as not – 50/50 chance
3	**Possible**	May arise once or twice in 10 years	Less likely, but still appreciable – probably less than 50% but still quite high
2	**Unlikely**	May arise once or twice in 10 years to 25 years	Unlikely but not negligible – probably low but noticeably greater than zero
1	**Rare**	Unlikely during the next 25 years	Negligible – probably very small, close to zero

CONSEQUENCE

Consequence rating		Economic Impact	Social Impact, including health and safety	Environmental Impact
5	**Catastrophic**	Widespread economic impact, business failure, loss of employment	Widespread social impact on the industry/communities, on the well-being on individuals, organisations and other groups	Major widespread loss of environmental amenity or other features and progressive irrecoverable environmental damage
4	**Major**	Regional economic impacts – businesses can't thrive, underemployment	Regional social impacts on surrounding community, or a subset of the industry – affected communities and industries can't thrive	Severe loss of environmental amenity or other features and a danger of continuing environmental damage
3	**Moderate**	Significant general reduction in economic performance relative to current forecasts	Isolated but significant social impacts on communities or the industry	Isolated but significant instances of environmental damage that might be reversed with intensive efforts
2	**Minor**	Individually significant but isolated areas of reduction in economic performance relative to current forecasts	Minor impacts on surrounding communities, or industries which could be reversed	Minor instances of environmental damage that could be reversed
1	**Negligible**	Minor shortfall relative to current forecasts	Minimal social impacts	No environmental damage

OPPORTUNITY

Opportunity rating		Economic Opportunity	Social Opportunity, including health and safety	Environmental Opportunity
5	**Very Significant Opportunity**	Widespread economic improvements, businesses thrive, employment increases significantly	Widespread social improvements on the industry/communities and on the well-being of individuals, organisations and other groups	Major widespread improvements of environmental significance which actively counteract previous damage and increase biodiversity
4	**Significant Opportunity**	Regional economic improvements – businesses expand, employment opportunities increase	Regional social improvements on surrounding community, or a subset of the industry	Significant improvement of environmental status which benefits biodiversity
3	**Moderate Opportunity**	Significant general increase in economic performance relative to current forecasts	Isolated but significant social improvements on communities or the industry	Isolated but significant environmental improvements
2	**Minor Opportunity**	Individually significant but isolated areas of increased economic performance relative to current forecasts	Minor improvements on surrounding communities, or industries	Minor environmental improvements
1	**Negligible Opportunity**	Minor increase relative to current forecasts	Minimal social improvements	Negligible environmental improvements

Annex 13: Risks from a changing climate and adaptation actions

Risks by sector

Rural Communities

Around 1 in 3 of the Welsh population live in an area classed as rural. Certain rural communities can face challenges such as less access to public transport and public services. The assumption that communities in rural areas are inevitably healthier than urban populations is also increasingly coming under challenge (WCFH, 2007). The assessment and prioritisation of risks for rural communities within Wales identified four key impacts and one opportunity for prioritisation in risk management and adaptation strategies. For each of the risks and opportunities recognised, social, economic and environmental implications were identified.

Risk 1: Flooding

Extreme weather events such as heavy rainfall and storms can affect rural communities through negative impacts including flash flooding, particularly for some of the Welsh rural landscape at steep gradients. Around 357,000 properties (1 in 6) in Wales (not just rural communities) are at risk from flooding and it is estimated that between 40% and 250% more properties will be at a significant likelihood of flooding by the 2080s (Defra, 2012) if no further adaptation measures are implemented. Flood risk in rural areas was deemed to be the highest risk and therefore a focus for adaptation. Flood risk in rural areas should be reviewed regularly to understand which areas are in greatest need of investment in flood defences or similar. Implications of flooding for rural communities include damage to buildings and property, disruption to supply chains and essential support services and increased costs for flood insurance. Conversely, increased winter rainfall provides an opportunity for rainwater harvesting, both by rural communities and rural businesses. Storage mechanisms for ‘grey’ water uses such as irrigation will reduce demand for domestic supplies and increase water security within Wales.

Risk 2: Drought

A decrease in summer precipitation and increase in drought events will lead to a reduction in water availability to meet demand during dry months of the year, resulting in increased pressure for water companies to supply domestic customers. With reduced water availability, demand by domestic customers is likely to compete with that of agricultural uses and others creating local tensions. Over 90% of the population may be affected by water shortages by the 2080s, although there are large uncertainties in the projection. The costs associated with importing water from other areas may affect rural communities and despite its relatively high rainfall Wales already experiences significant pressures on its water supplies. Conversely if the wider UK experiences heavy drought there may be increasing pressure on Wales (as an area that generally receives greater precipitation) to export water across the borders. Periods of decreased water availability can be adapted to by the construction of further reservoirs, or localised storage of water (e.g. storage tanks or ponds on farms). More efficient use of water in all sectors can help ease pressure in times of drought.

Risk 3: Coastal erosion

For coastal communities, a combination of sea level rise and storms can lead to infrastructure damage. Under a medium emissions scenario it is projected that Cardiff (although not a rural community) could experience a relative sea level rise (taking into account land level changes) of 21-68cm by 2095 with South Wales being particularly vulnerable. In the flooding of December 2013, 155 properties were flooded and a further 150 affected in the following month. This, however represented less than 1% of the properties and agricultural land that were at potential risk (Davies, 2014). The immediate cost of repairing flood defences from this incident was £8.1M, excluding any other costs such as property damage. As impacts get more severe and affect more areas, the cost of these events will increase considerably. It was predicted by the former Environment Agency Wales that £135M would be needed to be spent annually on flood and coastal defences by 2035 to maintain the current level of risk. For rural communities in flood risk areas insurance premiums for property are likely to increase substantially along with risk. If particularly vulnerable areas become too untenable for property to be placed, in the long term communities may shift inland.

Risk 4: Landslides due to heavy rainfall events

Heavy rainfall events may lead to an increased number of landslides which can lead to infrastructure damage and a disruption to supply and support services for rural communities. Landslips are a particular concern due to the steepness of much of the Welsh landscape. Whilst landslips are likely to be restricted to a limited number of rural communities located in isolated and vulnerable areas, impacts for those communities could be devastating.

Opportunity 1: Milder winters reduce heating bills and cold related deaths

Whilst uncertain, theoretically warmer winters will reduce heating bills and cold related deaths. This is a particularly important opportunity for vulnerable groups, such as older people. Research has predicted cold related deaths to decrease by 2% by 2050 in the UK (Hajat *et al.* 2013). This is a positive impact if it involves less public spending, and resource allocation of healthcare during winter periods.

Rural Businesses

Rural businesses includes those in the agriculture and forestry sectors (see other sections of this report), but also other businesses such as manufacturing, construction and those in the service sector (e.g. hotels) amongst others. Some rural business rely on tourism for their main source of revenue. The assessment and prioritisation of risks for rural businesses within Wales identified three key impacts for prioritisation in risk management and adaptation strategies, as shown in Table 14. Two opportunities for rural businesses were also identified. For each of the risks and opportunities recognised, social, economic and environmental implications were identified.

Risk 1: Decrease in water availability

By the 2050s drier summers are likely to lead to a decrease in water availability for rural businesses in Wales. Serious threats to agricultural businesses are likely to arise from a lack of water, including the availability of water for livestock and crop irrigation. Rural businesses, other than those in agriculture or forestry may have to compete with other uses for water which could lead to higher prices, or lack of availability. It is likely that water stress could occur at times in heatwaves, or hotter summers thereby exacerbating conditions. Small scale adaptation measures such as the creation of ponds/reservoirs and rainwater harvesting systems could be encouraged. This water could be used for 'grey' uses and provide an alternative to mains drinking water for some agricultural practices.

Risk 2: Flooding

Extreme weather events such as heavy rainfall events and storms can affect rural businesses through negative impacts including flash flooding and increasing landscape instability and susceptibility to landslips, particularly for some of the Welsh rural landscape at steep gradients. Non-residential properties at a significant risk of river or tidal flooding in Wales (all areas) are estimated between 30,000 and 65,000 by the 2050s, against a current figure of 24,000 (Defra, 2012). Flooding also poses a risk to transport infrastructure such as roads which if affected could prevent some rural businesses from operating during flood events leading to impacts on the rural economy. In addition, as more commercial properties become at risk of flooding this will lead to higher insurance premiums for the associated businesses. Flood risk management plans detail priority areas for adaptation measures in the form of food defences.

Risk 3: Coastal erosion and flooding

Rural businesses in coastal areas may be at particular risk from flooding through a combination of sea level rise and storm events. In 2004 it was estimated that the English and Welsh coastline was being eroded 20-67m every 100 years, but this is predicted to increase to 82-175m depending on the emissions scenario considered (NAWC, 2011). Coastal erosion as seen in the 2013/2014 winter can destroy sea defences and leave coastal towns such as Aberystwyth vulnerable to further erosion and flooding. For businesses in rural coastline communities, the combined risk from coastal, fluvial and surface water flooding is often much more significant than flood events that occur inland.

Opportunity 1: Tourism expansion due to a warmer climate

Central climate estimates indicate that temperatures in Wales will increase from a summer average maximum of 18.5°C to 20.4°C (UKCP09, 2009). A warming climate will more likely than not encourage further expansion of Wales's important tourist sector, especially on the coast which equates for approximately 80% of all Wales's tourism income. This has the potential to benefit Welsh rural businesses operating in sectors which rely on tourist income.

Opportunity 2: Warmer winters

Central climate estimates indicate that temperatures in Wales will increase from a current winter average maximum of 6.9°C to 8.4°C (1981 to 2010 baseline), reducing the occurrence of air and ground frost. This will provide an opportunity for rural business to reduce expenditure on heating buildings and decrease the costs and number of delays lost to cold-related incidents (e.g. poor transport conditions from snow and ice).

Arable / Horticulture

The arable and horticulture sectors in Wales are comparatively small when compared with livestock, accounting for only a 4.8% share in total gross output of Welsh agricultural production. Wales has a productive arable area of approximately 79,000ha of arable and 1,500ha of horticulture, against productive grazing land of approximately 1.5M ha (Welsh Government, 2013). There are approximately 505 holdings of cereal and general cropping farms, 494 horticulture holdings and 849 mixed holdings that have cropping and livestock.

Risk 1: Flooding due to an increase in winter mean precipitation

Waterlogged land can have an impact on cropped areas if farmers are unable to travel on the land to perform vital operations, and also on the physiology of crops. If growing crops are underwater, impacts do not occur immediately but yield penalties can be evident if this is for a prolonged period of time. If flooding occurs at a later stage in development of standing crops (such as wheat), this can lead to yield damage from lodging. Of all best and most versatile land (Agricultural Land Classification (ALC) grades 1, 2 and 3) in Wales, 10% is currently located on land designated as floodplain. Of all agricultural land in Wales with an ALC grade located in a floodplain (128,000ha), 63,700ha has some kind of flood defence (either fluvial, coastal or a mixture) (Roca *et al* 2011). If land is particularly prone to flooding various adaptation measures are possible. This may include the relatively costly option of flood defences, changing land use to a crop which grows outside of times most prone to flooding (e.g. spring cropping) or changing land use to grazing/ another use. In the long term flood tolerant crop varieties could be available which may present a cost-effective adaptation option.

Risk 2: Decrease in water availability for crops

Rising agricultural water demand due to a drier climate, coupled with rising water demand from other sectors (e.g. energy and water companies), could coincide with less water being available for agriculture. Whilst drier summers will limit the potential yields of cereal crops due to water deficiencies, Wales will still continue to be a wetter region than others in the UK and as such, impacts are not likely to be large. Crops most heavily affected will be those requiring irrigation such as potatoes and some fruit crops. If water stress becomes a problem that severely limits the yield of such crops, land use change to crops which do not require irrigation will be prevalent. Apart from land use change, adaptation may involve the use of more efficient irrigation systems or on-farm harvesting and storage of water to use in periods of drought.

Risk 3: Temperature extremes (heatwaves)

The physiological impact on crops associated with high temperatures in summer include reproductive (flower) development impaired in cereals, oilseeds, peas, tomatoes and apples. The probability of heat stress around flowering that might result in considerable yield losses is predicted to increase. Adaptation actions may include the introduction of new varieties of crop that have a greater resilience to heat stress. Temperature extremes can have environmental impacts if they cause the ground to crack, and subsequently increase surface run off and wash loose soil and nutrients away. Winter crop varieties are affected by heavy rainfall in the winter but they are less susceptible in terms of yield impact to hot temperatures in the summer. Conversely spring crops miss periods of heavy winter rainfall, but may be vulnerable to heavy rainfall events in spring and can have more severe physiological impacts from heat stress in the summer. As such, choosing a crop variety which has the highest resilience to a particular climate variable is the most imperative adaptation action.

Risk 4: Pest and disease pressure

The interactions between crops, pests and pathogens are complex and currently poorly understood in the context of climate change. It is difficult to analyse future risks given the speculation around the occurrence of pests and diseases, hence pest and disease pressure is a lower risk due to high uncertainty. Examples include pests that can survive over winter more readily as a result of a warmer climate such as aphids, spider mites and thrips. These pests will then likely have greater activity in summer periods and cause greater crop damage if not effectively controlled. Impact will depend on the crop in question, and whether adequate control methods exist to protect against damage. Wider impacts could mean an uncompetitive agricultural industry, with higher food prices. The main adaptation action is development of adequate control methods, either chemical or others (e.g. biological). Availability of funding for research and development can stimulate this.

Opportunity 1: Improved crop yields

Extreme weather events such as drought, heatwaves and flooding are likely to decrease yields of some crop species. However, in general the effects of climate change have the potential to increase yields of some species, especially cereal crops. With warmer temperatures and increased levels of atmospheric CO_2, there will be opportunities for some crops to be grown in Wales that were not favourable previously (e.g. garlic and rocket), and expand growth of crops currently in small quantities (maize, blueberries).

Opportunity 2: Longer growing season

An increase in temperatures throughout the year has led to a lengthening of the growing season, which is currently around 10 days longer than it was in the 1960's and will likely increase further as temperatures continue to increase in the coming decades, which could encourage more winter cropping. With better conditions there will be a possibility to drill and sow slightly earlier or later than is currently practiced (unless extreme weather conditions prevent this) giving slightly more flexibility to achieve a greater yield.

Livestock and Grassland

In 2013 the livestock sector in Wales exhibited 13,160 beef and sheep holdings (the majority in Less Favoured Areas), 1,788 dairy farms, 109 specialist pig farms and 471 specialist poultry farms. The area of grassland equates to roughly 1 million hectares of permanent grass and 444,000ha of rough grazing (Welsh Government 2014). The industry is highly significant to Welsh agricultural production, with milk and milk products accounting for 33%

share of gross output, whilst cattle and sheep account for 24.2% and 16.6% respectively (WG, 2014).

Risk 1: Increase in liver fluke disease

Liver fluke is an internal parasite that infects the liver and causes disease (fasciolosis) in grazing animals such as cattle and sheep. Liver fluke is a particular problem in parts of Wales due to its wet climate. With increased temperature and rainfall as a result of climate change there is expected to be major outbreaks from 2020. The host animal can suffer a range of impacts from inhibited growth and reduced production efficiency, down to mortality. Impacts have been calculated at the cost of delaying finishing of lambs at £6.00 per animal, which does not include the reduced value of damaged liver once the lamb is slaughtered, or any premature mortality. With 9.46M sheep in Wales in 2013 this is a possible loss of income of approximately £57M from delayed finishing. In beef cattle the cost of delaying finishing as a result of liver fluke can be up to £90 per animal. With 1.1M cows this is a possible loss of income of £99M. In Great Britain as a whole fluke infection is estimated to currently cost £13-15M per year.

The most effective adaptation actions are to help farmers understand the risks and prevent livestock grazing in potentially high risk areas such as boggy or wet areas using fencing, tree planting or selective grazing pasture. In some areas and under some conditions this may not be possible. Planting trees in high risk areas provides multiple benefits by restricting livestock from wet areas, increasing infiltration rates, decreasing the likelihood of foot rot and aid in outdoor lambing by providing shelter from cold winds in the winter and shade from heat-stress in the summer.

Risk 2: Increase in wildfires

Wildfires are a persistent, widespread, costly and dangerous issue in South Wales. A decrease in precipitation and increase in temperatures will lead to hotter, direr conditions, which will increase the conditions favourable for the development and spread of wildfires. Between 2000 and 2008 there were over 55,000 recorded grassland fires in South Wales, which is highly significant as this equates to eight times more wildfires per unit area than in the UK as a whole. The majority (90%) of which were started by arson. It is estimated that each wildfire costs between £1,000 and £1,950 in Fire and Rescue Service time and resources and has wider socio-economic implications as firefighters engaged in extinguishing wildfires are unavailable to respond to other emergency calls, meaning lives are potentially put at risk. Adaptation actions include the creation of sector breaks in-between grassland or woodland areas, such that if a wildfire broke out, it would be contained to an area and not spread so easily. Encouragement of risk management plans in the areas affected can help management of fires, tools such as weather prediction models can be developed to provide advance warning of conditions available for wildfires.

Risk 3: Heat stress

Heatstroke and sunburn can cause animal welfare issues and loss in production of all major livestock species in Wales. Estimates at the UK level suggest production losses of £5.8M and mortality losses of £34M by 2080 from gradual temperatures increases (excluding any heatwave conditions) (Wall *et al* 2010). Consequences may be significant for individual farmers, whilst the industry as a whole will likely be resilient as heatwave conditions will only occur periodically during the summer. In 2013, there were approximately 9.46 million sheep, 1.1 million cattle, 8.7 million poultry and 24,900 pigs in the Welsh livestock sector (WG, 2014). The impact of heat stress will result in minor to moderate production losses, but it is generally expected that conditions in Wales will be more favourable than many other regions in the UK. Providing shade to grazing livestock is the simplest way to avoid heat stress. This may consist of manufactured shelters, or planting of trees which would also have multiple benefits in adapting against wet conditions due to high precipitation (see Risk 1).

Risk 4: Availability of animal feed
As a whole the EU is reliant on third countries for 70% of its animal feed, largely in the form of soybeans. The livestock sector in Wales is highly reliant on imported animal feed, largely in the form of soya. With a changing climate soya yields are predicted to increase in some areas and decrease in others. Some livestock farmers use home-grown feed, or alternative sources however generally any lack of availability and consequent price rises are likely to lead to large effects on profitability of the sector. Adaptation may naturally occur (use of other protein sources), however it is uncertain whether this will happen at a rate which mitigates impacts. Adaptation interventions may include measures to make home-grown feeds a more attractive option, or continuing funding R&D into alternative and more sustainable sources of protein.

Opportunity 1: Improved grass yields
Increasing temperatures of approximately + 2.5°C by the 2050s will provide more favourable conditions for increased grass yields (if water and nutrients don't act as limiting factors) and may enable more of the Welsh landscape to support livestock, particularly in disadvantaged areas in which grass yields are not as favourable. Increase in grass yields are projected to be between 20% and 50% by the 2050s, assuming other factors affecting growth are not limiting[43].

Opportunity 2: Farm diversification
A combination of projected changes in the climate including an increase in summer mean temperatures, increased occurrence of heatwaves and a decrease in summer mean precipitation all lead towards more favourable conditions for increased tourism. This provides an opportunity to farmers for diversification on their land to utilise the benefits that alternative revenue streams can offer e.g. Farm-holidays, camping, pony trekking etc.

Opportunity 3: Livestock performance improvements
Warmer temperatures may provide more favourable temperatures for extended duration of outdoor grazing of livestock, which could lead to increased winter grazing and forage, assuming access is not limited due to wet conditions. Milder winters will in theory reduce feed and bedding costs by cutting the length of time livestock need to be housed, however this will be subject to precipitation rates, which may counteract this if increased winter rainfall is significant (e.g. when straw usage can rise in wet winters in attempts to keep stock bedding areas dry). Higher average winter temperatures will reduce problems for livestock in freezing weather, as well as reducing the risk of mortality from cold related issues.

Food Chain
The Welsh food and drink industry employs around 230,000 people, representing 18% of the Welsh workforce. The industry generates around £6.5 billion sales revenue each year (WFDSP, 2014). The scope of this review was on the food chain for food derived from primary products produced in Wales. As such, many climate change impacts occur at the production stage and are covered in the other sectors, however supply chain and consumer specific risks were identified.

Risk 1: Transport disruptions
The food supply chain relies on distribution networks to ensure timely delivery of products to consumers. Extreme weather events such as heavy snow, floods or fog may close roads, and high winds or coastal flooding may close sea ports which handle over 90% of imported food. The likelihood is increased in the long term, but uncertain given the unpredictability of extreme weather events.

[43] Baseline: 1970s-1990s

Risk 2: Market price of livestock products

The climate change risks associated with livestock production are discussed in Section 0 above. Risks such as availability of animal feed and disease and pest pressures will have a direct impact on price of products. If price of livestock products rise this cost will likely be passed onto consumers, making the cost of livestock products less affordable. If impacts such as the threat of Liver Fluke, cause sudden reductions in the availability of beef, lamb or dairy products this is likely to peak cost of these products from Wales. The retail industry may naturally adapt from sourcing elsewhere in the world, however this comes with its own challenges. Adaptation involves ensuring security of supply from the Welsh livestock sector by addressing climate change risks through adaptation interventions in this sector.

Risk 3: Market prices of crop products

Climate change impacts, especially extreme weather events are already affecting crop yields globally. This has a large influence on import prices for crops, and consequently leads to consumer price rises for many items. Whilst the arable industry in Wales will face its own climate related risks, this is likely to be inconsequential for market prices of the products considering the relatively small cropped area. The key impact is likely to be the prices of everyday staples such as bread in Wales as a result of changing crop prices globally. If availability is constrained prices for key staples such as bread could go up dramatically in a small space of time making the cost of living for Welsh consumers more expensive.

Risk 4: Supply planning

Demand and supply planning for primary products could become more difficult as unexpected extreme weather events (both locally in wales, and internationally) can disrupt the availability of produce to meet demand. Oversupply will lead to food wastage and economic losses, whereas undersupply will lead to price rises. The severity of this impact is dependent on a number of factors, many of which are outlined in the sections above. As such, the likelihood and severity of this impact is very uncertain.

Risk 5: Food Safety

There are multiple factors through which climate related factors may impact food safety including changes in temperature and precipitation patterns, increased frequency and intensity of extreme weather events and changes in food contaminants' transport pathways. If food safety incidents become more prevalent then this can result in economic losses from recall or destruction of product, and crucially human health impacts if food safety events are undetected. Given the high importance placed on food safety, the food industry will likely adapt to pressures with extra controls and thus impacts are uncertain.

Forestry

The area of woodland (land under stands of trees with a canopy cover of at least 20%) in Wales covers 306,000ha or 15% of the land, with approximately 150,000ha of conifers and 156,000ha of broadleaves (Natural Resources Wales, 2014). The area of new planting and restocking in 2013-14 was approximately 900ha and 2,300ha respectively. The Welsh forest sector is made up of woodland-based businesses and traditional forest industries, which contributes more than £340 million per annum to the Welsh Economy and it employs over 16,000 people in hundreds of small to medium rural businesses. The environments they create offer opportunities for people, businesses and biodiversity. Five key risks and two opportunities were identified in the risk assessment. Adaptation measures for all of the risks essentially equate to species diversification and selection to create multiple-species forests which exhibit a greater resilience to climatic pressures and associated impacts.

Risk 1: Pest and disease pressures

Projected changes in the climate for milder, wetter winters are likely to have significant implications for forestry production in Wales due to an increased pressure from pests and diseases, which has been identified as a high risk in the 2020s, 2050s and 2080s. The problem is current and likely to be exacerbated as the climate changes. The principal effects of tree pests and diseases are economic as they can damage the appearance, growth, yield and ultimately the value of timber, resulting in a loss of productivity, increased mortality and susceptibility to other pest and diseases. The most significant pressures identified were from *Phytophthora ramorum* (Larch), *Chalara dieback* (Ash), *Red band needle blight* (Pine), and *Green spruce aphid* (Sitka Spruce). A major issue is controlling further distribution of disease which can be spread via the wind, relocation of infected wood, on the feet of tourists and dogs etc. Consequently, large areas of ancient forest need to have restricted access or be felled in order to reduce further spread.

Risk 2: Water stress and drought crack
Projected changes in precipitation patterns are likely to increase the risk of water stress and drought crack (in Sitka Spruce), especially in the summer months when precipitation is estimated to decrease by 20%. Loss of forestry yield due to drought is projected to be between 10% under present conditions to 18% in the 2080s. Sitka Spruce is likely to be particularly affected from water stress through drought crack. The species is already being grown near the limit of its climatic tolerance (i.e. not grown in Eastern Wales). Drought crack is associated with water deficit in the trees, which will cause a lack or growth, quality and stability, limiting its use and favourability when sold as a finished product. Furthermore, drought crack increases the susceptibility of the tree to wind throw.

Risk 3: Soil degradation and erosion
Changes in soil degradation will have a significant impact on the productivity of forests and will also increase the susceptibility of forests to other climatic impacts, such as wind throw, waterlogging and flooding. Projected changes in soil degradation may include increases in soil organic matter turnover, hydrophobicity of highly organic soils induced by drought, and impacts on soil structural stability. Soil structure changes may include a decline in aggregate stability, susceptibility to compaction, slower infiltration rates, increased run-off rates, and increased susceptibility to erosion. Consequently, there will be an increased risk of flash flooding as increased surface water run-off will exacerbate the amount and timing of rainfall reaching watercourses.

Risk 4: Waterlogging and flood events
Waterlogging (or soil saturation) can occur after prolonged rainfall and have a number impacts on forestry productivity. Wetter winters, resulting in a greater saturation of soils, will impact on the root depth of trees, leaving species which are unsuited to fluctuating water tables (such as Douglas fir and Beech) vulnerable. Continued periods (e.g. over 21 days) of waterlogged soil and flood events can decrease soil health/quality which will lower productivity and the finished quality of timber. Waterlogging can also decrease the general health of trees, leaving them more susceptible to diseases and wind throw.

Risk 5: Wind throw (trees uprooted or broken)
Wind throw severely damages trees and decreases the forests resilience to further weather damage. Production (single species) forestry is much less resilient to wind damage to that of natural, diverse forest and losses are likely to be much greater when woodland has been thinned. Additionally, there is a significant issue with acidification of watercourses and mobilisation of silt with large scale wind throw, particularly with Sitka Spruce (very vulnerable to wind throw), having implications for biodiversity and water quality, as well as impacting on the carbon balance of forests.

Opportunity 1: Improved timber yields
The expected warmer climate and CO_2 increases will improve tree growth nationally. Productivity will generally increase, by up to 2–4 cubic metres per hectare per year for conifers on sites where water and nutrients are not limiting. Sitka spruce represents about 70% of the total timber yield in Wales and estimated increases of 20% by the 2050s is

expected, assuming water and nutrient availability remains stable. However, this may limit the scope to achieve C16 strength grade as increased growth rates may compromise timber quality. The average value per stocked hectare of coniferous forest was £7,057 in 2013 and trade between October 2012 and September 2013 totalled approximately £15.5m for Welsh forestry. Assuming timber quality is not compromised and water and nutrients are not limiting, increased yields could lead to a £3.1 million increase per year in revenue by the 2050s.

Opportunity 2: Forest Diversification

Forest diversification provides opportunities to offer tourist attractions in forested areas either no longer favourable for production, or as an extra stream of revenue. Activities could include mountain biking, high ropes or nature trails. However, this opportunity is regarded as low as there are many other factors such as wider policy changes that could catalyse such action rather than just a changing climate. Alternatively, agricultural diversification to provide remit for new production forests to be set up on land no longer suitable for agriculture has great potential if arable, horticultural or grassland productivity is no longer cost effective.

Summary of priority actions

Across all sectors, the climate change related risks to the Welsh land use sector that scored the highest were those related to flooding. This includes risks to rural communities and rural businesses where flooding can lead to widespread economic damage, and resultant social impacts in short space of time, with comparatively little warning of the event. For livestock flood events can make land unusable for grazing, and have resulting impacts in terms of destruction of feed (grass, cereal crops, forage). Waterlogging as a result of extreme rainfall can have yield and disease impacts for forestry, and crops. Construction of physical flood defences is costly, and benefits must be weighed up against risks. Total properties (not just in rural areas) in Wales at risk from flooding is estimated at £55.3 Billion[44]. In the winter flood events of 2013/14, 155 properties in Wales were flooded (not just in rural areas) and the cost of repairing flood defences was expected to be £25 Million. Cost effective adaptation interventions in rural areas such as planting of trees to provide a natural flood defence clearly are an attractive adaptation option is schemes can be shown to be effective.

The increase in pest and disease pressure in both forestry and livestock sectors is a significant risk, largely due to milder and wetter winters. Liver fluke is a major threat to sheep and cows, of which in 2013 in Wales there were 9.46M and 1.1M respectively. It is expected there will be epidemics of the disease affecting high numbers by the 2050s. Ensuring farmers are aware of prevention and treatment methods for diseases is key, this paired with early warning systems for times of higher risk may serve to reduce the occurrence of outbreaks. For forestry new diseases may be introduced to Wales such as Oak Processionary Moth, gypsy moth and European spruce bark beetle. For forestry, species diversity is a key adaptation method to increase forest resilience to pests and diseases. Ensuring a system is in place to give notification of sightings of prevalence of new pests and diseases is important to try and contain any outbreaks.

Water stress, in times of drought affects rural communities, rural businesses, livestock and forestry sectors in Wales. Impacts range from a lack of availability of water for people and businesses at higher prices, and yield impacts of between 18-20% by the 2080s. Increased drought leads to impacts on livestock through a lack of availability of drinking water. Much of Wales receives comparatively more rainfall than the majority of the UK, and as such the impact of water stress will be less severe. However to reduce impact, relatively cost effective actions to harness rainwater can be taken to ease impacts. This is most straightforward on

[44] Based on an average house price in North, West and South Wales of £155k (RightMove.co.uk, 2014), and a total number of properties at risk of 357,000.

livestock farms in the form of troughs, or ponds. For domestic customers grey water can be harnessed, using rainwater harvesting systems. On a larger scale reservoirs can be built to meet demand, however the cost of doing so needs to be judged against benefit. Consumers in the UK on average use 150 litres of water a day, a figure which increases by 1% each year. Significant benefits may be gained by encouraging greater stewardship of water, and the promotion of relatively cheap water saving tools.

Wildfires, both affecting grassland and forestry areas, and in some cases rural communities are increasing in Wales as drier conditions in the summer become more favourable for their development. South Wales Fire & Rescue services estimated an annual spend on wildfires of £7 Million in South Wales alone, with each wildfire costing between £1,000 and £1,950. Whilst wildfires are predominately caused by arson, drier conditions make their spread more favourable. Given the high cost, adaptation measures can be cost effective and include raised awareness amongst the general public and partnership working to reduce arson related crime, as well as fire breaks.

Annex 14: Stakeholders consulted

1. Land Use Sub-Group (LUSG) of the Climate Change Commission for wales

- Project presented to the group for discussion and steer (26 March 2014)
- Workshop to scope priority actions for climate change mitigation and adaptation (1 July 2014)

Membership of LUSG (as at 1 July 2014)

Chair: Prof. Gareth Wyn Jones

Secretariat: Dr. Eurgain Powell, Cynnal Cymru

Members

- Prof. Nigel Scollan, Aberystwyth University IBERS
- Prof. D L Jones, Bangor University
- Prof Dave Chadwick, Bangor University
- Dr. Havard Prosser, Cardiff University
- Prof. Bridgett Emmett, Centre for Ecology and Hydrology
- CFfI Cymru – Wales YFC
- Peter Davies, Climate Change Commission for Wales
- Dr. Clive Walmsley, Natural Resources Wales
- Karen Anthony, Country Land and Business Association
- Delyth Davies, Dairy Co
- Simon Neale, Natural Resources Wales
- Rhian Nowell-Phillips, Farmers Union of Wales
- Future Farmers of Wales
- Sion Aron Jones, Hybu Cig Cymru – Meat Promotion Wales
- Eirwen Williams, Menter a Busnes (Farming Connect)
- Bernard Llywellyn, NFU Cymru
- Peter Jones, Wales Environment Link
- Neville Rookes, Welsh Local Government Association
- Jane Gibson, Welsh National Park Authorities
- David Jenkins, Coed Cymru
- Dewi L Jones, Welsh Government

Welsh Government Observers

- Ken Stebbings
- Bill MacDonald

2. Welsh Government Natural Resources and Food Policy Board

- Project presented to the group for discussion and steer (26 March 2014)

3. Industry stakeholder

- ➢ Face-to-face and telephone interviews (August 2014)

<u>Consultees</u>

- 2 Sisters Food Group
- Coed Cymru
- DairyCo
- Farming Connect
- First Milk
- Farmers' Union of Wales (FUW)
- Hybu Cig Cymru - Meat Promotion Wales (HCC)
- RESolved Renewables
- LUCC Chair
- NFU Cymru
- Western Power Distribution
- WRAP

Annex 15: Industry stakeholder views

Productive Agriculture

Efficiency gains are generally seen as the best way to promote climate change actions to the industry but there is also a need to manage carbon sequestration via grassland management. Farmers need an incentive to change and this needs to be done in a strategic way. Efficiency is the route to sell climate change mitigation actions to the industry.

There is good support and engagement with farmers but some reports are too long and obsession with process and standards can hinder. Farmers need help with capital expenditure to deliver changes and remove fear of failure - grants are needed for behaviour change.

WG natural resource management and Payment for Ecosystem Services PES) concepts are difficult to explain to farmers and need to be translated at a practical level. One stakeholder commented that uncertainty around benefits for carbon sequestration may limit what organisations will pay for (e.g. DCWW). NRW needs to think about developing a partnership approach to dealing with the agricultural community and reconsider the baseline approach of regulation.

Group working can assist as farmers can engage with others in communities and use knowledge transfer.

Capital cost: Common barriers for advice not being taken up include resistance to behaviour change and availability of time and money. The Sustainable Production Grant (SPG)[45], part of the Wales Rural Development Programme 2014-2020 (RDP) won't enable changes needed to happen quickly enough or shift behaviour for the next 5-10 years. SPG requires a business plan which is a barrier to applications and is unnecessary. WG need to identify which is the priority target audience and make sure that the application process is proportionate.

It was also felt that new tax incentives for building reservoirs and water storage.

Evidence of benefits: it was felt that there is a lack of data and sharing of data, for example on intensive and extensive units. There is also a need for carbon footprinting to show financial and GHG impacts of technologies such as high sugar grasses. Need more consistent carbon footprinting of dairy sector; a project with Bangor University on Farming Connect demonstration farms showed results for farms with and without carbon sequestration were the same. Overall, a need for benchmark data to see evidence of effects.

Nutrient Management Planning: Farming Correct offers 80% funded Nutrient Management Planning and would like to continue to offer this service but unsure it can be justified at the same level. Savings in terms of CO_2e and financial savings can be quantified but there is no requirement at present. Data shows that 74% of farmers receiving nutrient advice have shown an improvement in commercial viability and environmental performance (independent evaluation).

Nutrient Management Plans have a high uptake in the Welsh dairy sector at 90% as they are part of Farm Assurance Schemes.

[45] The SPG is a capital grant scheme is designed to help farmers modernise their on-farm facilities with the aim of enhancing profitability and environmental outcomes. Grants of between £2,000 and £50,000 at a maximum rate of 40% of the eligible project costs will be available. http://wales.gov.uk/docs/drah/publications/140805rdp-sustainable-production-grant.pdf

A number of barriers to increasing productivity in the dairy sector were put forward, including:

- The average yield per cow in Wales is low as most Welsh systems as grass based (milk yield just over 7000 litres/cow per year) and believe there are limited opportunities for reducing greenhouse gas emissions per litre of milk. Housed systems will not be viewed favourably by retailers whose consumers prefer the image of a cow grazing on grass.
- More milk should be produced from forage based systems in a more economically robust business that helps overcome commodity "peaks and troughs". Wales can grow good quality forage but there is a gap in the knowledge.
- The drive to increase milk yield per cow ignores a necessary focus on "milk solids" (protein and fat value content) per unit of milk. This has further benefits as value per litre higher and transport costs lower.
- Do not recommend housing as has unintended outcomes of housed cattle are the increase in concrete and import of feed. Believe this is a narrow view and more holistic approach is required.
- One stakeholder was aware of a planning proposal considering methane collection, and believes this is an opportunity and that concerns about animal welfare and odour could be addressed.
- There is not enough information available about methane capture methods and if it is there it is not cascaded out.
- Slurry storage units can cause planning issues and planning permission for new dairies (to increase agricultural output of Wales) can cause issues with local communities for fears of turning into "mega dairies"
- Need more information on impact of liver fluke, genetics, fertilisers and finding alternative feed such as soya
- CH_4 capture cannot work in isolation in Wales as there is a need to consider the wider impacts such as impact on export and import.
- Some intensive grassland will have a high uptake of carbon and this needs managing; this is about mitigation rather than conservation and intensive farming has a place.
- Farmers need support on NVZs.
- Nutrient targeting using precision fertiliser applications are important for climate change e.g. using GPS for fertiliser apps. This is the kind of action that will allow intensive sustainable systems to become a reality. Funding for precision equipment helps to make the target achievable. Another stakeholder commented on the importance of precision agriculture but the investment being a barrier (e.g. £30k for fertiliser drill).
- Carbon trading at present is valueless and the major corporates are giving lip service to carbon offsetting - there is a need to increase the value of carbon.
- The "roadmaps" are not based on Welsh systems and not relevant.
- There needs to be incentives for producing reservoirs and storing water.

Food Supply Chain

The following industry-level comments were made:

- There is a commitment by WG to increase the value of Food and Drink production by 30% in the Food Strategy for Wales[46]. The DairyCo task force estimates that a 25% increase in milk production is achievable and a recent survey of milk producers in Wales[47] indicated a 20% rise in milk production over the next five years. However, market volatility may limit the realisation of these aspirations.

- The dairy industry needs to look at innovation of products to increase shelf life, developing ambient stored products and work with supply chains to consider milk cheese yields and milk solid products to buffer the seasonal availability of milk. Wales should showcase the natural advantage of Welsh dairy section with quality grassland.

- It was commented that Welsh food producers need to work across sectors to share opportunities to work together such as long term storage to buffer out supply/demand peaks, chilled transport and access to market. Increasing EU funding to develop ICT within resource efficiency sector could help.

- Extending lamb shelf life to compete with the New Zealand market. The NZ lamb has a longer shelf life due to the cleanliness of stock at point of presentation. This could be equally important for the smaller abattoirs. Lamb packaging R&D is already underway.

- Fifth sector (offal hide and skins etc.) market is under development particularly with the Chinese market. The climate change greenhouse gas impacts of diverting this material from landfill and rendering has not been assessed.

Food waste

The Wales Rural Observatory Households Survey 2013 looked at recycling and attitudes towards environmental issues. Also the Rural Business Survey 2013 looked at rates of recycling amongst businesses in rural Wales and whether they were taking any other environmental measures. Both surveys were carried out on a triennial basis.

Several stakeholders raised the issue of food waste which needs to be addressed. Comments include:

- Food waste is a target sector for WRAP with a focus on post-harvest waste and on farm losses. A project is underway with WRAP England and will include looking at inefficiencies in the production systems for resources, energy and water.
- AD and biosolids is of particular interest within the food sector due to a need to avoid landfill costs and seek a reduction of energy production costs (e.g. energy for chilling with is a big energy requirement).
- There is a need to engage with the general public as post farm gate losses are very important such as efficiency in the supply chain and food waste. This was picked up by multiple stakeholders
- There should have been more support for the public to instil confidence in the supply chain following “Horsegate”

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[46] Food for Wales, Food from Wales 2010:2020: Food Strategy for Wales. http://wales.gov.uk/docs/drah/publications/101207foodforwalesfoodfromwalesen.pdf
[47] The Welsh Dairy Farmers Survey – ‘Your Voice, Your Future’. July 2014.

Reducing Environmental Impacts Food Processing
Comments include:

- The Agri food policy should have regard to the sustainability agenda and there needs to be a balance between the departments in WG and a clear view of the priorities – production and sustainability where there is conflict.
- There are no processor GHG targets for dairy. However every processor should have an Environmental Management System with targets for 20% reduction in water 20% reduction in COD at the treatment plant, zero waste to landfill and 10-15% energy derived from renewable energy.
- In England there is a national EA lead for food sector which can be approached and the EA and have a national improvement environmental business plan to focus funding. there is not such structure or support in Wales.
- Reuse of process water via reverse osmosis of water used for treatment of food offers an opportunity to reduce water use. Reverse Osmosis plant costs £1 million but could reduce consumption of water by £400k.
- WG also need to consider R&D funding for innovative treatments of Water

Land use and management

A wide range of issues were raised, many relating to government policy and interventions.

- The take up of Glastir has been lower than thought and with the new RDP is it likely that fewer farmers will opt to join as slurry storage is not included. There is a general conflict between profitability of business and agri-environment schemes as taking land out of production is not worthwhile.
- There is an aspirational target for woodland and it is questionable if farmers would prefer to revert good land out of agricultural production.
- Peatlands under spruce forests are managed for the optimisation of timber production. This is the wrong approach. These landscapes should be managed for "husbandry of water and carbon stocks". Forestry is managed for felling contractors and agents where a % cut is taken for timber and fees for replanting; this raises the question of why taxpayers' money is being used to put in crop after crop which are environmentally unsound and commercially unsound. Need to change to 'close to nature' and 'continuous cover forest' practice rather than "plantation" approach.
- WG is perpetuating the systems of war and post war times. Since the 1950's spruce has been planted in areas of high rainfall with wet soils. The impact has changed the hydrology and fisheries of the catchment. There is evidence that the negative impact is reversible and the forests can be replaced by appropriate systems such as natural forests. Evidence is available from the Plynlimon project, Conwy project and Pontbren project plus other work completed in Northern England. There needs to be systematic coordination of projects and cohesion with less energy spent on competing for R&D funding and project outcomes to be shared.
- There is a need to reconsider current plans which focus on timber production quantity rather than quality, need more focus on water management as the value of water and fisheries will be more valuable than timber produced.
- At present for every £50 million spent, £25 million is lost as the forests are losing £0.5 million per week of tax payer's money (England is £1 million per week). This needs to be addressed.

- Reference to a project looking at wood chip for bedding with wood derived from farm land or forestry land and some with waste wood
- Once improved land has gone to forestry cannot be returned to improved land
- Ash dieback means even more trees have to be planted to replace those felled but there is no scheme to replant Phytophthora damaged trees.
- There is a grant for 25% grant for planting broadleaf trees but this grant scheme is time limited and there is no means of making a living
- The majority of trees in Wales are in the private sector and there is scope to manage these to maximise carbon sequestration. Managing trees to maximise growth rate is one way this can be achieved.
- The agri environment schemes are supportive for business. Areas of conflict can arise in situations such as biodiversity requirements whereby there is conflict for socio economic reasons. A financial incentive may help - planting trees in uplands to alleviate flooding for example.
- The purpose of the GHG platform is to identify R&D on global scale but what works in New Zealand and Australia do not always transfer to welsh systems. There is a need for more Welsh systems R&D.
- Farming connect have soil temperature figures and 80% subsidy for soil testing. NRW have some free soil testing but is there anybody else who needs or has this data. Are we good enough about sharing information and data?
- Information transfer needs to be in "bite size" such as smart phones and test messages and would fit in with innovation

Renewables

The following general points were made by industry stakeholders:

- Generally acknowledged amongst stakeholders that there is an appetite in the farming community to increase output of renewables. A major driver of this is farms being able to provide own energy for farm and community.
- Access to the grid and capacity within the grid were cited as barriers to farmer uptake on renewables by multiple stakeholders. Exporting energy created can be an issue in that pylons and overhead lines may be required to export power and this can create objections such as in Montgomeryshire and Powys.
- The UK Government Low Carbon Transition Plan[48] will impact on distribution in terms of demand and capacity. Targets for low carbon energy generation need to consider OFGEM pricing rounds and reviews. Need to align to ensure funds available to deliver changes and accommodate increase in supply in particular from rural locations where access is limited.

[48] The UK Low Carbon Transition Plan National is part of the national strategy for climate and energy and has a five point plan to tackle climate change, including 30% of electricity from renewables by 2020
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228752/9780108508394.pdf

- Concern about how the connection and distribution network required for renewables investment will run and suggested the costs of connection fees should be reviewed.
- While renewable energy knowledge is increasing amongst farmers, planning remains an issue. This view was reflected with multiple stakeholders. Getting planning approvals through Local Planning Authorities (LPA) is a major blockage in development and judgements are made under political pressures of time. While technical aspects of planning applications can be overcome as required (e.g. highways access) Welsh Government needs to improve the facilitation of renewables schemes which currently can be ruled by individual preferences.
- Total current renewable power in Wales is 2.6 TWh with 6 TWh aim. There are inconsistencies in carbon reporting figures that make comparison between distribution companies difficult.
- Changes in Feed-In Tariffs (FiTs) are creating problems
- Presence of protected species can create blockages and there can be difficulty in getting work approved by Natural Resources Wales (NRW) and the bureaucracy involved hampers renewable energy generation.
- Payback for renewables of 7-8 years should be considered acceptable rather than 2-3 years.
- Renewables schemes for rural communities are often very small so a feasibility study is deemed too expensive. To make the output of these schemes more meaningful the scale of these schemes should be increased. However, some make a distinction between small scale AD and wind development and large scale development (+3 turbines).
- A barrier is that renewables can only be used on farm with no option to sell energy on. R&D is looking at energy storage which could increase uptake. In the RDP the grant for renewable energy is only applicable if the energy is used solely on the farm. The preference is to also be able to sell electricity generated but this is deemed as double accounting. As a result few farmers will opt for the RDP grant for renewables.

Anaerobic digestion

The renewable energy association has a register of UK biogas plants[49] which highlights that only a minority are farm-based. A number of stakeholders commented on AD potential, one stakeholder expressed concerns over the focus given to AD in the report. One stakeholder commented that small scale plants have been shown to work in Germany. Biomass from forestry is another option and one stakeholder commented that they felt there was a place for biomass and farm woodland management.

The potential for CHP and waste disposal with digestate being composted and used as land fertilisers was highlighted by one stakeholder; however community lobby groups object at planning level. It was suggested that AD works best for housed systems which are not common in Wales. While small AD plants work well there is little horticulture or greenhouse use in Wales and distances between sites may be too large.

[49] http://www.biogas.org.uk/plants

Concerns identified and research needs were highlighted as below:

Planning and community objections: Several stakeholders cited planning as a constraint to AD development with long periods to obtain planning permission being the main issue. Bryn Pica AD plant in Aberdare took five years to obtain planning and over this period. During that period there were changes in the political market place, the local authority procurement process and the availability of feedstock. A related issue is community tensions which can lead to polarisation of communities. Potential applications need to be aware of this a have the capacity to drive through this opposition. One community fear around AD is a change in property value which needs to be overcome.

Capital investment: A lack of faith in the market was cited as the reason for a lack of capital investment. The cost of AD is a major barrier for implementation

Land use: There is a low energy output from putting slurry through AD system and the requirement for other organic input causes problems with storage of other organic materials. Production of these materials such as maize is driving up land rental fee. This was highlighted by several stakeholders. An example was quoted where a farm paid £85/acre to rent land to produce maize 2-3 years ago but following commissioning of a nearby AD plant that requires 1000 acres of maize, rents have gone up to £250/acre.

Biomass
Miscanthus is grown in Pembrokeshire and Glamorgan but the crop needs to be grown close to the biomass plant otherwise the cost of transport can be too high

Wind
One stakeholder identified active support for small scale wind developments but not for larger scale sites (3+ turbines)

PV
There are concerns that the costs of installation of PV in the LUCC report not being realistic and requiring review.

PV and wind have the greatest return but question whether PV outputs meet manufacturers' specification and how this can be addressed to monitor actual output compared to a theoretical maximum.

PV can create issues with land use change and local opposition

Hydro
In Cwmystwyth one farmer has installed 2 hydro schemes but this has taken a commitment of 12 months' work by the farmer to get through planning etc.

One stakeholder commented that hydro would be the most popular as there is a lot of running water in upland areas

Hydro schemes have huge potential but most viable schemes are located in protected areas such as the National Parks.

Annex 16: Glossary and table of acronyms, units and conversions

Glossary of terms

Term	Definition
Ammonia volatilisation	Ammonia volatilisation occurs when urea fertiliser is converted to ammonia gas, a process which takes place in the first 48 hours after application.
Carbon equilibrium	A switch from arable to grass, or from grass to forest will lead to carbon sequestration but after a time a new equilibrium is reached and carbon stops accruing in the soil or (in the case of trees) above ground biomass. Carbon sequestration is greatest in the first few years of the growth and development cycle, with the gains declining over time. Soils tend to become saturated after about 20-100 years.
Carbon leakage	Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country (e.g. due to emission reduction policies).
Carbon sequestration	Terrestrial ecosystems have the potential to take up carbon (C) from the atmosphere and store it, thereby mitigating, at least temporarily, some of the increase in atmospheric carbon dioxide (CO_2) that is occurring largely as a result of fossil fuel emissions. Woodland and peatland are important stores or sinks for carbon.
Carbon sink	A carbon sink is a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period. The process by which carbon sinks remove carbon dioxide (CO_2) from the atmosphere is known as carbon sequestration.
CO_2e or carbon dioxide equivalent	CO_2e or carbon dioxide equivalent, is a standard unit for measuring the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming over a set period – usually a hundred years. Values for the non-CO_2 greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), are presented as CO_2 equivalents (CO_2e) using Global Warming Potential (GWP) factors from the Intergovernmental Panel on Climate Change (IPCC)'s second assessment report (GWP for CH_4 = 21, GWP for N_2O = 310), consistent with reporting under the Kyoto Protocol.
Earth Observation	Earth observation is the gathering of information about planet Earth's physical, chemical and biological systems via remote sensing technologies supplemented by earth surveying techniques. It is used to monitor and assess changes in the natural environment and the built environment.
Ellenberg scores	Ellenberg scores scale the flora of a region along gradients reflecting light, temperature, continentality, moisture, soil pH, fertility and salinity. They can be used to monitor environmental change.
Emission factor (EF)	In order to report the greenhouse gas emissions associated with an organisation's activities, users must convert 'activity data' such as litres of fuel used into carbon emissions. The default emission factors are averages based on the most extensive data sets available and they are largely identical to those used by the Intergovernmental Panel on Climate Change (IPCC).

Enteric fermentation	Enteric fermentation occurs when methane (CH_4) is produced in the rumen of ruminant livestock as microbial fermentation takes place.
Eutrophication of waters	Eutrophication arises from the oversupply of nutrients, which induces explosive growth of plants and algae which, when such organisms die, consume the oxygen in the body of water.
Greenspace	Areas of grass, trees, or other vegetation set apart for recreational or aesthetic purposes in an otherwise urban environment
Hub and PoD	Component of Anaerobic Digestion. The hub carries out collection and de-packaging of the feedstock as well as pasteurisation.
Heterotrophic denitrification	Denitrification is a microbially facilitated process of nitrate reduction (performed by a large group of heterotrophic facultative anaerobic bacteria
Intergeneric hybrid	An intergeneric hybrid is a cross between plants in two different genera in the same family. They are closely related enough that pollination will produce a hybrid, though the seeds of this hybrid are usually sterile.
LUCI	The Land Utilisation and Capability Indicator (LUCI) model allows the mapping of ecosystem services from the sub-field to national scale, the impact of management services on these services, likely trade-offs, and opportunities for spatially optimising interventions.
Miscanthus	Miscanthus or "Elephant Grass" is a the sterile grass that has risen to prominence since the early 1980's as a potential biofuel on account of its high dry weight annual yield.
Molinia	A genus of two species of flowering plants in the grass family Poaceae, native to damp moorland.
Nitrification Inhibitors (NIs)	Nitrification inhibitors delay the transformation of ammonium ions into nitrate ions and may be useful in reducing N_2O emissions from the application of fertilisers and from livestock manures.
Onshore wind	A renewable energy technology, where wind turbines are located on land to harness the energy of moving air, to generate electricity.
Organo-mineral soils	Organo-mineral soils have an organic layer of 40-50 cm or less. These can include humus-iron podzols, peaty podzols, surface and ground water peaty gleys, peaty rankers and podzolic rankers.
Renewables obligation	Introduced in 2002 by the UK government to incentivise renewable energy technology deployment. It requires electricity companies to source a proportion of their commercial supply from renewable sources – via the setting of annual obligation targets, which rise year on year (DECC, 2012c).
Roadmap	A roadmap lays out a set of practical actions, including short, medium and long-term targets, to deliver GHG abatement from farm sectors.
Smart grid	A future version of our current electricity grid system, which aims to enable more efficient and cost-effective delivery of electricity, by applying information and communications technologies (ICT) to the electricity system (DECC, 2009).
Unabated gas	Gas from power plants built without carbon capture and storage, a technology which captures carbon dioxide emitted from fossil fuel plants.

List of Acronyms

Acronyms	Full term
AD	Anaerobic digestion
AFBI	Agri-Food & Biosciences Institute
AFOLU	Agriculture, Forestry and Land Use
ALC	Agricultural Land Classification
BBSRC	Biotechnology and Biological Sciences Research Council
BGS	British Geological Survey
BSFP	British Survey of Fertiliser Practice
C	Carbon
CAP	Common Agricultural Policy
CARBINE model	Forest Research's model
CBG	Compressed biogas
CCF	Continuous Cover Forestry
CEH	Centre for Ecology and Hydrology
CER	Certified Emission Reduction
C-Flow model	The CEH model currently used for forests planted after 1920
CHP	Combined heat and power
CL	Cropland
ClimateXChange	Scotland's centre of expertise on climate change
CO_2e	Equivalent carbon dioxide
COD	Chemical Oxygen Demand
CORINE	Coordination of Information on the Environment. Dataset supplemented by IACS
CS	Countryside Survey
Dairy UK	The trade association for the British dairy supply chain
DARDNI	Department of Agriculture and Rural Development Northern Ireland
DC-Agri	Digestate and Compost in Agriculture
DCD	Dicyandiamide
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DM	Dry matter
EBLEX	The levy organisation for the English beef and sheep industry
ECOSSE model	Estimating Carbon in Organic Soils - Sequestration and Emissions Model

ECOSSE-2	Version 2 of ECOSSE model
EFs	Emission Factors
EPS	Energy Policy Statement
EU LIFE project	EU's financial instrument supporting environmental, nature conservation and climate action projects
EU-ETS	The EU emissions trading system
FARMSCOPER	ADAS modelling framework
FC	Forestry Commission
FiT	Feed in Tariff
FSC	Forestry Stewardship Council
FYM	Farmyard manure
GHG	Greenhouse gas
GHGE	Green House Gas Emissions
GIS	Geographic Information System
Glastir	The sustainable land management scheme for Wales
GMEP	Glastir Monitoring and Evaluation Programme
GPS	Global Positioning System
GWC	Glastir Woodland Creation scheme
GWM	Glastir Woodland Management (scheme)
GWP	Global Warming Potential
HCC	Hybu Cig Cymru - responsible for the development, promotion and marketing of Welsh red meat
HWP	Harvested Wood Products
IACS	Integrated Administration and Control System
IBERS	The Institute of Biological, Environmental and Rural Sciences
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KT	Knowledge Transfer
LCA	Life Cycle Analysis/Assessment
LCM	Land Cover Map
LFA	Less Favoured Areas
LISS	Low impact silvicultural systems
Lolium	Ryegrass
LPAs	Local Planning Authorities

LUCCG	Land Use Climate Change Group
LUCI	Land Utilisation and Capability Indicator
LULUCF	Land Use, Land-Use Change and Forestry
LUSG	Land Use Sub-Group
lwt	Liveweight
MACC	Marginal Abatement Cost Curve
MANNER-NPK	ADAS Decision Support Software
MCA	Multi-criteria analysis
MTP	Maximum technical potential
N	Nitrogen
NO_3	Nitrate
NOx	Mono-nitrogen oxides NO and NO_2
N*opt*	Optimum rate for nitrogen use from Defra Fertiliser Manual RB209
NAW	National Assembly Wales
NERC	Natural Environment Research Council (UK)
NFI	National Forest Inventory
NFU	National Farmers Union
NGO	Non-Government Organisation
NIs	Nitrification inhibitors
NNFCC	National Non-Food Crops Centre, UK consultancy focused on understanding bio-renewable markets and technologies.
N*opt*	Optimum rate for nitrogen from Defra Fertiliser Manual RB209
NOx	Mono-nitrogen oxides NO and NO_2
NRW	Natural Resources Wales
NUE	Nitrogen use efficiency
NUTS2	Regions belonging to the second level of Nomenclature of Territorial Units for Statistics
NVZ	Nitrate Vulnerable Zone
NW	North Wyke (Research), part of Rothamsted Research
OFGEM	Office of Gas and Electricity Markets
OSCAR	Optimal Strategies for Climate change Action in Rural areas
PEFC	Programme for the Endorsement of Forest Certification
PES	Payment for Ecosystem Services
PoD	Point of Digestion - a component of Anaerobic Digestion where the digestion takes place.

ppmv	Parts per million by volume
PPW	Planning Policy Wales
RB209	Fertiliser Manual
RDP	Rural Development Plan
RE	Renewable electricity
REF	Research Excellence Framework
RFI	Residual Feed Intake
RHI	Renewable Heat Incentive
Ricardo-AEA	International energy and environmental company
SAP	Sector Adaptation Plan
SIP	Sustainable Intensification Platform, Defra research initiative
SMART	5 steps of specific, measurable, attainable, relevant, and time-based goals
SOC	Soil organic carbon
Solar PV	Solar power by means of photovoltaics
SPG	Sustainable Production Grant
SRUC	Scotland's Rural College
UKAGHGI	UK Agricultural GHG Inventory
UKCP09	UK Climate Projections 2009 is a climate analysis tool, funded by Defra
UKFS	UK Forestry Standard
UKGHGEI	UK Greenhouse Gas Emissions Inventory
UKWAS	UK Woodland Assurance Standard
WAG	Welsh Assembly Government
WFDSP	Welsh Food and Drink Skills Project
WFPS	Wales Farm Practice Survey
WG	Welsh Government
WRAP	Waste & Resources Action Programme
Yara N-sensor	A tractor-mounted tool that allows farmers to measure a crop's nitrogen requirement
Ym	Proportion of animal gross energy intake that is excreted as methane energy
Ynni'r Fro	The WG programme of support (advice, grants and loans) to community-scale renewable energy schemes.

Abbreviations for Greenhouse Gases

Type of greenhouse gas	Formula or abbreviation	Name
Direct	CH_4	Methane
Direct	CO_2	Carbon dioxide
Direct	N_2O	Nitrous oxide

Units and Conversions

Emissions of greenhouse gases presented in this report are normally given in Million tonnes (Mt), Thousand tonnes (kt) and Tonnes (t).

Energy is expressed in terms of Watt hours (Wh)

To convert between the units of emissions, use the conversion factors given below.

Multiplication factor	Prefix	Symbol
1,000,000,000,000	tera	T
1,000,000,000	giga	G
1,000,000	mega	M
1,000	kilo	k