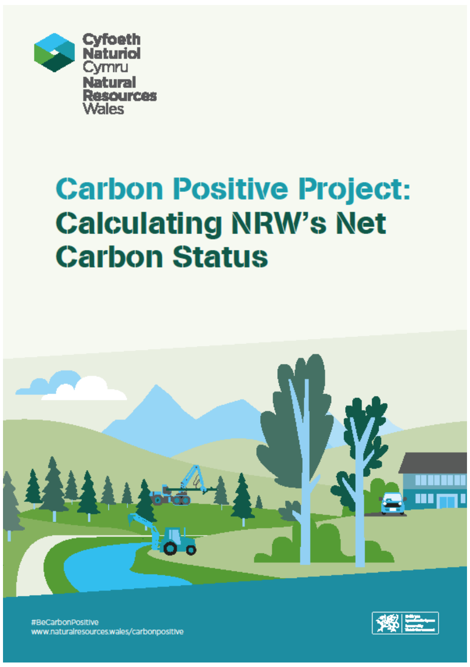
Cyfoeth Naturiol Cymru
Natural Resources Wales

Carbon Positive Project Technical Report: Calculating Natural Resources Wales' Net Carbon Status

NRW Evidence Report No. 303



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About this report

This report was written as part of the NRW Carbon Positive Project to outline the method carried out to conduct our calculation of NRW's Net Carbon Status.

The information within this report has been used to prioritise the areas to investigate and evaluate the potential measures NRW may take forward to deliver decarbonisation in the future as part of the Carbon Positive Enabling Plan and its supporting Action Plan.

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Our carbon stock and sequestration calculations for the NRW estate are underpinned by modelling and mapping work for woodland and peatland habitats carried out for NRW by Forest Research and the Centre for Ecology and Hydrology, as detailed and referenced in the report.
For some of the more challenging elements of our net carbon status calculation we sought external advice from North Energy Associates around interpretation of guidelines, emissions calculation methods and categorisation.

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AFOLU	Agriculture, Forestry and Other land use
CALM	Carbon Accounting for Land Managers
CEH	Centre for Ecology and Hydrology
CenSA	Centre for Sustainability Accounting
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
CPP	Carbon Positive Project
CS	Countryside survey
DEFRA	Department for Environment, Food and Rural Affairs
EAW	Environment Agency Wales
EEIO	Environmentally-extended input output
EF	Emission factor
EMS	Environmental Management System
FR	Forest Research
GHG	Greenhouse gas
GIS	Geographic Information System
HWP	Harvested wood products
IDB	Internal Drainage Board
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied petroleum gas
NNR	National Nature Reserve
N_2O	Nitrous oxide
NRW	Natural Resources Wales
PV	Photovoltaic
REGO	Renewable Energy Guarantee of Origin
ROA	Reservoir operating agreement
SCDB	Sub-compartment database
SIC	Standard industrial classification
SLA	Service level agreement
SMNR	Sustainable management of natural resources
T & D	Transmission and distribution
WGWE	Welsh Government Woodland Estate

Crynodeb gweithredol

Mae Cyfoeth Naturiol Cymru wedi ymrwymo i gamau cadarnhaol ar y newid yn yr hinsawdd. Rydym yn cydnabod pwysigrwydd manteisio ar gyfleoedd i leihau allyriadau nwyon tŷ gwydr o'n gweithgareddau ein hunain ac i ddiogelu a gwella storfeydd carbon hirdymor sydd o dan ein dylanwad. Mae'r ymgyrch i wella statws carbon net y sefydliad yn rhan allweddol o gyfraniad Cyfoeth Naturiol Cymru at broses bontio Cymru i economi carbon isel. Mae gan sector cyhoeddus Cymru swyddogaeth i ddangos arweinyddiaeth o ran cymryd camau i leihau allyriadau ac mae Llywodraeth Cymru wedi arianni'r Prosiect Carbon Bositif i ddangos sut y gall y sefydliad werthuso a gwella ei statws carbon net. Mae'r Prosiect yn rhannu ei ddysgu gyda sefydliadau sector cyhoeddus eraill Cymru i hwyluso datgarboneiddio carlam yng Nghymru.

Mae'r adroddiad technegol hwn yn nodi'r rhesymeg sy'n sail i'r gwaith a wnaed gan Cyfoeth Naturiol Cymru i gyfrifo ei statws carbon net, yn ogystal â'i ddull ar gyfer gwneud y gwaith a'r canlyniadau. Gwnaed y gwaith gyda'r cydamcanion o: ddarparu llinell sylfaen ar gyfer allyriadau nwyon tŷ gwydr a dal a storio carbon i alluogi Cyfoeth Naturiol Cymru i nodi blaenoriaethau ar gyfer camau lliniaru yn strategol, gan gynorthwyo'r gwaith o werthuso'r opsiynau mwyaf cost a charbon effeithiol ar draws ein gweithgareddau a'n gweithrediadau; a chynnig adnodd a chyfeiriad defnyddiol i sefydliadau sector cyhoeddus eraill sy'n rheoli eu heffaith garbon.

Diffinnir statws carbon net yn y Prosiect Carbon Bositif fel y cydbwysedd rhwng cyfanswm y nwyon tŷ sy'n cael eu hallyrru gan weithrediadau'r sefydliad a'r cyfanswm carbon net sy'n cael ei ddal a'i storio mewn cynefinoedd ar ystâd Cyfoeth Naturiol Cymru. Gwnaed dau ddarn o waith cyfochrog i gynnig ffigurau ar gyfer cyfrifo statws carbon net Cyfoeth Naturiol Cymru:

1. Datblygu rhestr allyriadau nwyon tŷ gwydr ar gyfer Cyfoeth Naturiol Cymru, gan fesur allyriadau yn deillio o asedau a gweithrediadau.
2. Amcangyfrif y carbon sy'n cael ei ddal a'i storio yn llystyfiant a phriddoedd cynefinoedd ar yr ystâd y mae Cyfoeth Naturiol Cymru yn berchen arni ac yn ei rheoli.

Ochr yn ochr â cholledion ac enillion carbon, amcangyfrifwyd cyfanswm y stociau carbon ym mhob math o gynefin hefyd i gynnig dealltwriaeth lawn o effaith garbon yr ystâd. Fodd bynnag, nid yw amcangyfrifon stoc carbon yn rhan o'r statws carbon net a gyfrifwyd ar gyfer Cyfoeth Naturiol Cymru.

Mae cylch gwaith unigryw ac eang Cyfoeth Naturiol Cymru, gan gynnwys bod yn geidwad a rheolwr 7% o arwynebedd tir Cymru, yn her o ran cyfrifo nwyon tŷ gwydr. Er nad yw'n elfen safonol o restrau nwyon tŷ gwydr corfforaethol, ystyriwyd bod amcangyfrif y carbon sy'n cael ei ddal a'i storio yn llystyfiant a phriddoedd yr ystad y mae Cyfoeth Naturiol Cymru yn berchen arni ac yn ei rheoli yn elfen hanfodol o ddeall statws carbon cyfredol y sefydliad, o ystyried swyddogaeth Cyfoeth Naturiol Cymru fel perchennog a rheolwr tir.

Dyma'r asesiad cyntaf o statws carbon net a stociau carbon y sefydliad, ac roedd yr holl ddata mewnbwn sefydliadol a ddefnyddiwyd yn y cyfrifiadau yn gysylltiedig â'r flwyddyn sylfaen ddethol - blwyddyn ariannol 2015/16.

Dulliau

Rhestr nwyon tŷ gwydr

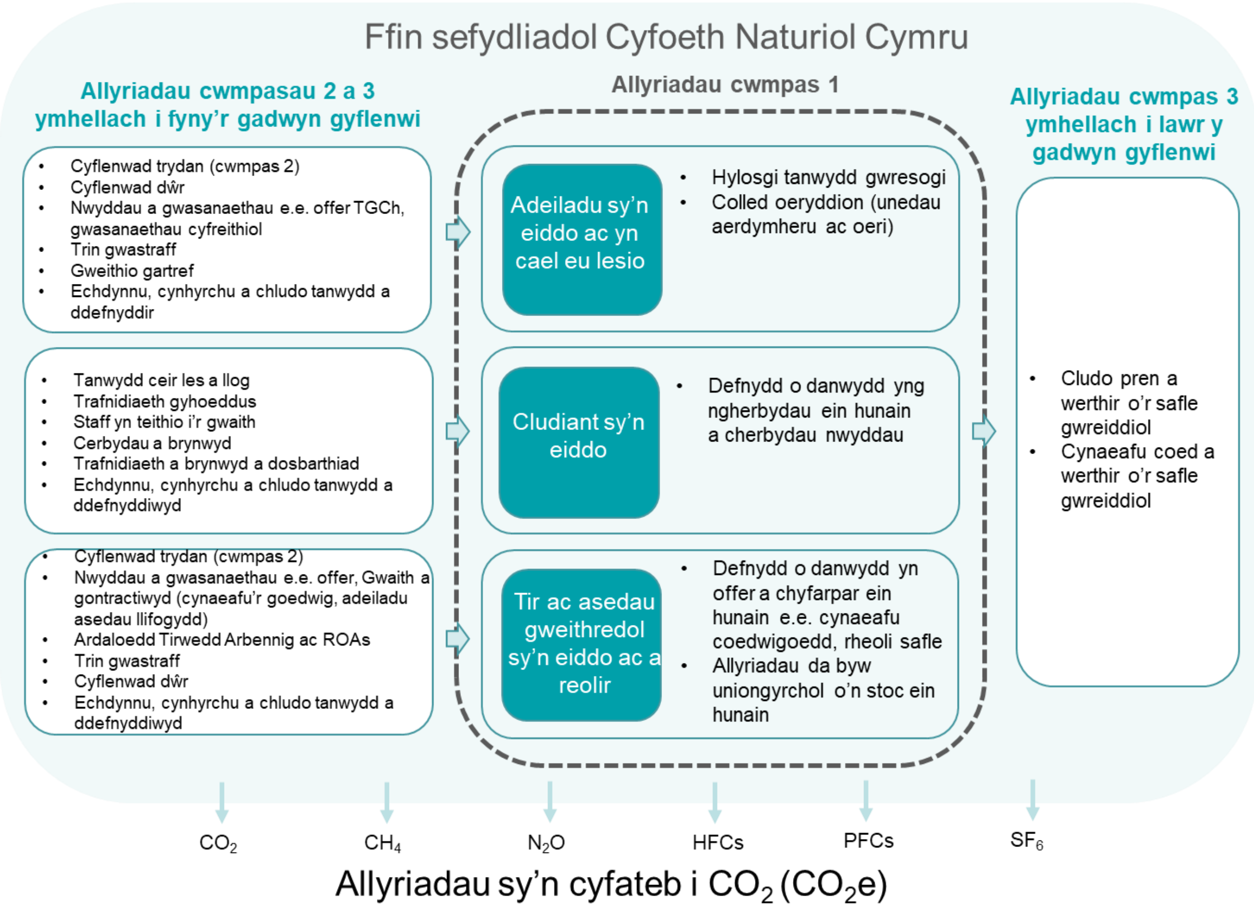
Cyfrifwyd allyriadau nwyon tŷ gwydr gan ddilyn canllawiau Safon Gorfforaethol y Protocol Nwyon Tŷ Gwydr (Ranganathan *et al*., 2004) a chan hysbysu am y chwe nwy sydd wedi eu cynnwyd o dan Brotocol Kyoto mewn unedau cyffredin o allyriadau sy’n cyfateb i garbon deuocsid (CO_2e).

Mae’r ffin sefydliadol a ddewiswyd ar gyfer cyfrifo a hysbysu am nwyon tŷ gwydr yn cynnwys yr holl asedau a gweithrediadau o dan reolaeth weithredol Cyfoeth Naturiol Cymru. Ystyrir bod yr holl asedau y mae Cyfoeth Naturiol Cymru yn berchen arnynt yn eu rheoli o ddydd i ddydd o fewn ein rheolaeth weithredol h.y. adeiladu sy’n eiddo i ni, cerbydau ac offer ffordd sy’n eiddo i ni, tir sy’n eiddo i ni ac a reolir gennym, asedau yr ydym yn berchen arnynt ac yn eu rheoli fel y rheini sy’n gysylltiedig â rheoli perygl llifogydd. Aseswyd a gwerthuswyd categorïau o asedau a leswyd ar sail achosion unigol yn erbyn y maen prawf rheoli gweithredol i benderfynu a ydynt o fewn y ffin sefydliadol. Er enghraifft: rheolir ein hadeiladau a lesir o ddydd i ddydd gan Cyfoeth Naturiol Cymru ac ystyrir felly eu bod o fewn ein rheolaeth weithredol ar gyfer cyfrifo allyriadau; ystyrir bod tir sy’n cael ei lesio gan Cyfoeth Naturiol Cymru i sefydliad arall o dan reolaeth weithredol y sefydliad allanol sy’n gyfrifol am reolaeth o ddydd i ddydd; ystyrir bod tir sy’n cael ei lesio i Cyfoeth Naturiol Cymru a’i reoli gennym e.e. Ystad Goed Llywodraeth Cymru o fewn ein rheolaeth weithredol ac o fewn ein ffin sefydliadol ar gyfer hysbysu am allyriadau yn sgil hynny.

Ar ôl nodi asedau a gweithrediadau i’w cynnwys, diffiniwyd pa ffynonellau allyriadau yr oeddem yn eu cyfrifo. Cafodd pob un o’r 3 chategori allyriadau, a elwir yn gwmpasau, ar restr nwyon tŷ gwydr Cyfoeth Naturiol Cymru. Dyma nhw:

- cwmpas 1 - allyriadau nwyon tŷ gwydr uniongyrchol i’r atmosffer o ffynonellau y mae Cyfoeth Naturiol Cymru yn berchen arnynt neu’n eu rheoli e.e. hylosgi tanwydd mewn bwyleri a cherbydau yr ydym yn berchen arnynt;
- cwmpas 2 – allyriadau anuniongyrchol i’r atmosffer o gynhyrchu trydan a brynwyd gan Cyfoeth Naturiol Cymru i’w ddefnyddio mewn asedau ac adeiladau o dan ein rheolaeth weithredol;
- cwmpas 3 – allyriadau anuniongyrchol eraill sy’n deillio o ffynonellau y tu allan i reolaeth weithredol Cyfoeth Naturiol Cymru ond sy’n ganlyniad o’n gweithgareddau e.e. deunyddiau a brynwyd, gwasanaethau contractwyr, cymudo cyflogeion.

Mae Ffigur 1 yn dangos y ffynonellau allyriadau a gyfrifir a’r cwmpasau yr hysbyswyd amdanynt yn unol â nhw. Fel categori hysbysu dewisol, yn y Protocol Nwyon Tŷ Gwydr, ni chyfrifir allyriadau cwmpas 3 yn aml ar restrau nwyon tŷ gwydr corfforaethol. Fodd bynnag, er mwyn cynnig crynodeb mor gyflawn â phosibl o allyriadau nwyon tŷ gwydr Cyfoeth Naturiol Cymru, rydym wedi cynnwys amrywiaeth eang o allyriadau cwmpas 3 ar ein rhestr, gan ganolbwyntio ar y rheini y disgwylir iddynt wneud y cyfraniadau mwyaf, a’r rheini y gall y sefydliad ddylanwadu arnynt.



Ffigur 1. Ffin weithredol Cyfoeth Naturiol Cymru h.y. y ffin allyriadau a ddefnyddir ar restr nwyon tŷ gwydr y sefydliad.

Ar gyfer pob ffynhonnell a nodir yn Ffigur 1, mae'r adroddiad hwn yn nodi math a ffynhonnell y data gweithgarwch a ddefnyddir mewn cyfrifiadau allyriadau, unrhyw drosiadau neu dybiaethau sydd eu hangen, y ffactor(au) allyrru a ddefnyddiwyd a'u ffynonellau, cafeatau cyfrifo, tybiaethau a gwersi a ddysgwyd. Roedd manylder y data gweithgarwch yn amrywio rhwng categorïau allyriadau, ac yn gymysgedd o ddata sylfaenol penodol i'r sefydliad, a data eilaidd e.e. cyfartaleddau diwydiant neu ddata ariannol. Ar gyfer ein hamcangyfrif o allyriadau cwmpasau 1 a 2, dibynnwyd yn drwm ar ddata sylfaenol presennol a gesglir gan ein tîm System Rheoli Amgylcheddol i sicrhau achrediad IS04001, e.e. cyfansymiau tanwydd gwresogi a ddefnyddiwyd. Roedd cyfrifiadau cwmpas 3 yn seiliedig i raddau helaeth ar ddata ariannol eilaidd, e.e. nwyddau a gwasanaethau a brynwyd, neu ar ddata sylfaenol wedi eu hategu gan dybiaethau, e.e. allyriadau cymudo staff. Defnyddiwyd y data gweithgarwch mwyaf cywir a'r dulliau cyfrifol mwyaf ymarferol o fewn ein hamserlenni gennym. Fodd bynnag, mae rhai cyfyngiadau yn parhau a gellid gwella'r rhain trwy ailystyried dulliau cyfrifo yn y blynyddoedd i ddod, e.e. gwella cywirdeb data tanwydd gwresogi trwy safoni ffactorau trosi i gilowat-oriau a chasglu data penodol i'r sefydliad ar fodd cymudo staff i ddisodli tybiaethau cyfartaledd cenedlaethol.

Dal a storio carbon a stociau carbon

Gan adlewyrchu egwyddorion ein rhestr nwyon tŷ gwydr, cyfrifir carbon sy'n cael ei ddal a'i storio a stociau carbon o fewn ffin sefydliadol a ddiffinnir fel asedau a gweithrediadau o dan reolaeth weithredol Cyfoeth Naturiol Cymru. Felly, mae ein hamcangyfrifon o garbon sy'n cael ei ddal a'i storio a stociau carbon yn ymwneud â llystyfiant a phriddoedd ar dir a reolir o ddydd i ddydd gan Cyfoeth Naturiol Cymru, pa un a ydynt yn berchen arno neu'n ei lesio. Yn ogystal â dal a storio a stociau ar safle, mae ein hamcangyfrifon ar gyfer yr ystad goed hefyd yn cynnwys yr holl gynhyrchion pren a gynaeafwyd sy'n deillio o'r pren a gynhyrchwyd ar yr ystad goed, ac sy'n dal i fodoli, yn ystod y flwyddyn sylfaenol (2015/6).

Addaswyd mapiau wedi'u digideiddio sydd eisoes yn bodoli o ystad Cyfoeth Naturiol Cymru i lunio map wedi'i deilwra ar gyfer y Prosiect Carbon Bositif gan baru'r ffiniau tir sefydliadol dethol o dan ein rheolaeth weithredol. Diffiniwyd maint pob math o gynefin ar ystad Cyfoeth Naturiol Cymru gan ddefnyddio mapiau dosbarthu cynefin Cyfnod 1, wedi eu mireinio gyda mapiau penodol i gynefin mwy diweddar neu fwy manwl yn ofodol pan fo'n briodol. Roedd hyn yn wir ar gyfer cynefinoedd morfeydd heli, mawn dwfn wedi'i erydu neu ei adfer a choetir ar yr ystad, e.e. diffiniwyd maint yr ystad goed gan ddefnyddio'r gronfa ddata is-gompartmentau coedwig ar gyfer y goedwig a reolir yn fasnachol, ac yn unol â'r categorïau coetir yn y Rhestr Goedwigaeth Genedlaethol ar gyfer ardaloedd coetir nad ydynt yn fasnachol gan mai hon oedd y dystiolaeth orau ar gael.

Yn absenoldeb canllawiau ar gyfrifo carbon sefydliadol sy'n cael ei ddal a'i storio (a stociau carbon), mabwysiadwyd a datblygwyd methodolegau cyfrifo penodol i gynefinoedd gennym, gan ddilyn egwyddorion eang Safon Gorfforaethol y Protocol Nwyon Tŷ Gwydr ar gyfer cyfrifo allyriadau (Ranganathan *et al*., 2004). Mae'r cronfeydd carbon a'r nwyon tŷ gwydr a gyfrifwyd yn y ffin gyfrifo carbon sy'n cael ei ddal a'i storio a stociau carbon yn amrywio rhwng gwahanol fathau o gynefin yn seiliedig ar y dull cyfrifo a ystyriwyd oedd yn fwyaf priodol ar gyfer pob un. Roedd hyn yn seiliedig ar: ba un a ystyriwyd bod y cynefin yn flaenoriaeth ar gyfer asesu manwl (e.e. mawndir, coetir), y data rheoli a oedd ar gael ar gyfer y math o gynefin ar draws ystad Cyfoeth Naturiol Cymru, dealltwriaeth wyddonol bresennol o'r allyriadau a'r gwarediadau nwyon tŷ gwydr sy'n gysylltiedig â phob math o gynefin. Roedd y dulliau cyfrifo yn amrywio o ran penodoldeb a manylder, o gymhwyso ffigurau allyriadau, dal a storio neu stociau carbon cyfartalog i ardaloedd cynefinoedd (e.e. ar gyfer cynefinoedd glaswelltir) i weithio gydag arbenigwyr diwydiant i fodelu'r carbon sy'n cael ei ddal a'i storio neu stociau carbon ar gyfer mathau o gynefin ar yr ystad, e.e. cynefinoedd coetir.

Roedd y dull mwyaf manwl a fabwysiadwyd ar gyfer cynefinoedd coetir gan fod ystad Cyfoeth Naturiol Cymru yn goedwig i raddau helaeth. Mae hyn o ganlyniad i'n swyddogaeth fel ceidwad Ystad Goed Llywodraeth Cymru. Modelwyd stociau carbon presennol a newidiadau blynyddol rhagamcanol (h.y. dal a storio) ar gyfer pridd, biomas, deunydd organig marw a chronfeydd cynnyrch pren a gynaeafwyd gan ddefnyddio data manwl a ddarparwyd gan Cyfoeth Naturiol Cymru ar rywogaethau, arwynebedd, dosbarth oed, math o bridd a threfn reoli, ynghyd ag amcangyfrifon ar lefel y DU o strwythur celli, twf a chynnwys carbon. Ochr yn ochr â chynefinoedd coetir, teimlwyd y byddai amcangyfrif y carbon sy'n cael ei ddal a'i storio / allyriadau carbon a stociau carbon priddoedd mawn dwfn yn hanfodol i ddeall statws carbon yr ystad. Gweithiwyd gydag arbenigwyr y diwydiant i fapio maint a chyflwr draenio cynefinoedd mawn dwfn ar yr ystad, gan neilltuo'r ffactorau allyrru gorau sydd ar gael i fawndiroedd wedi'u grwpio fesul math o gynefin a chyflwr.

Canlyniadau

Mae Tabl 1 yn nodi canlyniadau amcangyfrifon rhestr allyriadau nwyon tŷ gwydr a charbon sy'n cael ei ddal a'i storio Cyfoeth Naturiol Cymru ar gyfer y flwyddyn sylfaen, gan ddangos y cydbwysedd rhwng y ddau h.y. statws carbon net y sefydliad. Gwnaeth Cyfoeth Naturiol

Cymru ddal a storio 349,621 tunnell CO_2e (tCO_2e) yn fwy mewn cynefinoedd ar yr ystad nag allyrrwyd ganddo trwy ei weithrediadau yn 2015/16. Gellid ystyried bod y sefydliad yn bositif o ran carbon net felly. Adroddir allyriadau i'r atmosffer fel rhifau positif a gwarediadau fel rhifau negatif.

Tabl 1. Statws carbon net Cyfoeth Naturiol Cymru

Statws Carbon Net Cyfoeth Naturiol Cymru yn 2015/16	tunelli CO_2e/blwyddyn
Cyfanswm allyriadau nwyon tŷ gwydr cwmpasau 1, 2 a 3	41,304
Cyfanswm (net) y carbon a gafodd ei ddal a'i storio	-390,924
Statws carbon net	**-349,621**

41,304 tCO_2e oedd cyfanswm allyriadau nwyon tŷ gwydr Cyfoeth Naturiol Cymru yn y flwyddyn sylfaen (2015/16). Mae'r rhain yn cynnwys allyriadau nwyon tŷ gwydr uniongyrchol i'r atmosffer o ffynonellau y mae Cyfoeth Naturiol Cymru yn berchen arnynt neu'n eu rheoli, ac allyriadau nwyon tŷ gwydr anuniongyrchol i'r atmosffer o ganlyniad i weithgareddau Cyfoeth Naturiol Cymru. Yn y flwyddyn gyfrifo sylfaen, 2,997 a 1,869 tCO_2e oedd cyfanswm allyriadau cwmpasau 1 a 2, yn eu trefn, ac amcangyfrifwyd mai 36,437 tCO_2e oedd allyriadau cwmpas 3. O fewn cwmpasau 1 a 2, hylosgi tanwydd mewn cerbydau y mae Cyfoeth Naturiol Cymru yn berchen arnynt yw'r ffynhonnell allyriadau fwyaf sylweddol, a daw 37.2% o geir a cherbydau nwyddau ac 13.7% o beiriannau offer. Mae allyriadau sy'n deillio o gynhyrchu trydan a ddefnyddir gan Cyfoeth Naturiol Cymru, sef 38.4% (1,869 tCO_2e), hefyd yn gwneud cyfraniad sylweddol at gyfanswm cwmpasau 1 a 2. Mae defnydd trydan ar safleoedd sydd wedi eu staffio fel swyddfeydd a depos yn gyfrifol am 63% o gyfanswm y trydan, a safleoedd nad ydynt wedi eu staffio fel gorsafoedd pwmpio ac asedau telemetreg sy'n gyfrifol am y 37% sy'n weddill.

Allyriadau cwmpas 3 anuniongyrchol yw'r rhan fwyaf o'r rhestr nwyon tŷ gwydr, ac mae'r rhain yn deillio o ffynonellau sydd y tu allan i reolaeth weithredol Cyfoeth Naturiol Cymru ond yn ganlyniad i'n gweithgareddau. Y ffynhonnell fwyaf o allyriadau cwmpas 3 yw allyriadau cadwyn gyflenwi yn gysylltiedig â nwyddau a gwasanaethau a brynwyd gan Cyfoeth Naturiol Cymru (62.2% o gyfanswm cwmpas 3). O fewn hyn, dyma'r categorïau caffael eang cyfrannol mwyaf: gwaith a wneir gan gontractwyr (35% (7,942 tCO_2e)), e.e. cynaeafu coedwigoedd, peirianneg ac adeiladu asedau llifogydd; rheoli cyfleusterau ac agweddau cysylltiedig â thechnoleg gwybodaeth a chyfathrebu (21.5% (4,883 tCO_2e)), Cytundebau Lefel Gwasanaeth a Chytundebau Gweithredu Cronfeydd Dŵr (13.8% (3,118 tCO_2e)). Gellir ystyried bod y meysydd gwario hyn yn feysydd lle ceir allyriadau uchel yn y gadwyn gyflenwi ar gyfer gwaith pellach, i wella cywirdeb cyfrifiadau allyriadau a / neu i ganolbwyntio ymdrechion lleihau allyriadau. Dylid asesu meysydd lle ceir allyriadau uchel ar y lefel ddadgyfunol hefyd. Er enghraifft, gallai adolygu allyriadau ar y lefel cyfrif a chod cynnyrch helpu i dargedu ymdrechion lliniaru i fframweithiau a chyflenwyr o bosibl. Ochr yn ochr â nwyddau a gwasanaethau a brynwyd, mae allyriadau ymhellach i lawr y gadwyn gyflenwi sy'n gysylltiedig â chynaeafu a chludo pren a werthir o'u safleoedd gwreiddiol ar yr ystad a reolir gan Cyfoeth Naturiol Cymru (14.2% o gyfanswm cwmpas 3), ac allyriadau sy'n deillio o gyflogeion yn cymudo ac yn gweithio gartref (7.8% o gyfanswm cwmpas 3) hefyd yn ffynonellau sylweddol i allyriadau cwmpas 3.

-390,924 tCO_2e oedd cyfanswm net y carbon a oedd yn cael ei ddal a'i storio mewn cynefinoedd ar ystad Cyfoeth Naturiol Cymru yn ystod blwyddyn sylfaen 2015/16 (roedd ffigur negyddol yn dynodi y gwaredwyd carbon o'r atmosffer a charbon a oedd wedi ei storio mewn cynefinoedd). Roedd cyfanswm net y carbon yr oedd y sefydliad yn ei ddal a'i storio yn y flwyddyn sylfaen yn cyfateb i werth 9.5 mlynedd o allyriadau sefydliadol o'i weithrediadau. Gwarediadau mewn cynefinoedd coetir sydd i'w gweld yn bennaf ar yr ystad o ran carbon sy'n cael ei ddal a'i storio (-418,156 tCO_2e yn y flwyddyn sylfaen). Coetir conwydd llwyrgwympo oedd y prif gyfrannwr at hyn, gyda mwy neu lai yr un cyfraniadau o ran dal a storio carbon o bridd, sbwriel a chronfeydd cynnyrch pren wedi ei gynaeafu. Mae cynefinoedd arfordirol yn gwneud cyfraniad bach ar warediadau ar yr ystad hefyd (-6,661 tCO_2e). Amcangyfrifwyd bod yr holl gynefinoedd eraill yn allyrwyr net, ac eithrio dŵr agored, creigiau agored a gwastraff na thybiwyd unrhyw allyriadau neu warediadau ar eu cyfer. Cynefinoedd glaswelltir, cors a llaid yw'r ffynonellau mwyaf o allyriadau. Mae'r cynefinoedd hyn yn allyrwyr net pan gânt eu hystyried ar draws yr ystad gyfan oherwydd allyriadau o briddoedd mawn dwfn a addaswyd trwy ddraenio sylfaenol.

Er nad yw stociau carbon yn rhan o'r cyfrifiad statws carbon net, cawsant eu hamcangyfrif a'u cyflwyno i gynnig dealltwriaeth lawnach o werth cynefinoedd ar ystad Cyfoeth Naturiol Cymru ar gyfer carbon. Amcangyfrifwyd bod cyfanswm y stociau carbon a ddelir mewn cynefinoedd ar ystad Cyfoeth Naturiol Cymru, yn ystod blwyddyn sylfaen 2015/16, yn 32,862,217 tunnell o garbon. Pe baent yn cael eu rhyddhau, byddai'r stociau hyn yn arwain at allyriadau sefydliadol yn cyfateb i werth 2,917.3 o flynyddoedd (ar y gyfradd ryddhau yn 2015/16 fel yr amcangyfrifwyd ar y rhestr nwyon tŷ gwydr). Delir 80.9% o gyfanswm stociau mewn coetir a phrysgwydd a delir 9.1% arall o'r cyfanswm mewn lleidiau (mawnog a chorsydd yn bennaf).

Trafodaeth a chasgliadau

Ymgymerwyd â'r darn hwn o waith gyda'r amcan o ddatblygu dull i amcangyfrifo effaith Cyfoeth Naturiol Cymru o ran nwyon tŷ gwydr yn gynhwysfawr, gan gymryd allyriadau nwyon tŷ gwydr o weithrediadau'r sefydliad a charbon sy'n cael ei ddal a'i storio mewn cynefinoedd ar yr ystad a reolir i ystyriaeth. Cyflwynir y canlyniadau ar wahân ac fel statws carbon net. Mae'r dull statws carbon net hwn yn cydnabod y cyfraniad cadarnhaol y gall gweithgareddau rheoli tir Cyfoeth Naturiol Cymru ei wneud at reoli carbon.

Mae'r canlyniadau yn dangos y gellir ystyried yn bositif o ran carbon net, gan ddal a storio 9.5 gwaith yn fwy o garbon nag yr allyrrwyd ganddo fel nwyon tŷ gwydr trwy ei weithrediadau yn ystod blwyddyn sylfaen 2015/6. Ni ystyrir bod y carbon hwn sy'n cael ei ddal a'i storio yn mantoli allyriadau gan mai dim ond prosiectau newydd sy'n ychwanegol i'r senario llinell sylfaen all fantoli. Mae lleihau allyriadau nwyon tŷ gwydr o weithrediadau yn dal i fod yn elfen allweddol o reoli effaith garbon y sefydliad, ynghyd â dal a storio a diogelu stociau carbon presennol. Yn y pen draw, mae'r pwyslais parhaus hwn ar leihau allyriadau yn cydnabod y gall Cyfoeth Naturiol Cymru wneud mwy na dibynnu ar swyddogaeth carbon sy'n cael ei ddal a'i storio i reoli ei effaith garbon, gan gymryd camau i leihau allyriadau mewn ymdrech i osgoi effeithiau gwaethaf y newid yn yr hinsawdd ar lefel fyd-eang.

Aeth ein proses o gyfrifo nwyon tŷ gwydr y tu hwnt i allyriadau cwmpasau 1 a 2 i gynnwys amrywiaeth eang o allyriadau cwmpas 3, gyda phwyslais ar y rheini y disgwylir iddynt wneud y cyfraniadau mwyaf, a'r rheini y gall y sefydliad eu dylanwadu.
Er bod allyriadau cwmpasau 1 a 2 yn cynrychioli cyfran gymharol fach o gyfanswm rhestr nwyon tŷ gwydr y sefydliad, mae'n debygol mai'r ffynonellau hyn fydd yr hawddaf y Cyfoeth Naturiol Cymru ddylanwadu arnynt ac efallai mai'r rhain felly fydd yn cynnig y

cyfleoedd mwyaf uniongyrchol i liniaru allyriadau. Hylosgi tanwydd mewn cerbydau ffordd a pheiriannau offer y mae Cyfoeth Naturiol Cymru yn berchen arnynt a defnydd o drydan yw'r cyfraniadau mwyaf sylweddol i allyriadau cwmpasau 1 a 2. O ystyried y dadansoddiad allyriadau, gallai blaenoriaethau ar gyfer lliniaru gynnwys adolygu fflyd gerbydau Cyfoeth Naturiol Cymru o safbwynt allyriadau i ddeall yn well y mathau o deithiau sy'n cael eu gwneud a'r potensial i gerbydau a thanwyddau allyriadau isel gael eu cynnwys yn y fflyd i leihau allyriadau cwmpas 1, ac archwilio cyfleoedd i leihau'r galw am drydan trwy newid ymddygiad, effeithlonrwydd o ran offer a chynhyrchu ynni adnewyddadwy ar y safle fel ffordd o leihau allyriadau cwmpas 2.

Fel sy'n aml yn wir ar restrau nwyon tŷ gwydr corfforaethol, allyriadau cwmpas 3 yw elfen fwyaf sylweddol rhestr Cyfoeth Naturiol Cymru. Gan fod y ffynonellau hyn o allyriadau y tu allan i reolaeth uniongyrchol y sefydliad, maent yn debygol o fod yn fwy anodd i ddylanwadu arnynt. Fodd bynnag, mae cyfrifo a hysbysu am allyriadau cwmpas 3 y sefydliad yn cynnig cyfle gwerthfawr i gael dylanwad cadarnhaol pellach o ran datgarboneiddio trwy weithio gyda'n cyflenwyr, ein cwsmeriaid a'n staff. Y categori sy'n cyfrannu fwyaf at allyriadau cwmpas 3 y sefydliad yw nwyddau a gwasanaethau a brynwyd, sy'n awgrymu y dylai gweithio i ddylanwadu ar allyriadau ymhellach i fyny'r gadwyn gyflenwi fod yn elfen allweddol o weithgarwch lliniaru'r sefydliad. Gallai ysgogwyr i wneud hyn gynnwys ymgorffori ystyriaethau allyriadau mewn polisi a gweithdrefnau caffael mewnol, rhoi meini prawf penodol mewn fframweithiau, a manylebau contract. Gallai ymchwilio'n fwy dwys i ganlyniadau'r dadansoddiad allyriadau seiliedig ar wario ar gyfer nwyddau a gwasanaethau a brynwyd alluogi fframweithiau, codau cyfrif, codau cynnyrch a chyflenwyr allweddol wedi hynny i gael eu nodi i ganolbwyntio ymdrechion i leihau allyriadau Cyfoeth Naturiol Cymru ymhellach i fyny'r gadwyn gyflenwi.

Mae sawl categori cwmpas 3 yn ffynonellau sylweddol o allyriadau i Cyfoeth Naturiol Cymru o'u cymharu â chyfansymiau cwmpasau 1 a 2. Fodd bynnag, mae mwy o ansicrwydd yn gysylltiedig ag amcangyfrifon allyriadau cwmpas 3 na gyda chwmpasau 1 a 2 (yn enwedig ar gyfer y dadansoddiad seiliedig ar wario i nwyddau a gwasanaethau a brynwyd). Bydd blaenoriaethu rhagor o waith ar allyriadau cwmpas 3 yn gydbwysedd felly rhwng gofynion am ddata mwy cywir ar gyfer rhai categorïau allyriadau i gael dealltwriaeth lawnach, a'r angen i leihau allyriadau ar unwaith. Mae meysydd o bwyslais ar gyfer gwaith pellach yn cynnwys allyriadau sy'n gysylltiedig â nwyddau a gwasanaethau a brynwyd, ac yn benodol: gwaith gan gontractwyr, cynaeafu a chludo pren a werthir o'i safle gwreiddiol ymhellach i lawr y gadwyn gyflenwi, a staff yn cymudo a gweithio gartref.

O gyfrifo allyriadau ar y tir a gwarediadau ar draws pob math o gynefin, canfuwyd fod ffigur yr ystad ar gyfer dal a storio carbon yn net yn ystod y flwyddyn sylfaen. Seiliwyd y cyfrifiad dal a storio net hwn ar waith modelu a mapio ar gyfer cynefinoedd coetir a man dwfn ar yr ystad, a gomisiynwyd gan y Prosiect Carbon Bositif ar gyfer Cyfoeth Naturiol Cymru ac a gyflawnwyd gydag arbenigwyr diwydiant. Mae'r canlyniadau yn cadarnhau pwysigrwydd y cyfraniad a wneir gan y cynefinoedd hyn at statws cadarnhaol net yr ystad o ran carbon. Mae'r adroddiadau ar y gwaith hwn yn cynnig gwybodaeth am reoli'r cynefinoedd hyn i sicrhau buddion carbon, sy'n rhan hollbwysig o'r sail dystiolaeth sydd ei hangen i Cyfoeth Naturiol Cymru wella o ran y carbon sy'n cael ei ddal a'i storio, a diogelu stociau carbon presennol trwy waith reoli tir yn y dyfodol. Mae'r adroddiad coetir yn awgrymu amrywiaeth o strategaethau rheoli coetir posibl ar gyfer buddion carbon ond yn amlygu na ellid cynnal ffigur dal a storio net yng nghoetiroedd Cyfoeth Naturiol Cymru am byth, wrth i gyfran y coetiroedd hŷn gynyddu. Mae'r canlyniadau priddoedd mawn dwfn yn seiliedig ar y dystiolaeth allyriadau orau sydd ar gael ar hyn o bryd c yn awgrymu bod pob cynefin mawn dwfn, ac eithrio mawnogydd mewn cyflwr sy'n agos at fod yn naturiol, yn allyrwyr net. Fodd bynnag, mae'r sail dystiolaeth ar allyriadau mawn dwfn yn y DU yn tyfu, a dylid ailystyried ffactorau allyrru yng nghyfrifiad y statws carbon net yn y dyfodol i gymryd gwelliannau i ddealltwriaeth wyddonol i ystyriaeth. Er gwaethaf rhyw lefel o ansicrwydd, mae canlyniadau presennol yn amlygu allyriadau sylweddol yn gysylltiedig â mawn dwfn a addaswyd gan ddraeniad, a buddion lliniaru posibl adfer.

Cydnabyddir bod cyfrifiadau dal a storio ar gyfer cynefinoedd nad ydynt yn goetir ar briddoedd mwynol yn seiliedig ar dybiaethau sylweddol, ac y gallai fod yn bosibl gwella'r fethodoleg hon yn y dyfodol pe bai gwybodaeth ofodol fanwl am reoli tir yn y gorffennol a'r presennol yn cael ei chasglu, e.e. ar gyfer holl laswelltiroedd Cyfoeth Naturiol Cymru. Fodd bynnag, efallai bod yr adnoddau sydd eu hangen i fireinio'r cyfrifiadau hyn yn anghymesur i gynyddu o ran cywirdeb yn yr amcangyfrif dal a storio carbon net cyffredinol ar gyfer yr ystad, o ystyried mai cynefinoedd coetir a mawndir sydd ar yr ystad yn bennaf.

Mae maint amcangyfrifedig y stoc carbon a ddelir ym miomas, priddoedd a chynhyrchion pren cysylltiedig ystad Cyfoeth Naturiol Cymru yn awgrymu y dylid blaenoriaethu diogelu stociau carbon yn rhan o weithgareddau rheoli carbon y sefydliad yn y dyfodol. Bydd diogelu stociau carbon ar yr ystad a reolir gan Cyfoeth Naturiol Cymru yn hanfodol i osgoi cynnydd i allyriadau nwyon tŷ gwydr ar y tir (a fyddai'n lleihau swm net dal a storio carbon Cyfoeth Naturiol Cymru). Gallai ocsidiad stociau presennol ryddhau hyd at 3,000 gwaith cyfanswm allyriadau gweithredol llinell sylfaen y sefydliad. Mae'r allyriadau sylweddol a adroddir o gynefinoedd man dwfn a addaswyd trwy ddraenio yn y flwyddyn sylfaen yn amlygu pwysigrwydd atal gwaethygiad yn y mathau hyn o gynefin. Dylid alinio sicrhau bod cyn lleied â phosibl o darfu ar briddoedd neu gynefinoedd ac osgoi newidiadau defnydd tir negyddol i ddiogelu stociau gydag arferion rheoli presennol Cyfoeth Naturiol Cymru, o gofio diben y sefydliad i geisio sicrhau bod adnoddau naturiol yn cael eu rheoli'n gynaliadwy.

Mae canlyniadau'r cyfrifiad yn amlygu ffynonellau allyriadau gweithredol mwyaf sylweddol y sefydliad, yn ogystal â'r allyriadau carbon a'r carbon sy'n cael ei ddal a'i storio mwyaf sylweddol ar y tir. Bydd y ddealltwriaeth hon yn sail i'r broses o nodi a blaenoriaethu camau lliniaru i wella statws carbon net y sefydliad ymhellach yn y dyfodol. Wrth i'r cyfrifiadau hyn fynd rhagddynt, maent eisoes wedi hysbysu'r gwaith o ddethol prosiectau arddangos y Prosiect Carbon Bositif, gan gymryd camau i wella statws carbon net y sefydliad o gychwyn y prosiect.

Mae'r adroddiad hwn yn cynnig cofnod cyflawn a thryloyw o'n dull cyfrifo a bydd yn gweithredu fel sail i fireinio unrhyw gyfrifiadau ar gyfer ffynonellau allyriadau unigol yn ôl yr angen yn y broses o ddarparu a monitro camau lliniaru. Dylai lefel y manylder a ddarparwyd ynghyd â gwersi a ddysgwyd wneud hwn yn gyfeiriad ymarferol defnyddio i sefydliadau eraill sy'n cyfrifo eu heffaith garbon eu hunain, gan ymestyn manteision datgarboneiddio y tu hwnt i Cyfoeth Naturiol Cymru i sector cyhoeddus ehangach Cymru.

Executive summary

Natural Resources Wales (NRW) is committed to positive action on climate change. We recognise the importance of pursuing opportunities to reduce greenhouse gas (GHG) emissions from our own activities and to protect and enhance long-term stores of carbon within our influence. The drive to improve the organisation's net carbon status is a key part of NRW's contribution to Wales' transition to a low carbon economy. The Welsh public sector has a role to show leadership in taking emissions reduction action and Welsh Government has funded the Carbon Positive Project (CPP) to demonstrate how an organisation can evaluate and improve its net carbon status. The Project is sharing its learning with other Welsh public-sector organisations to facilitate accelerated decarbonisation in Wales.

This technical report sets out the rationale for, method and results of the work undertaken by NRW to calculate its net carbon status. The work was undertaken with the joint objectives of: providing a GHG emission and carbon sequestration baseline to enable NRW to strategically identify priorities for mitigation action, supporting the evaluation of the most cost and carbon effective mitigation options across our activities and operations; and providing a useful resource and reference for other public sector organisations managing their carbon impact.

Net carbon status is defined within the CPP as the balance between the quantity of GHG emitted by the organisation's operations and the net quantity of carbon sequestered in habitats on the NRW estate. Two parallel pieces of work were undertaken to provide figures for the calculation of NRW's net carbon status:

1. Development of a GHG emissions inventory for NRW, quantifying emissions arising from assets and operations.
2. Estimation of the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate.

Alongside carbon losses and gains, total existing carbon stocks in each habitat type were also estimated to provide a full understanding of the carbon impact of the estate. However, carbon stock estimates do not form part of the net carbon status calculated for NRW.

NRW's unique and broad organisational remit, including being custodian and manager of 7% of Wales' land area, presents a challenge in terms of GHG accounting. Although not a standard component of corporate GHG inventories, estimating the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate was considered a crucial element of understanding the organisation's overall carbon status, given NRW's role as a land owner and manager.

This is the first assessment of the organisation's net carbon status and carbon stocks, and all organisational input data used in calculations related to the selected base year – the financial year 2015/16.

Methods

Greenhouse gas inventory

GHG emissions were calculated following Greenhouse Gas Protocol Corporate Standard guidelines (Ranganathan *et al*., 2004) and reporting the six gases covered by the Kyoto Protocol in common units of carbon dioxide equivalents (CO_2e).

The organisational boundary selected for GHG accounting and reporting includes all assets and operations within NRW's operational control. All assets owned and managed day-to-day by NRW are considered to be within our operational control i.e. owned buildings, owned road vehicles and plant, owned and managed land, owned and managed assets such as those associated with flood risk management. Categories of leased assets were assessed and evaluated on a case by case basis against the operational control criterion to determine whether they sit within the organisational boundary. For example: our leased buildings are managed day to day by NRW and are therefore considered to be within our operational control for emissions accounting; land leased by NRW to another organisation is considered to be under the operational control of the external organisation responsible for day to day management; land leased to and managed by NRW e.g. the Welsh Government Woodland Estate is considered to be within our operational control and consequently within our organisational boundary for emissions reporting.

After identifying assets and operations to be included, we defined which emission sources we were accounting for. All 3 emissions categories, known as scopes, were included within the NRW GHG inventory. These are:

- scope 1 - direct GHG emissions to the atmosphere from sources owned or controlled by NRW e.g. fuel combustion in owned boilers and vehicles;
- scope 2 - indirect emissions to the atmosphere from the generation of electricity purchased by NRW for use in assets and buildings under our operational control;
- scope 3 - other indirect emissions that arise from sources outside of NRW's operational control but are a consequence of our activities e.g. purchased materials, contractor services, employee commute.

Figure 1 shows the emissions sources accounted for and the scopes under which they were reported. As an optional reporting category, in the GHG Protocol, scope 3 emissions are frequently not accounted for within corporate GHG inventories. However, to provide as complete an account of NRW's GHG emissions as possible, we have included a broad range of scope 3 emissions within our inventory, focussing on those expected to make the biggest contributions, and those which the organisation can influence.

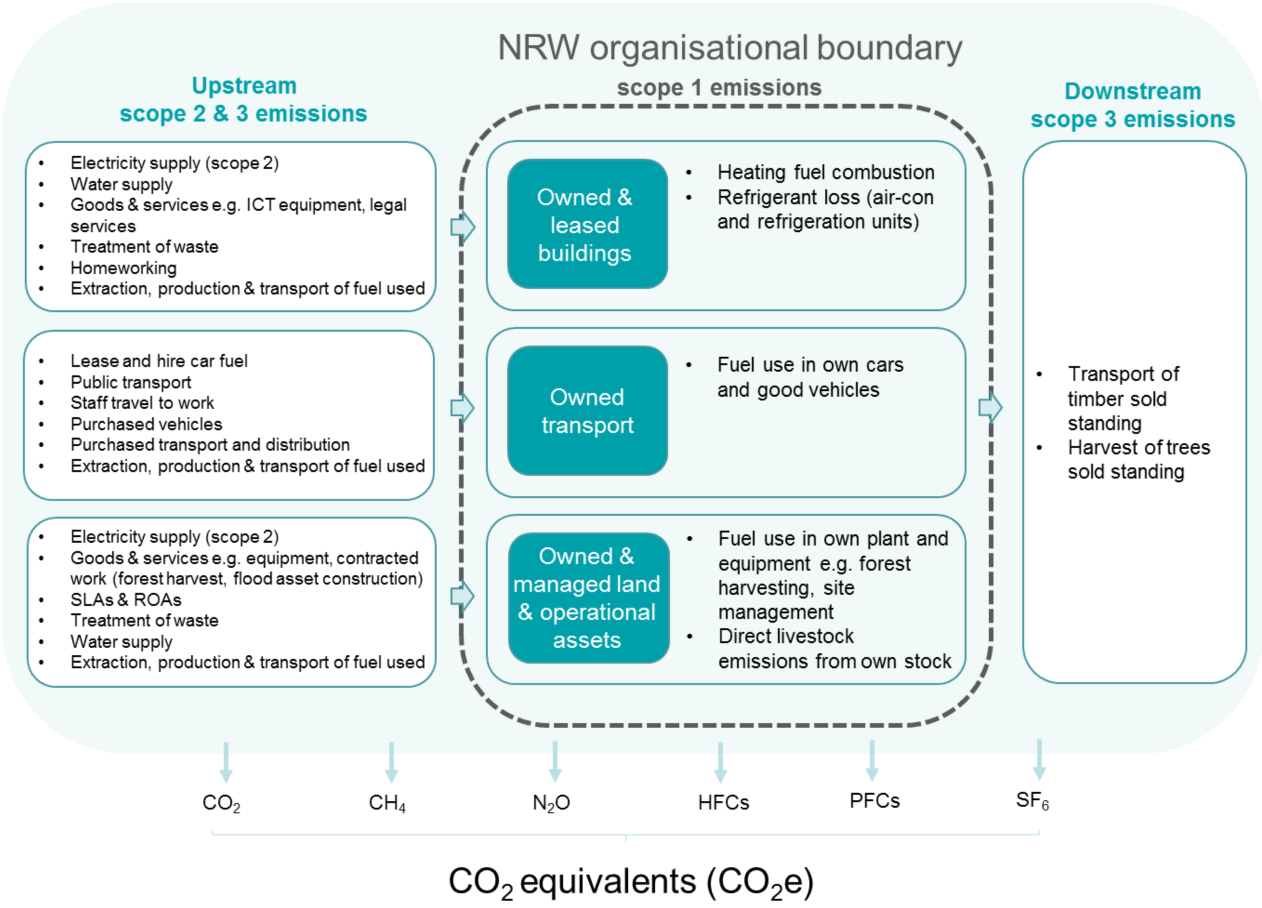


Figure 1. NRW operational boundary i.e. the emissions boundary used for the organisation's GHG inventory.

For each source identified in Figure 1, this report details the type and source of activity data used in emissions calculations, any conversions or assumptions needed, the emission factor(s) (EFs) used and their sources, calculation caveats, assumptions and lessons learned. The specificity of activity data varied between emissions categories, being a mix of primary data specific to the organisation, and secondary data e.g. industry averages or financial data. For our estimation of scope 1 and 2 emissions we relied heavily on existing primary data collated annually by our Environmental Management System team to attain IS04001 accreditation, e.g. quantities of heating fuel used. Scope 3 calculations were largely based on secondary financial data, e.g. purchased goods and services, or on primary data supplemented by assumptions, e.g. staff commute emissions. We used the most accurate activity data and calculation methods practicable within our timescales. However, some limitations remain and could be improved upon through revisiting calculation methods in future years, e.g. improving the accuracy of heating fuel data by standardising conversion factors to kilowatt hours and collecting organisation specific data on staff commute mode to replace national average assumptions.

Carbon sequestration and stocks

Mirroring the principles of our GHG inventory, carbon sequestration and stocks are calculated within an organisational boundary defined as assets and operations under NRW's operational control. Therefore, our estimates of carbon sequestration and stocks relate to vegetation and soils on land manged day-to-day by NRW, whether owned or leased. In addition to sequestration and stocks on site, our estimates for the woodland estate also include all harvested wood products arising from the timber produced on the woodland estate, and in still in existence, in the base year (2015/6).

Existing digitised maps of the NRW estate were modified to create a bespoke map for the CPP matching the selected organisational boundary of land under our operational control. The extent of each habitat type on the NRW estate was defined using Phase 1 habitat classification maps, refined with more recent or spatially detailed habitat specific maps where appropriate. This was the case for saltmarshes, eroded and restored deep peat and woodland habitats on the estate, e.g. the extent of the woodland estate was defined using the forest sub-compartment database for the commercially managed forest, and according to the woodland categories within the National Forest Inventory for non-commercial woodland areas as this was the best available evidence.

In the absence of guidelines on accounting for organisational carbon sequestration (and stocks), we adopted and developed habitat specific calculation methodologies, where possible following the broad principles of the GHG Protocol Corporate Standard for emissions accounting (Ranganathan *et al*., 2004). The carbon pools and GHGs accounted for within the carbon sequestration and stocks calculation boundary differ between habitat types based on the calculation method considered most appropriate for each. This was based on: whether the habitat was deemed a priority for detailed assessment (e.g. peatland, woodland), the availability of management data for the habitat type across the NRW estate, current scientific understanding of the GHG emissions and removals associated with each habitat type. Calculation methods varied in specificity and detail, from applying average emission, sequestration or carbon stock figures to habitat areas (e.g. for grassland habitats) to working with industry experts to model sequestration or stocks for habitat types on the estate, e.g. woodland habitats.

The most detailed approach adopted was for woodland habitats due to the NRW estate being largely afforested. This is a consequence of our role as custodian of the Welsh Government Woodland Estate. Current carbon stocks and projected annual changes (i.e. sequestration) were modelled for soil, biomass, dead organic matter and harvested wood product pools using detailed data provided by NRW on species, area, age-class, soil type and management regime, coupled with UK derived estimates of stand structure, growth and carbon content. Alongside woodland habitats, it was felt that accurately estimating the sequestration / emissions and carbon stocks of deep peat soils would be crucial to understanding the estate's carbon status. We worked with industry experts to map the extent and drainage condition of deep peat habitats on the estate, attaching the best available EFs to peatlands grouped by habitat type and condition.

Results

Table 1 reports NRW's GHG emissions inventory and carbon sequestration estimate results for the base year, showing the balance between the two i.e. the organisation's net carbon status. In 2015/16 NRW sequestered 349,621 tonnes CO_2e (tCO_2e) more in habitats on the estate than it emitted through its operations. The organisation could therefore be considered net carbon positive. Emissions to the atmosphere are reported as positive numbers and removals as negative.

Table 1. NRW's net carbon status

NRW's Net Carbon Status in 2015/16	tonnes CO_2e/year
Total scope 1, 2 & 3 GHG emissions	41,304
Total (net) carbon sequestration	-390,924
Net carbon status	**-349,621**

NRW's total GHG emissions in the base year (2015/16) were 41,304 tCO_2e. These include both direct GHG emissions to the atmosphere from NRW owned or controlled sources, and indirect GHG emissions to the atmosphere arising as a consequence of NRW activities. In the base calculation year, total scope 1 and 2 emissions were 2,997 and 1,869 tCO_2e respectively, whilst scope 3 emissions were estimated to be 36,437 tCO_2e. Within scopes 1 and 2, the most significant source of emissions is fuel combustion in NRW owned vehicles, with 37.2% from cars and goods vehicles and 13.7% from plant machinery. Emissions arising from the generation of electricity used by NRW also make a significant contribution to the scope 1 and 2 total at 38.4% (1,869 tCO_2e). Electricity use in manned sites such as offices and depots accounts for 63% of the electricity total, and unmanned sites such as pumping stations and telemetry assets for the remaining 37%.

The GHG inventory is dominated by indirect scope 3 emissions, that arise from sources outside of NRW's operational control but are a consequence of our activities. The largest source of scope 3 emissions is supply chain emissions associated with goods and services purchased by NRW (62.2% of the scope 3 total). Within this, the largest contributing broad procurement categories are: work carried out by contractors (35% (7,942 tCO_2e)), e.g. forest harvesting, engineering and flood asset construction; facilities management and information and communication technology related (21.5% (4,883 tCO_2e)), Service Level Agreements and Reservoir Operating Agreements (13.8% (3,118 tCO_2e)). These areas of spend can be considered emissions hotspots in the supply chain for further work, to improve the accuracy of emissions calculations and / or to focus emission reduction efforts. Hotpots should also be assessed at the disaggregated level. For example, reviewing emissions at the account and product code level could help to target mitigation efforts to frameworks and possibly suppliers. Alongside purchased goods and services, downstream emissions associated with the harvest and transport of timber sold standing from the NRW-managed estate (14.2% of the scope 3 total), and emissions arising from employee commuting and homeworking (7.8% of the scope 3 total) are also significant sources of scope 3 emissions.

The net quantity of carbon sequestered in habitats on the NRW estate in the base year 2015/16 was -390,924 tCO_2e (a negative figure indicated a removal of carbon from the atmosphere and its storage in habitats). The organisation's net sequestration in the base year equated to 9.5 years' worth of organisational emissions from its operations. The estate's sequestration is dominated by removals in woodland habitats (-418,156 tCO_2e in the base year). Clearfell conifer woodland was the primary contributor to this, with almost equal sequestration contributions from soil, litter and harvested wood product pools. Coastal habitats are also making a small contribution to removals on the estate (-6,661 tCO_2e). All other habitats were estimated to be net emitters, apart from open water, rock exposure and waste for which no emissions or removals were assumed. Grassland, marsh and mire habitats are the largest sources of emissions. These habitats are net emitters when considered across the whole estate due to emissions from underlying drainage modified deep peat soils.

Although carbon stocks do not form part of the net carbon status calculation, they were estimated and presented to provide a fuller understanding of the value of habitats on the NRW estate for carbon. Total carbon stocks held in habitats on the NRW estate, in the base year 2015/16, were estimated to be 32,862,217 tonnes of carbon. If released, these stocks would give rise to the equivalent of 2,917.3 years' worth of organisational emissions (at the rate of release in 2015/16 as estimated in the GHG inventory). Woodland and scrub habitats hold 80.9% of total stocks and mires (primarily bog and fen) a further 9.1% of the total.

Discussion and conclusions

This piece of work was undertaken with the objective of developing an approach to comprehensively estimate NRW's GHG impact, accounting for both GHG emissions from the organisation's operations and carbon sequestration in habitats on the managed estate. The results are presented separately and as a net carbon status. This net carbon status approach recognises the positive contribution NRW's land management activities can make to carbon management.

The results show that the organisation can be considered net carbon positive, sequestering 9.5 times more carbon than it emitted as GHGs through its operations in the 2015/6 base year. This sequestered carbon is not considered an emission offset as offsets can only be provided by new projects that deliver sequestration which is additional to the baseline scenario. Reducing GHG emissions from operations remains a key element of managing the organisations' carbon impact, alongside enhancing sequestration and protecting existing carbon stocks. Ultimately, this maintained focus on emissions reductions recognises that NRW can do more than rely on the role of sequestered carbon to manage its carbon impact, delivering actions to reduce emissions in an attempt to avoid the worst impacts of climate change on a global level.

Our GHG accounting extended beyond scope 1 and 2 emissions to include a broad range of scope 3 emissions, with a focus on those expected to make the biggest contributions, and those the organisation can influence.

Although scope 1 and 2 emissions represent a relatively small proportion of the organisation's overall GHG inventory total, these sources are likely to be easiest for NRW to influence and may therefore offer the most immediate opportunities for emissions mitigation. The most significant contributions to scope 1 and 2 emissions are fuel combustion in NRW owned road vehicles and plant machinery, and electricity use. Given the emissions breakdown, priorities for mitigation could include reviewing the NRW vehicle fleet from an emissions perspective to better understand the types of journeys being made and the potential for low emission vehicles and fuels to be incorporated into the fleet to reduce scope 1 emissions, and exploring opportunities to reduce electricity demand through behavioural change, equipment efficiencies and renewable energy generation on site as means of reducing scope 2 emissions.

As is often the case in corporate GHG inventories, scope 3 emissions account for the most significant element of the NRW inventory. Because these emissions sources lie outside of the immediate control of the organisation they are likely to be more challenging to influence, however, accounting for and reporting the organisation's scope 3 emissions provides a valuable opportunity to exert further positive influence for decarbonisation through working with our suppliers, customers and staff. The largest contributing category to the organisation's scope 3 emissions is purchased goods and services, which suggests that working to influence upstream emission should be a key element of the organisation's mitigation activity. Levers available to do this may include incorporating emissions considerations into internal procurement policy and procedures, inserting specific criteria into frameworks, and contract specifications. Drilling down further into the results of the spend based emissions analysis for purchased goods and services could enable the identification of frameworks, account codes, product codes and subsequently key suppliers to focus efforts to reduce NRW's upstream emissions.

Several scope 3 categories are significant emission sources for NRW relative to scope 1 and 2 totals. However, there is greater uncertainty associated with scope 3 emission estimates than with scopes 1 and 2 (particularly for the spend based analysis of purchased goods and services). Prioritising further work on scope 3 emissions will therefore be a balance between requirements for more accurate data for some emissions categories to gain a fuller understanding, and the need to deliver emission reductions without delay. Focal points for further work include emissions associated with purchased goods and services, in particular: work by contractors, downstream harvest and transport of timber sold standing, and staff commute and homeworking.

Accounting for land-based emissions and removals across all habitats types, the estate was found to be a net sequesterer in the base year. This net sequestration calculation was underpinned by modelling and mapping work for woodland and deep peat habitats on the estate, commissioned by the CPP for NRW and carried out with industry experts. The results confirm the importance of the contribution made by these habitats to the estate's net carbon positive status. The reports on this work provide insights on managing these habitats for carbon benefit, forming a crucial part of the evidence base needed for NRW to enhance sequestration, and protect existing carbon stocks though future land management. The woodland report suggests a range of potential woodland management strategies for carbon benefit but highlights that net sequestration by NRW woodlands cannot be maintained indefinitely, as the proportion of older woodlands increases. The deep peat soils results are based on the best emissions evidence currently available and suggest that all deep peat habitats, other than bogs in a near natural condition, are net emitters. However, the evidence base on deep peat emissions in the UK is growing, and EFs adopted in the net carbon status calculation should be revisited in future to take account of improvements in scientific understanding. Despite some level of uncertainty, current results highlight significant emissions associated with drainage modified deep peats, and the potential mitigation benefits of restoration.

It is recognised that sequestration calculations for non-woodland habitats on mineral soils were based on significant assumptions, and it may be possible to improve on this methodology in future if detailed spatial information on past and present land management were collated, e.g. for all NRW grasslands. However, the resources needed to refine these calculations may be disproportionate to the gain in accuracy in the overall net sequestration estimate for the estate, given the dominance of woodland and peatland habitats.

The estimated magnitude of the carbon stock held in the biomass, soils and associated wood products of the NRW estate suggests that protecting carbon stocks should be prioritised as part of the organisation's future carbon management activities. Protecting carbon stocks on the NRW-managed estate will be crucial to avoid an increase in land based GHG emissions (which would decrease NRW's net sequestration). Oxidation of existing stocks could release up to 3,000 times the organisation's baseli operational emissions. The significant emissions reported from drainage modified deep peat habitats in the base year highlight the importance of preventing deterioration in these habitat types. Minimising disturbance to soils or habitats and avoiding negative land use changes to protect stocks should be aligned with current NRW management practices, given the organisation's purpose to pursue the sustainable management of natural resources.

The calculation results highlight the organisation's most significant sources of operational emissions, in addition to its most significant land-based emissions and sequestration. This understanding will underpin the identification and prioritisation of mitigation actions to further improve the organisation's net carbon status in future. As these calculations have progressed they have already informed the selection of CPP demonstration projects, delivering action to improve the organisation's net carbon status from the outset of the project.

This report provides a complete and transparent record of our calculation approach and will serve as a basis to refine any calculations for individual emissions sources as needed in the process of delivering and monitoring mitigation actions. The level of detail provided along with lessons learned should make this a useful practical reference for other organisations accounting for their own carbon impact, extending decarbonisation benefits beyond NRW to the wider Welsh public sector.

1. Introduction

This report details the approach taken by Natural Resources Wales (NRW), through its Carbon Positive Project (CPP), to calculate the organisation's net carbon status. **Net carbon status** is defined within the CPP as the balance between the quantity of greenhouse gas (GHG) emitted by the organisation's operations and the quantity of carbon sequestered in habitats on the NRW owned and managed estate[1]. Alongside GHG losses and carbon gains, total existing carbon stocks in each habitat type are also estimated to provide a full understanding of the carbon impact of the estate.

This technical document sets out the rationale for, method and results of the net carbon status and carbon stock calculations undertaken. For GHG emissions, carbon sequestration and stock calculations it details: the overall accounting approaches followed; the sources of emissions included and excluded from calculations; the organisational and emissions data used; and the individual methodologies followed for each emissions category. This detailed document, coupled with calculation spreadsheets, form the audit trail for the NRW's accounting and reporting practices for the calculation of its net carbon status, with the aim of providing the transparency required for the approach to be replicated internally in future. This document also supports the CPP aim of sharing our approach and experiences with the public sector in Wales to encourage action on decarbonisation.

Alongside the methodology for each emissions category, this report also details any limitations associated with our approach, issues faced and lessons learned in carrying out the individual calculations, which may be useful to other public sector organisations working to manage their own carbon impact. The results section presents the main results for each set of calculations and the overall balance of estimated GHG emissions and sequestration, the net carbon status. This is followed by a discussion of the results and shares key learning and experience from our calculation of NRW's net carbon status. The report is structured as follows:

Section 2 provides the background to the net carbon status calculation for NRW, briefly touching on the policy landscape, the CPP and NRW's remit as an organisation.
Section 3 introduces and explains the net carbon status approach to calculate and present the organisation's carbon impact.
Section 4 sets out the steps taken to develop a GHG emissions inventory for NRW, including the setting of organisational boundaries for calculations, identification of emission sources, the calculation methods followed for each and lessons learned in the process.
Section 5 sets out the steps taken to estimate carbon sequestration and stocks in habitats on the NRW estate, including mapping of habitats, prioritising habitats for calculations, the calculation methods developed and applied for each habitat and lessons learned in the process.
Section 6 presents the results of the GHG inventory, the carbon sequestration and stock calculations, followed by the overall net carbon status result for the organisation for the base year 2015/16.
Section 7 discusses the results and their implications for NRW, and overall lessons learned in the process of estimating our net carbon status.

[1] From here on referred to as the 'NRW estate'.

2. Background

2.1. The legislative context

The Environment (Wales) Act 2016[2] and the Well-being of Future Generations (Wales) Act 2015[3] together provide a legislative framework to enable sustainable development in Wales. They require the sustainable management of natural resources (SMNR) and provide a framework for improving the social, economic, environmental and cultural well-being of Wales.

Addressing climate change impacts and decarbonisation are crucial to achieving the objectives of the Acts. The Environment Act requires an 80% reduction in GHG emissions by 2050. The Well-being of Future Generations Act sets seven Well-being Goals that provide a shared vision for Wales to work towards, that include the development of a prosperous Wales based on a low carbon society.

The CPP helps NRW deliver on its purpose to pursue SMNR, the wider requirements of the Environment Act and its contribution to the Well-being goals, by:

- Delivering emissions reductions towards the Welsh public sector's contribution to meeting the current 2016-2020 Carbon Budget.
- Showing leadership in the public sector to help drive progress towards the ambition for a carbon neutral Welsh public sector by 2030.
- Seeking to optimise multiple benefits from decarbonisation in support of SMNR, such as better working environments for our staff, greater recreational opportunities for communities, enhanced biodiversity, and improved air and water quality.
- Helping to stimulate the move to a low carbon resource efficient economy through our procurement and supply chains by working with suppliers.
- Contributing to the delivery of the Well-being goals, particularly the prosperous and resilient Wales goals where addressing climate change is specifically mentioned, in addition to the globally responsible Wales goal.

2.2. Natural Resources Wales' work on climate change

NRW is committed to positive action on climate change. We recognise the importance of pursuing opportunities to reduce GHG emissions from our own activities and to protect and enhance long-term stores of carbon within our influence.

Our corporate and business plans recognise the environmental challenges posed by climate change, and commit to reducing emissions, enhancing sequestration and protecting carbon stocks, both through our own activities and through our broader influence on the activities of others. The CPP forms part of NRW's wider work on climate change, which includes assessing and managing climate risks across our remit through adaptation action and our role in enabling renewable energy development on the estate.

NRW has a unique and broad organisational remit, including being custodian and manager of 7% of Wales' land area, which encompasses water, woodlands, National Nature Reserves (NNRs), and flood defence schemes, and as an operator of our visitor centres, recreation facilities, a hatchery and a laboratory. In addition to being a land and water manager, NRW is an environmental advisor and regulator, it responds to environmental

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[2] Further information is available at: http://gov.wales/topics/environmentcountryside/consmanagement/naturalresources-management/environment-act/?lang=en

[3] Further information is available at http://gov.wales/topics/people-and-communities/people/futuregenerations-act/?lang=en

incidents and provides grant aid to others for sustainable land management activities. This broad remit brings with it challenges for GHG accounting, and opportunities for decarbonisation, i.e. to reduce our emissions and to protect and enhance the carbon captured on the land and water we manage (the estate).

2.3. Our Carbon Positive Project

Welsh Government funded NRW to deliver the CPP to show leadership in decarbonisation in Wales' public sector and to share our approach and experience to encourage further decarbonisation across the public sector and beyond. The drive to improve NRW's net carbon status forms part of our organisation's contribution to Wales' transition to a low carbon economy.

Over the last three years[4], the CPP has developed a systemic approach to understand and explore how our organisation can address its carbon impact across buildings, transport, land and operational assets, and procurement of goods and services. It has evaluated NRW's net carbon status (outlined in this report), accounting for both GHG emissions across our operations and the carbon captured annually (sequestration) across the estate, as well as estimating the existing stores of carbon (carbon stocks) on the estate. The Project has identified and evaluated opportunities to reduce the carbon impact of our organisation (mitigation measures) and delivered projects to demonstrate some of these measures. Throughout the project we have learned from other organisations managing their own carbon impact and gathered ideas from our colleagues to help us embed carbon management into NRW's activities.

The Project will also put in place a plan for future implementation to steer the delivery of mitigation measures across the organisation, embedding carbon management within NRW. We have recorded and shared our experience and approach in a series of publications[5] to help support other organisations seeking to manage their own carbon impact:

- Carbon Positive Project Summary Report.
- Carbon Positive Project Technical Report: Calculating NRW's Net Carbon Status (this report)
- Carbon Positive Project Technical Report: Evaluating NRW's Mitigation Options
- Demonstration project case studies.

3. The net carbon status approach

Net carbon status was defined, for the purpose of the CPP, as the balance between the quantity of GHGs emitted by the organisation's operations and the quantity of carbon sequestered in habitats on the NRW estate. Two parallel pieces of work were undertaken to provide figures for the calculation:

1. Development of a GHG emissions inventory for NRW, quantifying emissions arising from assets and operations. Calculated following the guidelines given in the Greenhouse Gas Protocol Corporate Standard (Ranganathan *et al*., 2004) and

[4] The Project started in September 2015.

[5] Reports and demonstration project case studies are available on the Project's webpages at: https://naturalresources.wales/about-us/corporate-information/carbon-positive-project

reporting the six gases covered by the Kyoto Protocol in common units of carbon dioxide equivalents (CO_2e)[6].

2. Estimation of the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate, also reported as CO_2e. Calculated by developing habitat specific methodologies, determined by data availability and current scientific evidence. This is a bespoke approach, following the broad principles of the GHG Protocol Corporate Standard for emissions accounting, in the absence of specific guidance on accounting for sequestration in a corporate context.

Alongside carbon losses and gains, total existing carbon stocks in each habitat type were also estimated to provide a full understanding of the carbon impact of the estate. However, carbon stocks estimates do not form part of the net carbon status calculated for NRW.

Although it is not a standard component of corporate GHG inventories, the GHG Protocol Corporate Standard (Ranganathan *et al*., 2004) recognises the importance of sequestered atmospheric carbon for some organisations and suggests reporting this as "optional information". Given NRW's significant role as a land owner and manager, estimating the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate was considered a crucial element of the organisation's overall carbon status.

We present the results of both pieces of work separately in this report, as well as the balance as the organisation's net carbon status. This approach is analogous to the net carbon calculations of other organisations with a land manager's remit such as the Crown Estate (The Crown Estate, 2013).

This is the first assessment of NRW's net carbon status and carbon stocks, and all organisational input data used in calculations relate to the selected base year – the financial year 2015/16. The results of this assessment will provide the evidence base needed for NRW to develop an implementation plan to reduce emissions, enhance carbon sequestration and protect existing carbon stocks.

As the understanding of NRW's carbon impact progressed this also informed the selection of CPP demonstration projects, which delivered action on identified priorities to improve the organisation's net carbon status during the project (e.g. through introducing electric vehicles into the fleet)[7].

4. Developing a GHG emissions inventory for NRW

Although multiple GHG accounting standards and guidelines exist, we have followed UK Environmental Reporting Guidelines (Department for Environment, Food and Rural Affairs (DEFRA), 2013) and the GHG Protocol Corporate Standard (Ranganathan *et al*., 2004). The former provides a UK perspective, and is based on the latter, which provides additional detail on accounting methodologies. Together, they provide a standardised, widely recognised and freely available approach to estimating a UK organisation's GHG

[6] Emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), (perfluorocarbons) PFCs and sulphur hexafluoride (SF_6) have been reported in units of tonnes of carbon dioxide equivalents (tCO_2e) based on their comparative global warming potentials.

[7] Further information on the Carbon Positive Project's demonstration projects can be found on our webpages at: https://naturalresources.wales/about-us/corporate-information/carbon-positive-project

emissions (also known as its corporate carbon footprint). Following freely available standards was considered a crucial part of the CPP's approach, to facilitate other public sector organisations to use the approach and learning of NRW. Adopting these standards should ensure a transparent and replicable approach to GHG accounting and reporting.

An early consideration for GHG reporting, set out by both standards, is the relevance of the GHG reporting approach adopted, i.e. that the information collated and reported is appropriate to the decision-making needs of the organisation. From NRW's perspective, the role and purpose of the CPP carbon accounting and reporting process was to:

- Provide a GHG emissions baseline for the financial year 2015/16 by bringing together and building upon existing emissions data from the three legacy bodies[8] whose roles and remits were incorporated into NRW.
- Enable identification of priorities for climate change mitigation action across the whole organisation. Informing the evaluation of mitigation options to identify the most cost and carbon effective options across all our activities and operations.
- Support future strategic planning for decarbonisation, through providing a robust evidence base for decision making. This will enable the organisation to put in place a plan for the implementation of mitigation measures.
- Prioritise efforts on data collection and emissions accounting on activities expected to be significant GHG contributors, and those within our influence for mitigation.
- Provide a useful resource and reference for other public sector organisations managing their carbon impact; detailing challenges faced, assumptions made, methodologies adopted and lessons learned. It was therefore important that our emissions accounting was as comprehensive as possible to maximise the benefit to wider organisations.

4.1. Setting organisational and operational boundaries - Which assets and operations are included?

Together, organisational and operational boundaries define which assets, operations and emissions sources are included in the organisational GHG inventory. The first step is setting an organisational boundary, i.e. defining which assets and operations make up the organisation for the purposes of GHG accounting and reporting. For organisations with complex operating structures, like NRW, where ownership and operation of assets can be mutually exclusive, the guidelines recommend selecting one of two approaches to asset and operation inclusion or exclusion. Organisations can determine whether assets and operations are within the organisational boundary according to either a) their equity share in the asset, or b) control over the asset. As the emphasis is on calculating emissions sources which NRW can influence, it was decided that our organisational boundary for GHG accounting and reporting should encompass all assets and operations within our operational control. Unlike the multi-national company examples given in the GHG Protocol, for NRW, there are no subsidiaries or joint ventures to consider when setting the organisational boundary.

The GHG Protocol states that the selected consolidation approach (in this case operational control) should be applied at all levels of the organisation. For NRW, operations associated with the use and management of individual buildings, parcels of land and other assets need to be categorised as within or outside of our operational control to enable the organisation to be defined for accounting purposes. All assets owned and managed day-

[8] The Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales.

to-day by NRW are considered to be within our operational control i.e. owned buildings, owned road vehicles and plant, owned and managed land, owned and managed flood risk assets.

Whilst the GHG Protocol considers the treatment of leased assets after having set the organisational boundary, for NRW, applying the selected consolidation approach to leased assets was a crucial part of defining the organisational boundary. This is because operations associated with land leased to NRW form a significant proportion of the organisation's work. Leased assets were therefore assessed and evaluated against the operational control consolidation criterion to determine whether they sit within the organisational boundary, as follows:

- Leased buildings - A large number of NRW's office buildings are leased long-term, which the organisation manages day to day and has the ability to refurbish and install technologies within. These buildings can be considered within our operational control and are therefore within the organisational boundary for GHG accounting purposes.
- Leased cars - NRW leases vehicles for business travel, which are not considered to be within our operational control. We could not, for example, install eco-driver telematics black box technology into these cars. Emissions associated with lease car use are therefore evaluated as part of the organisation's upstream impacts, rather than within the organisational boundary, as is consistent with the organisation's Environmental Management System (EMS) reporting.
- NRW is both a lessee and lessor of land. Land which is owned by NRW but leased out to others is considered to be within the operational control of the external organisations responsible for day to day management, i.e. it is outside of NRW's organisational boundary. Areas of land owned by NRW but managed under agreement or farm business tenancy by external organisations / individuals are also treated in the same way. Skomer island, for example, is NRW owned but let to and managed by Wildlife Trust South and West Wales. Emissions associated with the management of this land (and other NRW owned land managed externally) could be evaluated as part of the NRW's downstream impacts, however we do not currently have access to sufficient information to do so, therefore these emissions have not been accounted for.
- Land which is leased from an external organisation and managed by NRW has been considered within our operational control, irrespective of lease length. Emissions associated with the management of this land are therefore included within the organisational boundary. For example, NRW has a management agreement with Severn Trent Water for >2,000 hectares (ha) of land at Lake Vyrnwy. Therefore, the emissions (and carbon sequestration/stocks) associated with this land have been included within the net carbon status calculation.
- The majority of the commercial forest estate managed by NRW is the Welsh Government Woodland Estate (WGWE), leased on a 999 year agreement from Welsh Ministers. This is operated and managed day to day by NRW and is therefore within our operational control, and subsequently considered within our organisational boundary for GHG reporting. One exception to this is any areas where other parties develop on the NRW estate. For example, parts of the WGWE have been developed as windfarms. These windfarms have been developed and are operated by third party energy developers, under contractual agreement with Welsh Government, with NRW acting as a managing agent. These developments are therefore considered to be outside of NRW's operational control for GHG accounting purposes, and emissions associated with their construction and operation, including any carbon benefit associated with the renewable energy generated, are not accounted for within the organisational boundary.

These developments could be, but are not currently, accounted for as part of the organisation's indirect emissions. (The emission reduction benefit of zero carbon electricity generation is gained by the organisation utilising the electricity and will result in a reduction in their scope 2 electricity use related emissions, i.e. the end user of the renewable energy gains the carbon benefit).

- There are a small number of parcels of land that NRW does not own or lease but manages in partnership with another organisation. As these parcels of land are not currently digitally mapped and the extent of NRW's involvement in each is not centrally recorded, they are assumed to be outside of NRW's operational control. However, where fuel and materials have been used on these areas of land we currently have no means of identifying or removing them from the organisation totals, so these will have been accounted for in the GHG inventory.

Based on the above assessment of NRW's operational control, Figure 4.1 provides a high-level summary of NRW's organisational boundary as applied to owned and leased assets and used for GHG accounting and reporting.

This operational control consolidation approach was developed for GHG accounting, and was also adopted for land inclusion in carbon sequestration and stock accounting, with some small exceptions as explained in Section 5.1.

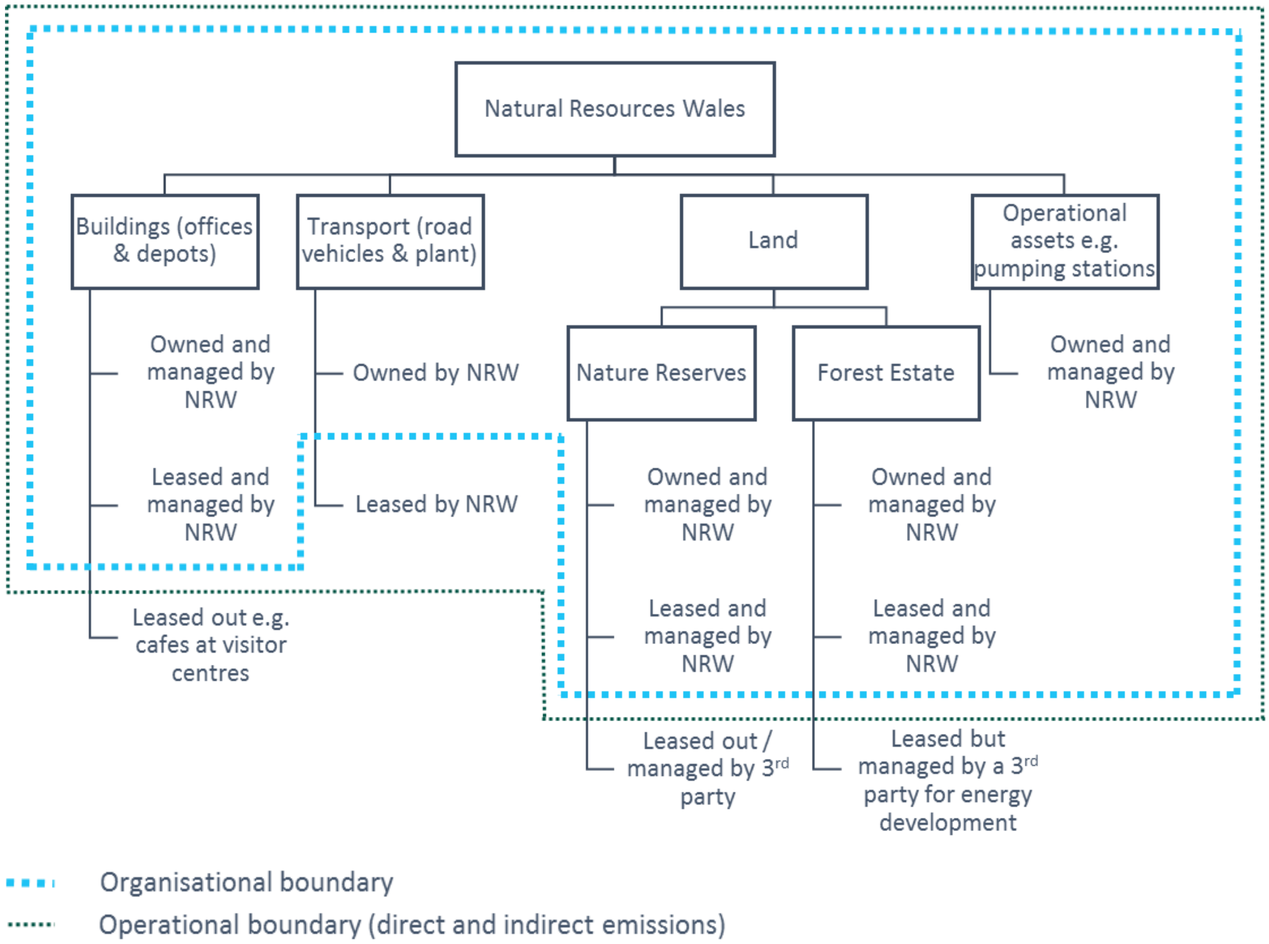

Figure 4.1. NRW's organisational boundary as applied to owned and leased assets, with a high-level representation of the operational boundary for GHG accounting and reporting.

4.2. Scopes 1, 2 and 3 - Which emissions sources are included and how are they categorised?

After setting the organisational boundary the GHG Protocol suggests that the organisation should set an operational boundary i.e. identifying emissions sources, determining which will be included and in which category they should be reported. The GHG Protocol defines 3 categories of emissions, providing a framework for emissions accounting and reporting, an overview of which is provided in Figure 4.2. Considered from the NRW perspective, the 3 emissions categories are:

- **Scope 1** – direct GHG emissions to the atmosphere from sources owned or controlled by NRW e.g. fuel combustion in owned boilers and vehicles.
- **Scope 2** – indirect emissions to the atmosphere from the generation of electricity purchased by NRW for use in assets and buildings under our operational control.
- **Scope 3** – other indirect emissions that arise from sources outside of NRW's operational control but are a consequence of our activities e.g. purchased materials, contractor services, employee commute.

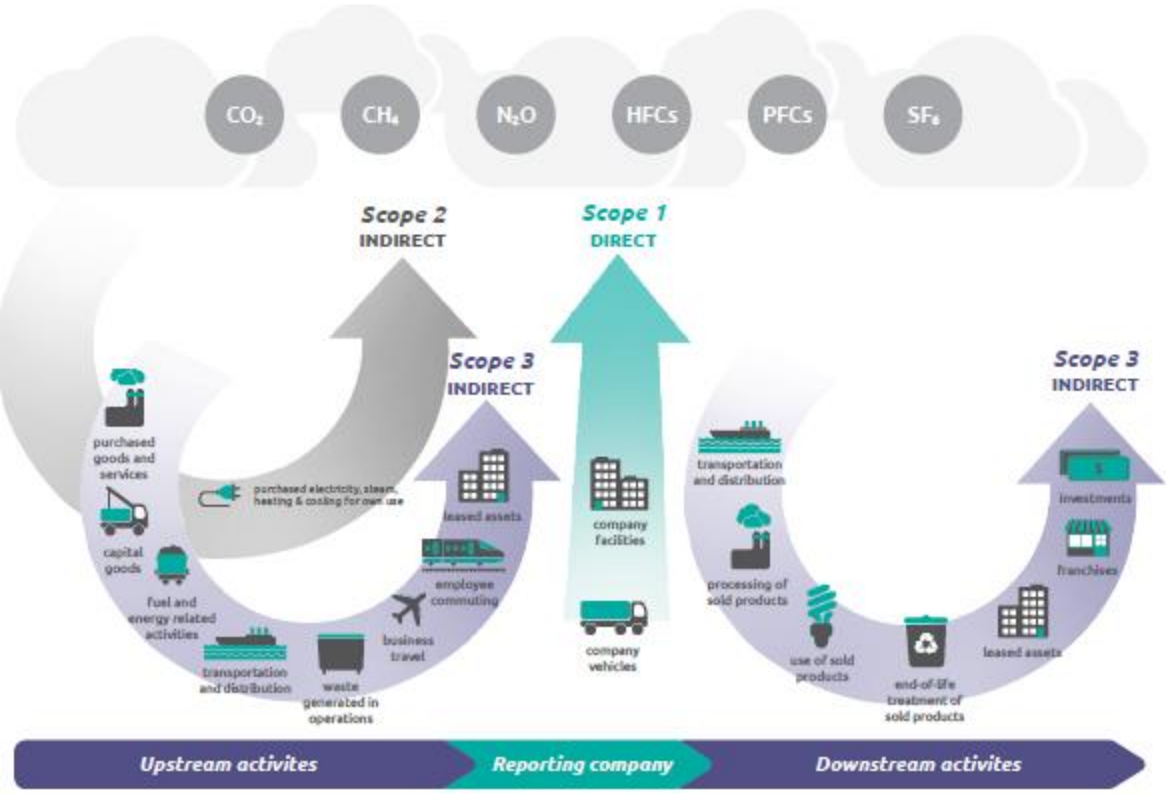

Figure 4.2. GHG Protocol categorisation of emissions by scopes (source: Bhatia *et al*., 2011).

Scope 2 and 3 emissions are considered to occur upstream or downstream of the organisation, rather than being released directly from assets and operations within the organisational boundary like scope 1 emissions. The GHG Protocol requires scope 1 and 2 emissions to be accounted for and reported as a minimum, with scope 3 being an optional reporting category. Together, the three scopes represent an organisation's total GHG inventory.

Having mapped out the structure of the organisation in terms of assets and operations in Figure 4.1, we then identified activities and potential sources of emissions relating to this structure. Four high level emissions categories were identified and used as an initial structure for calculations: 1) those arising from the use of buildings, 2) those arising from our transport, 3) those arising from the management of our land (both nature reserves and forest land), and 4) those arising from the operation of flood risk and operational assets. Each individual emissions source identified within this was mapped to a GHG Protocol emissions scope, delineating the operational boundary for the emissions inventory. Figure 4.3 shows the final emissions sources included, their scopes and operational boundary applied for GHG accounting.

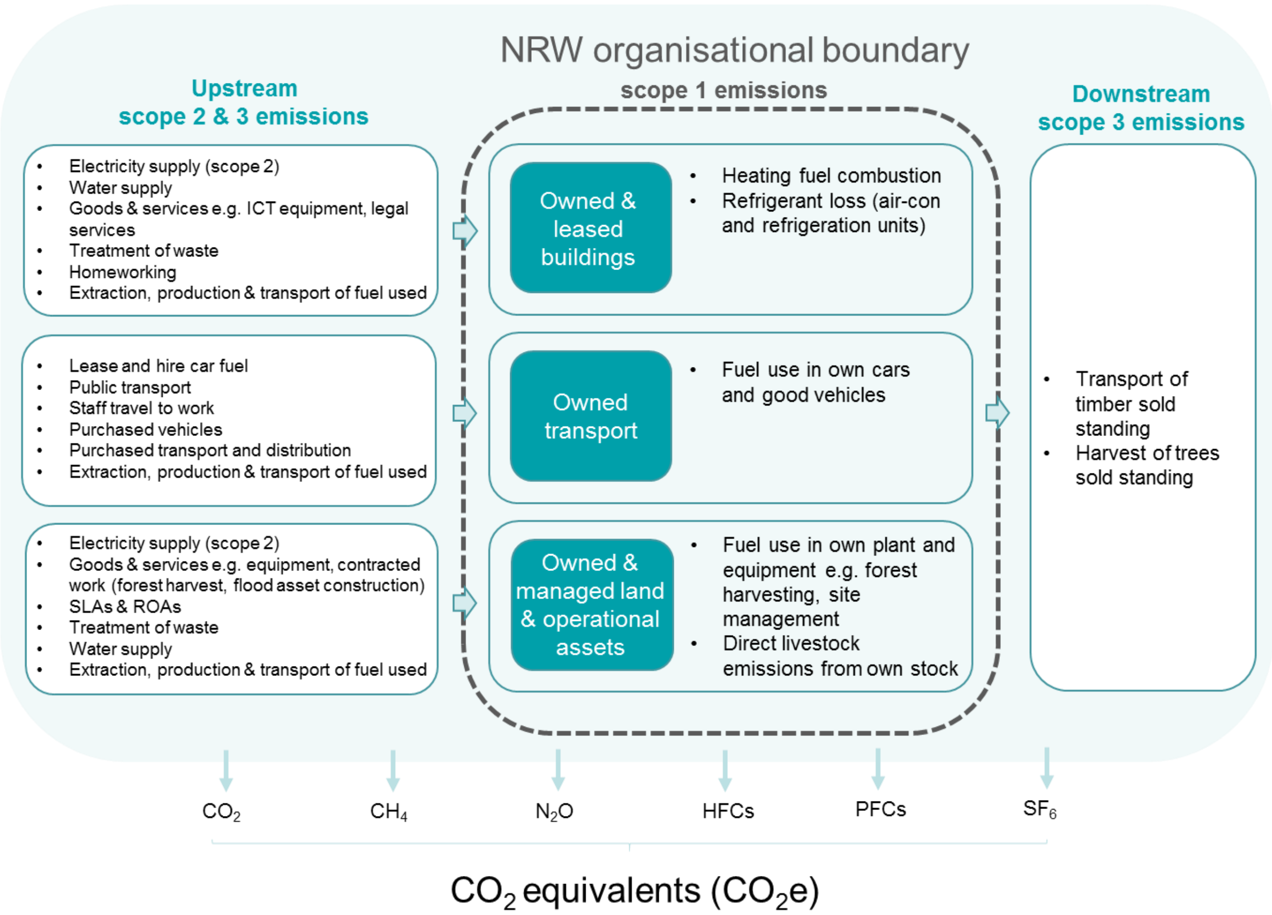

Figure 4.3. NRW operational boundary i.e. the emissions boundary used for the organisation's GHG inventory.

The organisational boundary adopted determines which emissions fall within the mandatory scopes 1 and 2 and which fall within the optional scope 3. For example, buildings leased by NRW have been deemed to be under NRW's operational control therefore emissions associated with fuel combustion in boilers on site will be categorised as direct, scope 1 emissions. Had these leased buildings been deemed to be outside of NRW's operational control the same heating fuel emissions could be reported as indirect, upstream scope 3 emissions. Accounting and reporting using this framework is designed to avoid double counting within the scope 1 and 2 emissions of different organisations (when using the same organisational boundary consolidation approach) (Ranganathan *et* *al*., 2004). NRW's scope 3 emissions are indirect, occurring at sources not owned or controlled by the organisation and therefore also represent other organisations' scope 1 and 2 emissions. This potential "double counting" of emissions between organisations is inherent within scope 3 emissions accounting approach and is not unique to the NRW GHG inventory.

As an optional reporting category, scope 3 emissions are frequently not accounted for within corporate GHG inventories. However, when estimated, they often account for more than 70% of company emissions (GHG Protocol, 2012a) and are therefore a crucial part of understanding an organisation's full carbon impact. The GHG Protocol provides guidelines for estimating 15 categories of scope 3 emissions upstream and downstream of organisations, ranging from emissions arising from goods and services purchased by the organisation to investments made by the organisation (Bhatia *et al*., 2011; Barrow *et al*., 2013). However, they also provide flexibility in terms the focus of scope 3 emissions accounting, suggesting prioritisation of emission categories based on criteria including the expected size of the emissions contribution and the influence the organisation has to reduce the emissions etc. (see Table 6.1 in Bhatia *et al*., 2011).

To provide as complete an account of NRW's GHG emissions as possible, we have included a broad range of scope 3 emissions within our inventory, focussing on those expected to make the biggest contributions, and those which the organisation can influence. Emissions associated with purchased goods and services were prioritised, given changes in NRW's business model towards outsourcing land management activities previously performed in-house e.g. a significant proportion of timber harvesting. Because of the complexity of estimating emissions from sources outside of the operational control of the organisation, it was not possible to account for all scope 3 emission sources initially identified. Exclusions primarily relate to downstream emission sources e.g. visitor travel to NRW owned and managed sites, management of NRW land leased to or managed by external organisations. Other potential downstream emissions associated with grant funding, advice and other resources provided by NRW were not accounted for. These sources do not fit well into any of the 15 GHG Protocol scope 3 categories, and no precedent for their calculation or inclusion in an organisational GHG inventory was found.

4.3. Collecting organisational data and selecting emission factors

Sections 4.4, 4.5 and 4.6 of this report provide the detailed methodology followed to estimate emissions from each source accounted for within scopes 1, 2 and 3 respectively. We sought to use the best internal activity data available within the timescales of the CPP. For estimation of scope 1 and 2 emissions we relied heavily on existing data collated annually by our EMS team to attain IS04001 accreditation. We updated and built upon these existing data sets, developing new ones where no previous organisation activity data were already available, with the input of colleagues from across the organisation. For each emission source the sections that follow detail the relevance of the emissions source to NRW, the type and source of activity data, any conversions or assumptions needed in emission calculations, the emission factor(s) (EFs) used and their sources, lessons learned in the process of estimating the emission, caveats of the approach and any improvement that could be made if the calculation were revisited in future.

4.4. Scope 1 emissions calculation methods

4.4.1. Heating fuels

Emissions arising directly from fuel combustion in boilers under NRW's operational control are categorised as scope 1 emissions. In 2015/16 the organisation had 72 occupied buildings under its operational control (owned and leased) including offices, depots, visitor centres, toilet blocks, deer larders, a fleet workshop, a fish hatchery and a laboratory. Thirty four of the 72 buildings used a heating fuel other than electricity in 2015/16. The organisation's EMS team issues a spreadsheet to be filled in monthly by facilities staff in each building to record key environmental performance data, including heating fuel use. These EMS site returns provide the activity data basis for all heating fuel calculations. Details of the activity data used and emissions estimation method followed for each category of heating fuel used by the organisation are given below:

- Natural gas heating - Twenty buildings under NRW's operational control were heated fully or partially through natural gas in 2015/16 including our largest offices in Bangor and Cardiff, with a combined floor space approaching 8,000 m^2. As part of the EMS site returns, natural gas use is recorded monthly at each building based on meter readings. Meter readings reporting volume used in cubic meters are converted to kilowatt hours (kWh) centrally using standard, consistent correction factors and calorific values by the EMS team (NRW, 2016). Newer meters report directly in kWh, requiring no conversion. For office space in shared buildings, such as our Aberystwyth office, total natural gas use for the whole building was subdivided between occupying organisations based on floor space under the operational control of each. Emissions associated with metered natural gas were then estimated centrally. The organisation's total natural gas use in the base year (1,185,470 kWh) was multiplied by the standard scope 1 EF from the UK Government conversion factors for Company Reporting spreadsheet, per kWh of natural gas based on gross calorific value (Ricardo-AEA and Carbon Smart, 2015).

- Kerosene heating - Six depots and workshops under NRW's operational control used heating oil (kerosene or premium kerosene) in 2015/16. As part of the EMS site returns, a facilities representative in each building records heating oil use. At four of the sites monthly meter/gauge readings are taken and entered onto the spreadsheet. For the remaining two sites the volume delivered in the year is recorded in the absence of meters. All spreadsheet entries are made in litres and are converted to kWh centrally by the EMS team using standard conversion factor of 10.35 kWh of energy content per litre of kerosene (NRW, 2016). The organisation's total kerosene use in the base year (133,686 kWh) was multiplied by the standard scope 1 EF from the UK Government conversion factors for Company Reporting spreadsheet, per kWh of burning oil a.k.a. kerosene, based on gross calorific value (Ricardo-AEA and Carbon Smart, 2015).

- Liquefied Petroleum Gas (LPG) heating - Eight buildings including visitor centres, depots and an office under NRW's operational control used LPG for heating purposes in 2015/16. As part of the EMS site returns, a facilities representative in each building records LPG use. Records are based on either bulk delivery in litres or cylinders purchased in kilograms, as they occur throughout the year. Both are converted to energy content in kWh centrally by the EMS team using standard conversion factors (NRW, 2016). The organisation's total LPG use in the base year (317,302 kWh) was multiplied by the standard scope 1 EF from the UK Government conversion factors for Company Reporting spreadsheet, per kWh of LPG, based on gross calorific value (Ricardo-AEA and Carbon Smart, 2015).

- Biomass heating (scope 1) - Ten buildings including offices, visitor centres, a depot, workshop and hatchery under NRW'S operational control used biomass for heating purposes in 2015/16. As part of the EMS site returns, a facilities representative in each building records biomass use. Use is typically recorded in terms of tonnes (t) of biomass used (whether logs, pellets or woodchip), as it occurs throughout the year. Two sites report usage directly in kWh from invoices, and another reports in terms of wood chip volume used (m^3). Usage by volume or weight is converted to kWh centrally by the EMS team using standard conversion factors (NRW, 2016). The organisation's total biomass use in the base year (woodchips 266,813 kWh, pellets 398,954 kWh, logs 55,370 kWh) was multiplied by standard scope 1 EFs from the UK Government conversion factors for Company Reporting spreadsheet, per kWh of each biomass fuel (Ricardo-AEA and Carbon Smart, 2015). The scope 1 EFs account for nitrous oxide (N_2O) and methane (CH_4) emitted during the combustion of biomass fuel only.

- Biomass heating (outside of scopes) - Direct carbon dioxide (CO_2) emissions arising from the combustion of biomass are not accounted for within scope 1 alongside CH_4 and N_2O emitted directly from NRW boilers. GHG Protocol guidelines state that CO_2 emissions from biologically sequestered carbon should be reported separately from the standard scopes (Ranganathan *et al*., 2004). Activity data on the organisation's total biomass use in kWh, as detailed under biomass heating scope 1 emissions, was multiplied by the standard outside of scopes EFs the UK Government conversion factors for Company Reporting spreadsheet, per kWh of each biomass fuel (Ricardo-AEA and Carbon Smart, 2015).

Table 4.1. Summary of heating fuels emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Natural gas combustion	1	Gas used in NRW owned and managed buildings (kWh)	Monthly meter readings from EMS site returns	Gas volume (m^3) used converted to kWh using standard correction factors and calorific value by EMS team	0.18445 kg CO_2e/kWh natural gas (gross calorific value)	Ricardo-AEA and Carbon Smart (2015)
Kerosene heating combustion	1	Kerosene used in NRW owned and managed buildings (kWh)	Monthly meter readings and delivery records from EMS site returns	Kerosene volume (litres) converted to kWh using standard fuel conversion factor by EMS team	0.24657 kg CO_2e/kWh burning oil (gross calorific value)	Ricardo-AEA and Carbon Smart (2015)
LPG heating combustion	1	LPG used in NRW owned and managed buildings (kWh)	Bulk fuel and cylinder delivery records from EMS site returns	LPG volume (litres) or weight (kg) converted to kWh using standard fuel conversion factors by EMS team	0.21468 kg CO_2e/kWh LPG (gross calorific value)	Ricardo-AEA and Carbon Smart (2015)
Biomass heating combustion	1	Wood chips, pellets and logs used in NRW owned and managed buildings (kWh)	Site records entered into EMS site returns	Biomass volume (m^3) or weight (t) converted to kWh using standard fuel conversion factors by EMS team	0.0132 kg CO_2e/kWh wood chips, pellets or logs	Ricardo-AEA and Carbon Smart (2015)
Biomass heating combustion	Outside of scopes	Wood chips, pellets and logs used in NRW owned and managed buildings (kWh)	Site records entered into EMS site returns	Biomass volume (m^3) or weight (t) converted to kWh using standard fuel conversion factors by EMS team	0.354 kg CO_2e/kWh wood chips; 0.349 kg CO_2e/kWh wood pellets; 0.3515 kg CO_2e/kWh wood logs	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- In shared buildings, heating fuel use needs to be allocated between organisations. The EMS team uses the proportion of floor space occupied by NRW to calculate our share of total the building’s heat related emissions. There is currently no list of all shared buildings occupied by NRW and the proportion of floor space used by our organisation in each. Future improvements should include drawing up such a list to confirm that all heating fuel use and associated emissions are being correctly allocated between organisations. This will help to ensure accurate reporting for shared spaces, such as the new NRW laboratory space in Swansea University. It may also be possible to install additional meters to directly capture NRW usage in shared buildings.
- The use of conversion factors is often necessary to match activity data units to those of EFs. We have used fuel data already converted to energy content in kWh by the EMS team. EMS conversion factors are recorded in NRW (2016), but the document does not provide references for these. In future, it is recommended that conversion factors should be revisited, brought up to date and documented with references to ensure accuracy of results and transparency of method. The UK Government conversion factors for company reporting spreadsheet provides up to date typical fuel property data to enable

conversion (Ricardo-AEA and Carbon Smart, 2015). It is recommended that the following should be addressed in any review of conversion factors:

- The conversion factor used for LPG (from kg to kWh) appears to differ marginally between cylinders of different weight.
- NRW gas bills provide a correction factor and calorific value for conversion (from m^3 to kWh), providing an opportunity to use an average value specific to the gas used by the organisation in future refinements of the calculation.
- Biomass used for heating at two sites is reported in EMS site spreadsheets in units of kWh, i.e. having already been converted to units of energy content from volume or weight. Currently there is no central record of these fuel specific conversion factor(s) used. These should be recorded and reported in future for improved transparency of method.
- All conversion factors should be consistently converting fuel quantity to energy content based on gross calorific value rather than net, matching the EFs used.

- For some fuels and sites, records are based on quantities delivered. This approach should be reviewed for each site to ensure that the full quantity delivered is used in the reporting year, and if not, that it is apportioned between years to accurately reflect use.

4.4.2. Refrigerant loss from air-con & fridge units

Emissions associated with refrigerant leakage from NRW owned or operated refrigeration and air-conditioning units are categorised as scope 1 emissions. This is because these are direct emissions arising from equipment under our operational control. These emissions are also referred to as fugitive emissions. The organisation has a range of air conditioning units associated with offices, server rooms and laboratory space. The organisation also has a range of refrigeration units, primarily domestic units, associated with office kitchens, visitor centres, laboratory space, depots and workshops. Refrigerant related emissions were estimated following the screening method outlined in Annex C of the DEFRA Environmental Reporting Guidelines (2013). This method is based on an inventory of NRW equipment and average data on leakage rates, as opposed to the more accurate material balance method which is based on primary records of quantities of refrigerants used in servicing equipment. The more basic method was thought to be sufficient for NRW purposes given that these emissions were expected to make a small contribution to overall scope 1 emissions. We undertook the following steps to estimate air-conditioning and refrigeration emissions:

1. Carrying out an equipment inventory – Each NRW office or depot building updates an inventory of refrigeration and air conditioning equipment annually as part of their EMS site returns. In which each piece of equipment is listed alongside information on the type of unit, the type of refrigerant it contains and its refrigerant capacity. These were brought together into a single spreadsheet.
2. Categorising equipment – Each piece of equipment was matched, according to its description and charge capacity, to one of the DEFRA (2013) equipment categories detailed in the guidelines. The guidelines do not provide a description of each type of equipment, making categorising equipment difficult. We therefore searched for supporting documentation with a description of each, creating Table 4.2 from the information in a background report by ICF International (2011). All NRW air-conditioning units were categorised as small or medium stationary air conditioning units; and all refrigerated equipment as domestic refrigeration or small hermetic stand-alone refrigeration units. NRW's inventory contained a number of unusual refrigeration units such as sample fridges in laboratories and deer larders. The EMS team who carry out site audits across the organisation advised that these are

conventional fridge units. Therefore, these were all categorised as domestic refrigeration units. Their charge capacities all fall within the typical range for this equipment category. Water coolers and refrigeration units in visitor centre cafes such as ice cream fridges and food display cabinets were categorised as small hermetic stand-alone refrigeration units.

3. Estimating installation emissions – Some additional units were reported this year that were not reported in previous years. This was followed up and these were found to be previously unreported not new units. No new units were reportedly installed during the base year therefore no installation emissions were estimated.
4. Estimating operating emissions – Operating emissions from equipment leaks and service losses were estimated based on the typical annual leakage rate values supplied in the DEFRA (2013) guidelines. For each unit the equipment charge capacity (kg) was multiplied by the proportion of time for which the unit was used during the reporting year (all 12/12 months for NRW this year), then by the “annual leak rate %” to give total operating losses for each unit (kg of refrigerant). Each unit’s losses were then multiplied by the refrigerant specific EF from the UK Government Conversion Factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015) to give emissions associated with operational losses for the unit for the year (kg CO_2e). Only emissions associated with Kyoto Protocol refrigerants, gases and blends were estimated. The UK Government Conversion Factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015) states that only Kyoto Protocol gases need be reported under scope 1. Emissions associated with Montreal Protocol gases such as R22 were therefore not estimated. Other unreported non-Kyoto Protocol gases contained within NRW equipment were R509, R290, R600A, R484a, NH_3 (a.k.a. R717) and R12.
5. Estimating disposal emissions – No disposals were reported during the base year therefore no disposal losses were estimated.

Although the data set used in the above assessment is considered complete for building based air-conditioning and refrigeration units, mobile air conditioning was not included as this type of equipment is not recorded by facilities staff as part of their EMS site returns. Some data on refrigerant use in NRW services forestry plant is recorded and collated by the EMS team, however this is not a complete data set as it excludes plant used by flood risk management teams, serviced externally. Similarly, no central record of refrigerant use in the servicing of the NRW car and LGV fleet is currently available. There is currently no inventory of fleet vehicles with air-conditioning, refrigerant type and capacity, meaning that mobile air-conditioning is currently excluded from the NRW GHG inventory. This exclusion is not expected to materially affect the organisation’s GHG inventory result, given that all building based refrigerant emissions from air-conditioning and refrigeration equate to <1% of total scope 1 and 2 emissions.

Table 4.2. DEFRA Environmental Reporting Guidelines equipment categories and typical charge capacity ranges (DEFRA, 2013); with equipment description from the ICF International report (2011) on modelling GHG emissions from refrigeration and air conditioning.

Type of equipment	Equipment description	Typical charge capacity (kg)
Domestic Refrigeration	Refrigerated appliances including refrigerators, chest freezers, upright freezers, and fridge freezers.	0.05-0.5
Small Hermetic Stand-Alone Refrigeration Units	Small, hermetic, stand-alone refrigeration units including ice cream cabinets and drinking water coolers. These systems are commonly used in retail food stores but are also found in pubs, restaurants, and other hospitality and catering outlets such as hotels, hospitals, and schools.	0.2-6.0
Condensing Units	Refrigeration systems composed of one (or two) compressor(s), one condenser, and one receiver assembled into a unit, which is located external to the sales area. These units are typically installed in small shops and have refrigeration capacities ranging from 1 Kw to 20 Kw.	50-2,000
Centralised Supermarket Refrigeration Systems	Refrigeration systems that are comprised of racks of compressors installed in a machinery room. These systems are commonly used in supermarket applications.	50-2,000
Industrial Systems	Refrigeration systems including industrial process refrigeration and cold storage.	10-10,000
Small Stationary Air Conditioning	Includes small self-contained Acs (including window units) and non-ducted split Acs. Units are used primarily in commercial applications, but there is some use in the residential sector. System cooling capacities typically range from 3 to 12 Kw.	0.5-100
Medium Stationary Air Conditioning	Includes ducted split, variable refrigerant flow non-ducted split, ducted split, and packaged AC. Units are used in the commercial UK sector. System cooling capacities typically range from 12 to 30 Kw.	0.5-100
Large Stationary Air Conditioning (Chillers)	Large, indirect chillers used for commercial comfort air conditioning.	10-2,000
Heat Pumps	Residential and small commercial heat pumps, including air-source heat pumps (air-to air and air-to-water systems) and ground-source heat pumps.	0.5-100
Land Transport Refrigeration	Refrigerated road vehicles (i.e., light commercial vehicles, trucks, trailers) and intermodal containers.	3-8
Marine Transport Refrigeration	Refrigerated general cargo ships, container ships and fishing vessels (1,000 GT and above).	3-8
Light-Duty Mobile Air Conditioning	AC systems for passenger cars and light commercial vehicles (up to 3.5 tonnes). Both of these vehicle types are covered under Directive 2006/40/EC (the MAC Directive).	0.5-1.5
Other Mobile Air Conditioning	AC systems for trucks (over 3.5 tonnes), buses/coaches, semi-trailers, trailers, and railcars.	0.5-1.5

Table 4.3. Summary of refrigerant loss emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Refrigerant emissions – building based	1	Number and type of fridge and air conditioning units, refrigerant type, refrigerant capacity (kg)	EMS site returns – annual update of inventory of refrigeration and air conditioning units at occupied sites	Typical annual leakage rates per equipment category from DEFRA (2013)	3,220 kg CO_2e/kg HFC 227a leaked; 2087.5 kg CO_2e/kg R410a leaked; 1,773.9 kg CO_2e/kg R407c leaked; 3,921.6 kg CO_2e/kg R404a leaked; 1430 kg CO_2e/kg R134a leaked; 1,100 kg CO_2e/kg R134 leaked	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- We followed the basic screening method to estimate emissions associated with refrigerant leakage from refrigeration and air-conditioning units. The EMS team does hold data on quantities of refrigerant used when servicing some units, however this is not a complete record of losses for all equipment. Therefore, a hybrid approach could be taken to refine this calculation in future, with the material balance method used for serviced pieces of equipment and the screening method used for all other equipment. Given the small emissions contribution of this category, pursuing this improvement in accuracy would only be worthwhile if the data were readily available, i.e. it does not warrant investing a significant amount of time.
- No units were purchased or disposed of in the reporting year according to the equipment inventory. As part of the EMS site data collection spreadsheet, it should be made clear that all new and disposed of units should be clearly recorded to ensure that these emissions are captured.
- Emissions associated with refrigerant use in mobile air-conditioning in NRW owned plant and vehicles are currently excluded from the calculation. The time investment needed to acquire all necessary data to estimate these emissions was considered disproportionate to the relative emissions contribution of the category. This exclusion is not expected to materially affect the organisation's GHG inventory result. However, if this information can be collected through inclusion in existing reporting structures, this could then be used to improve the calculation if revisited in future.

4.4.3. Fuel combustion in owned vehicles, plant and equipment

Emissions arising directly from fuel combustion in NRW owned and controlled vehicles, plant and equipment are categorised as scope 1 emissions. Emissions arising from fuel combustion in vehicles leased[9] by the organisation have historically been classed as scope 3 emissions in EMS reporting, as the vehicles are not owned or considered to be controlled by the organisation. We could not, for example, install eco-driver telematics black box technology into these vehicles. Emissions associated with lease vehicle use are therefore included as part of the organisation's upstream scope 3 impacts, rather than scope 1. In the year following the base year, changes to the lease car arrangements in NRW resulted in some lease vehicles becoming part of the fleet (this is discussed further in the Discussion (Section 7.2.1) of this report).

In 2015/16, the NRW vehicle fleet comprised 899 road vehicles and 204 pool vehicles. The organisation also owned: 167 plant machines including grass cutters, excavators, quads, tractors and forklifts for land and flood risk management purposes; 178 pieces of equipment such as chainsaws, generators and clearing saws and 69 marine units such as ribs and engines for marine survey purposes[10]. Owned vehicles including pool cars, LGVs and a small number of HGVs are either allocated to specific teams, and/or are bookable by staff for travel and transportation to managed sites and assets, for responding to incidents, taking samples and for travel to meetings. Despite an internal focus on the use of telecommunications to reduce travel, fuel usage was anticipated to remain high in the base year given the need for site and asset visits.

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[9] 'Lease cars' discussed in this section refer to the vehicles associated with the staff lease car scheme from the legacy Environment Agency. These vehicles had not been incorporated into the fleet in the base year 2015/6.

[10] Note that following the base year, there has also been a review of marine vessels as part of ongoing fleet improvements.

Diesel and petrol - The majority of the organisation's diesel and petrol use in owned road vehicles is accurately recorded through the use of fuel cards kept in individual cars and goods vehicles. NRW's fleet team receives a fuel card report annually, detailing all refuelling events including fuel type and number of litres used. A small amount of additional petrol and diesel is purchased directly by staff using charge cards, for use in some equipment and marine units. This is captured directly as spend from charge card reports by the EMS team. All spend categorised under "Fleet Fuel & Oil & Lubricants" in the reporting year is divided by the average fuel cost per litre for the year from fuel card reports (£1.17/litre) to give litres of additional (un-categorised) fuel use. The organisation's total fuel use in the base year in owned road vehicles, equipment and marine units (695,825 litres of diesel, 4,800 litres of petrol and 5,673 litres of un-categorised fuel) was multiplied by standard scope 1 EFs from the UK Government conversion factors for Company Reporting spreadsheet, per litre of average biofuel blend of each fuel (Ricardo-AEA and Carbon Smart, 2015). A diesel EF was applied to the uncategorised fuel.

Gas oil (i.e. red diesel) - NRW's fleet team hold delivery records for bulk fuels, detailing quantities, delivery dates and locations. These are aggregated annually by fuel type to report total usage for the organisation. Bulk deliveries of gas oil (i.e. red diesel) for use in plant in the base year were reported for operations delivery, forestry operations and unallocated operations. Some additional gas oil is purchased directly by staff using charge cards, for use in some plant. This is captured directly as spend from charge card reports by the EMS team. All spend categorised under "Fuel oil" in the reporting year is divided by the average cost per litre for the year from fuel card reports (£0.50/litre) to give litres of additional unallocated gas oil. The organisation's total gas oil use per operational team (95,413 litres for operations delivery, 106,862 litres in forestry operations, 27,214 litres unallocated) was multiplied by the standard scope 1 EF from the UK Government conversion factors for Company Reporting spreadsheet, per litre of gas oil (Ricardo-AEA and Carbon Smart, 2015).

Table 4.4. Summary of vehicle fuel emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Diesel, petrol and un-categorised fuel combustion	1	Diesel and petrol used in NRW owned road vehicles, equipment and marine units (litres); Charge card spend on vehicle fuels (£s)	Fleet fuel card reports; EMS analysis of charge card spend on vehicle fuel	All charge card spend categorised as "Fleet Fuel & Oil & Lubricants" assumed to be diesel fuel; diesel EF applied to both diesel and premium diesel; petrol EF applied to premium unleaded, unleaded, super unleaded and lead replacement petrol	2.5839 kg CO_2e/litre average biofuel blend diesel; 2.1944 kg CO_2e/litre average biofuel blend petrol	Ricardo-AEA and Carbon Smart (2015)
Gas oil (red diesel) combustion	1	Gas oil delivered to NRW depots (litres); Charge card spend on gas oil (£s)	Fleet team bulk fuel delivery records; EMS analysis of charge card spend on gas oil	All charge card spend categorised as "Fuel oil" advised to be gas oil by EMS team	2.90884 kg CO_2e/litre gas oil	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- All forecourt diesel and petrol contains a small proportion of biofuel, therefore the average biofuel blend EF should be used from the UK Government conversion factors for Company Reporting spreadsheet.
- NRW changed to a different fuel card provider in 2016, which will provide more precise reports of additional products purchased at garages such as screen washes and oil. These are currently excluded from organisation's GHG inventory but could therefore be added in future.
- Currently, fuel that is not purchased through fuel cards or bulk delivery is identified on a spend basis from charge card reports by the EMS team. For streamlined, replicable reporting, we recommend that the fleet team develop an approach to systematically identify and report any fuel purchases not captured by fuel card or bulk fuel delivery reporting (i.e. fuel purchased for use in and equipment and marine units) and to bring this into a central reporting system of fuel use across NRW.
- Fuel and lubricant spend identified from charge card reports could not be accurately categorised. We have made the assumption that this is all fuel and have applied a diesel EF to estimate associated emissions. Similarly, the EMS team advised that charge card spend categorised as "fuel oil" is gas oil, and this should be verified in future footprint years.
- As is the case for some heating fuels, records of gas oil use are based on quantities delivered rather than the quantities used in a period. This approach should be reviewed, particularly for sites with infrequent deliveries, to ensure that the full quantity delivered is used in the reporting year, and if not, that it is apportioned between years to accurately reflect use.

4.4.4. Grazing livestock (enteric fermentation and manure management)

Some non-mechanical emissions sources associated with grazing livestock are categorised as scope 1 emissions (WRI and WBCSD, 2014). Enteric fermentation (feed digestion) and manure management emissions associated with NRW owned livestock are therefore reported within this category. Other livestock related emissions such as associated fuel use in machinery, any feed and supplies are accounted for in other in other reporting categories (fuel emissions and purchased goods emissions). In 2015/16, NRW owned 297 Welsh Mountain ponies and 4 Koniks, for nature reserve management purposes, and although the organisation is not an agricultural enterprise, resulting emissions were accounted for to provide a comprehensive estimate of NRW scope 1 emissions. Emissions arising from non-NRW livestock grazing NRW owned or managed land are not accounted for, as this stock is owned by another party and not within the organisation's operational control.

The GHG Protocol agricultural guidance (WRI and WBCSD, 2014) refers users to the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) for the estimation of emissions associated with non-mechanical agricultural sources. Because livestock emissions were expected to represent a small element of the overall NRW organisational footprint, we used a freely available land management carbon calculator based on the simplest level of IPCC guideline equations (tier 1) to estimate this category of emissions. The Carbon Accounting for Land Managers (CALM) calculator is a free tool to estimate GHG emissions associated with land management activities (alongside carbon storage in trees and soils) (CLA, 2009). The only activity data needed to estimate CH_4 emissions associated with feed digestion, and N_2O

emissions associated with manure and urine deposits were the average number of livestock over the year, the average number of days spent grazing outside over the year and how manure from any housed animals was managed. These data were collated directly from all NNR managers, co-ordinated by the organisation's existing NNR greening group. All NRW ponies are outside all year, with no housing or associated manure management. The CALM calculator plugs the activity data provided into IPCC tier 1 equations and reports the results by emissions category. We categorised ponies as horses because the calculator did not provide a separate category for ponies, our results are therefore likely to be an overestimate, needing refining in future.

No fertiliser is applied to NRW managed land grazed by the ponies, therefore no resulting emissions from soil have been calculated. Other emissions arising from soils on the estate as a result of management are considered within the second half of this report on the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate.

Table 4.5. Summary of grazing livestock emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Grazing pony enteric fermentation CH_4, manure related CH_4 and N_2O emissions	1	Average number of livestock owned by NRW over the year; average days outside over the year	Collated from NNR managers	Ponies categorised as horses	Tier 1 IPCC methodology through the CALM calculator	Country Land and Business Association (2009)

Lessons learned, caveats and suggested future improvements:

- The CALM calculator is an easy to use, free tool which was particularly useful to NRW as an organisation with a small number of livestock and limited time to dedicate to estimating emissions from this source. As we work to refine organisational emissions estimates in future, tier 1 IPCC equations should be used directly for this emissions source to improve the transparency of the method.
- Results will be a slight overestimate of emissions due to the categorisation of ponies as horses. To refine this approach in future the organisation could collect data on the live weight of owned ponies and use IPCC tier 1 equations directly to estimate EFs revised by weight.

4.5. Scope 2 emissions calculation methods

Emissions arising from the generation of electricity purchased by the organisation are classed as scope 2 indirect emissions, because they occur at the generation facility but can be attributed to the organisation i.e. emissions arising at the point of generation are allocated to the end-user. NRW purchases grid electricity for use in both its buildings (offices, depots etc) and operational assets including pumping stations, hydrometry and telemetry equipment (gauges, sluices etc).

All 72 of the occupied buildings under NRW's operational control used some grid electricity in the base year. As part of EMS site returns a member of facilities staff records electricity meter readings in kWh for each of these manned sites monthly. The EMS team centrally calculates and records total usage in kWh for the year for each site. Metered electricity consumption was therefore the activity data used for manned sites.

For unmanned sites such as pumping stations and gauges and supporting infrastructure such as CCTV cameras, the EMS team reviews invoices from our primary supplier annually. To inform scope 2 calculations the CPP reviewed the organisation's electricity demand, and it became clear that there was no central list of electricity suppliers for all NRW buildings and assets, and a joint initiative between the project and central facilities staff was needed to investigate and pull together the information. The complex union of three legacies bodies in the formation of NRW meant that despite the majority of assets having been consolidated with our primary supplier, there remained a small number assets with others. Six electricity suppliers were identified in total.

In total, 319 sites under NRW's control including manned buildings and unmanned assets were identified as using grid electricity from supplier invoices. A small number of previously unreported assets were identified for which activity data were pulled from invoices and added to the consumption data from our primary supplier. These included one of the organisation's largest electricity users: Collister Pill pumping station (billed as Noah's Ark pumping station). In the base year, three pumping stations and one office-depot building were transferred into the ownership and operational control of NRW from the Internal Drainage Board (IDB). Electricity use in the transferred office-depot (Pye Corner) was captured through EMS manned buildings reporting. Electricity use at the three pumping stations (Sandy Lane, Sychpwll, and Powysland IDB) was taken from invoices from two separate suppliers.

This process of reviewing the organisation's electricity supply was time consuming and challenging because of the range of assets operated by NRW and the numerous legacy suppliers used, but it was necessary to confidently state that the activity data used is a comprehensive summary of all grid electricity consumed by the organisation's assets in the base year (see below for lessons learned from this process).

Two other key issues also required consideration when determining the activity and emissions data to be used to calculate NRW's scope 2 emissions, there were: 1) how to account for electricity generated by NRW owned renewable technologies, used on-site and 2) how to account for renewable electricity purchased from the grid. The original GHG Protocol Corporate Accounting and Reporting Standard (Ranganathan *et al*., 2004) was amended in 2015 to provide clearer guidelines on scope 2 accounting and reporting (Sotos, 2015). These issues were addressed as follows based on the amended guidelines:

1. Data collated by the EMS team indicated that 81,713 kWh of renewable electricity was generated by solar photovoltaic (PV) panels and used at manned sites in the base year. All of the electricity generated is used on site with none sold to the grid. A number of NRW operational assets including our Greenmoor and Clwyd pumping stations have existing PV installations, providing a direct supply of electricity. The total amount of electricity generated by renewable technologies on operational assets on the estate is not currently known, but the CPP is working to working to compile a list of all renewable installations for the future. None of the generated electricity is known to be sold to the grid, with all installations put in to provide a direct supply to assets (this will require future verification when a full list of renewables on assets has been complied). The GHG guidelines indicate that no scope 2 emissions need to be reported for energy produced and consumed on site, although any associated combustion emissions should be reported in scope 1 (Sotos, 2015). No scope 1

emissions arise from renewable generation; therefore, this is not applicable in this instance. As a result, no emissions associated with NRW's renewable generation are accounted for within the organisation's footprint (other than indirectly through the reduced need for grid purchased electricity). In future, when total renewable generation is known this could be reported alongside the organisation's footprint. The guidelines suggest that the grid emissions avoided by renewable generation can optionally be reported separately to scopes 1, 2 and 3.

2. As part of the review of the organisation's electricity supplies we also sought to assess whether electricity purchased was generated from renewable or non-renewable sources, and whether these should be treated differently in emissions accounting. The GHG protocol amendment (Sotos, 2015) presents two methods for allocating and estimating scope 2 electricity emissions: a location based approach, which applies a grid average EF for a defined geographic area over a defined time-period, e.g. the annual UK grid average EFs published as part of the UK Government conversion factors for company reporting; and a market based approach which applies a tariff or supplier specific EF to an electricity supply chosen by the reporting company based on particular attributes. This means that emissions rates specific to renewable tariffs can be applied, provided that this can be evidenced by a Renewable Energy Guarantee of Origin (REGO) in the UK or is disclosed by the supplier for a specific product/tariff. A review of the organisation's electricity invoices, suggested that a significant proportion of the organisation's supply was purchased on renewable tariffs, however no accompanying details of the breakdown of the supply (by generation type) were provided on the invoices. In conjunction with the NRW Facilities team we contacted each supplier and asked for details of all tariffs, requesting REGO certificate numbers for renewable supplies and / or disclosed EFs for each tariff. After multiple attempts to obtain this information, only one supplier was able to provide proof of renewable supply in the form of REGO certificate numbers and an accompanying disclosed EF for this renewable tariff. This supplier is a dedicated green energy supplier. For all other suppliers, although we have invoices suggesting that the supply to some assets was on a renewable tariff this could not be evidenced. We were therefore unable to fully differentiate between renewable and non-renewable tariffs meaning that we could not consistently apply a market-based approach to all electricity purchased by the organisation. As a result, we adopted the market-based approach for assets supplied with REGO certification, and we defaulted to a location-based approach for all other purchased electricity which reflects the average contribution of renewable and non-renewable generation to the grid.

The organisation's total electricity consumption in the base year, at manned sites, for which no tariff specific emissions data were obtained (2,555,790 kWh), was multiplied by the grid average scope 2 EF per kWh of electricity generated in the UK, from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015). Total electricity consumption, at manned sites, with proof of renewable supply (555,000 kWh), was multiplied by a renewable tariff disclosed by the supplier. All electricity consumption at unmanned sites (1,489,064 kWh), was multiplied by the grid average scope 2 EF per kWh of electricity generated in the UK, from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015).

Table 4.6. Summary of electricity emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Grid electricity use in manned and unmanned sites with no proof of renewable supply	2	Electricity used in NRW owned and managed buildings and assets (kWh)	Monthly meter readings from EMS site returns for manned sites, invoices for unmanned sites	Suppliers could not provide tariff specific EFs therefore grid average used	0.46219 kg CO_2e/kWh	Ricardo-AEA and Carbon Smart (2015)
Grid electricity use in manned sites with proof of renewable supply	2	Electricity used in NRW owned and managed buildings (kWh)	Monthly meter readings from EMS site returns, verified by invoices		0.00 kg CO_2e/kWh	Green Energy, Personal Communication (2016)

Lessons learned, caveats and suggested future improvements:

- The time taken to review electricity consumption and supply was far greater than anticipated. One significant problem was the inconsistent naming of buildings and assets internally and with suppliers e.g. a pumping station billed as 'Noah's Ark power station' on invoices was eventually identified as a under the name of 'Collister Pill Pumping Station' internally. Several assets were simply listed on invoices as "pumping station" or "rain gauge" hindering their identification. Frequently the postcodes of assets and depots differed slightly between NRW record and invoices. Input was needed from facilities and asset staff across the organisation to cross-reference assets between data sets.
- In future, a revision of asset names used with electricity suppliers, and in other organisational reporting, is required to adopt a single common name and a unique reference/identifier. In addition, it is recommended that a database be created of all NRW assets (to include buildings, depots, and operational assets (e.g. pumping stations, hydrometry and telemetry assets), to include a geographic information system (GIS) map layer showing locations spatially. This database should also seek to include details of any renewable energy installations on assets.
- Reviewing electricity supplies identified anomalies with electricity payments, and flagged issues that needed to be addressed by facilities staff to ensure that the organisation is not overpaying for electricity supplies e.g. identification of mothballed sites for which the organisation was still being billed based on estimated rather than actual electricity use; identification of sites for which billed use was considerably higher than metered use recorded by the EMS team; identification of small telemetry assets for which billed use was significantly higher than expected for the asset type, indicating a billing issue such as NRW paying for supplies to adjacent assets not owned by NRW. In identifying these sites, the CPP saved the organisation money and in future, further cost savings could be yielded from appropriate auditing of electricity use against billed data.
- The process we followed also enabled us to strategically identify top electricity users from across the organisations' manned and unmanned portfolio of operated buildings and operational assets, to strategically target efforts to reduce demand and associated emissions. This also provided additional benefit of the information needed by contractors to assess the potential for renewable energy installations to be built on the NRW estate to supply electricity to our own assets.
- Although there is an obligation for electricity suppliers in Great Britain to disclose their annual fuel mix, suppliers struggled to supply tariff specific EFs to NRW, possibly in part

due to the number of disparate assets supplied and the associated range of tariffs. Consolidating assets with a smaller number of suppliers and onto a smaller number of tariffs would therefore simplify the process of accounting for organisational scope emissions.

- This process of reviewing the organisation's electricity supply prompted a commitment to move to 100% renewable tariff in 2017 for all assets identified, consolidating all consumption with one supplier. In future, it should therefore be easier to apply tariff specific EFs to the organisation's total electricity consumption, subject to appropriate evidence being provided. As part of this transition, NRW's Facilities team has requested that REGO certification be supplied to prove the supplies' renewable status.

4.6. Scope 3 emissions calculation methods

As explained in Section 4.2, the GHG Protocol provides guidelines for estimating 15 categories of scope 3 emissions. Categories 1 to 8 account for an organisation's upstream emission impact and categories 9 to 15, the downstream impact. Upstream emissions are those associated with purchased or acquired goods and services, and downstream are those associated with the goods and services that the organisation sells or provides (Bhatia *et al*., 2011). For ease of cross referencing with the GHG Protocol guidelines (Barrow *et al*., 2013), calculation methods are reported in the sections that follow by scope 3 emissions categories.

4.6.1. Category 1 – Purchased goods and services

4.6.1.1. Water (upstream category 1 (water supply) and upstream category 5 (water treatment))

Both emissions associated with the energy used to supply water to, and treat waste water discarded by NRW, are categorised as upstream scope 3 emissions. This is because these emissions occur at the water utility company but can be considered a consequence of NRW's activities i.e. these are services purchased by NRW. Water supply emissions fall within category 1 – purchased goods and services, whereas water treatment emissions fall within category 5 – waste generated in operations. Although not expected to be significant emissions source, the EMS team collates and reports meter readings of water supplied to all manned offices, depots etc. providing accurate activity data to enable the estimation of water supply emissions using industry standard emissions data.

Emissions associated with the supply of water to NRW through the mains network were therefore estimated using site meter readings recorded as part of EMS reporting, and the standard scope 3 water supply EF per cubic meter (Ricardo-AEA and Carbon Smart, 2015) i.e. following a GHG protocol "average-data method". No supply emissions were attributed to water abstracted or rainwater harvested by the organisation. Although not currently used in EMS reporting, the EMS team hold a central spreadsheet of the type of drainage system at each NRW site which was used alongside data on the amount of water abstracted and rainwater harvested at each site to estimate returns to mains drains. Emissions associated with the treatment of water returned to mains drains by the organisation were estimated for the full volume of water supplied, abstracted and harvested on all sites with mains drainage, based on a standard scope 3 EF per cubic meter returned to the sewerage system. No treatment emissions were applied to water supplied or collected on sites with a treatment plant such as reed beds.

Table 4.7. Summary of water supply and treatment emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Water supply	3	Mains water supplied in 2015/16 (m^3)	EMS site returns of meter readings		0.344 kg CO_2e/m^3 water	Ricardo-AEA and Carbon Smart (2015)
Water treatment	3	Mains water supplied, rain water harvested, water abstracted (m^3), sites with mains drainage	EMS site returns of meter readings, harvested and abstracted water	All water supplied to or collected on sites with mains drainage assumed to be returned to sewerage system through mains drains	0.708 kg CO_2e/m^3 water	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- Emissions associated with the treatment of water from sites with septic or sealed tanks are not accounted for in this base year GHG inventory for the organisation. Although we have primary data on NRW sites serviced by tanks, no EFs were available for these water treatment services.
- Further work is needed to account for septic and sealed tank emissions in future. In the past a separate product code was in place within the organisation to record spend on septic tank maintenance. Reinstating this code would allow these upstream emissions to be captured within the organisational footprint in future.
- To avoid double counting of waste disposal service emissions between the supply chain spend analysis outlined in scope 3 category 1, and the primary data methods, it was necessary to remove waste related account codes from the spend analysis. It was not possible to differentiate between organisational spend on septic tank and other waste treatment services, therefore all waste treatment spend was excluded from the supply chain emissions analysis.

4.6.1.2. Purchased goods and services (upstream category 1) (excluding Service Level Agreements and Reservoir Operating Agreements)

Supply chain emissions associated with the procurement of goods and services are categorised as upstream scope 3, category 1 emissions (Barrow *et al*., 2013). This includes all upstream emissions from the extraction, production and transportation of goods and services used by NRW in the base year. This category excludes goods and services which have their own scope 3 category for reporting under the GHG protocol such as disposal and treatment of waste generated in NRW's operations (Barrow *et al*., 2013).

NRW's end of year accounts reported an organisational spend of £118 million (excluding staff costs) in the financial year 2014/15 (NRW, 2015), leading to potentially significant upstream supply chain emissions. Analysis of emissions associated with goods and services purchased requires consideration of all areas of spend including ICT hardware and software, construction materials, monitoring equipment, haulage, fleet purchases, land management consultants, legal fees, staff training and equipment, insurance etc. In many areas of the organisation a significant proportion of the work programme is carried out by contractors on NRW's behalf, including fuel and material intensive activities such as flood management asset construction and forest harvesting operations. Accounting for upstream emissions associated with outsourced activities is therefore crucial to ensure that the organisation takes responsibility for its outsourced emissions impact.

As is the case throughout the GHG protocol scope 3 technical guidance (Barrow *et al*., 2013), a range of methods are presented for estimating emissions associated with purchased goods and services. These differ in terms of how specific the approach is to individual suppliers, with the most specific involving the collation of GHG data for individual goods and services directly from suppliers. Secondary methods are non-supplier specific and rely on industry average emissions data. Although upstream emissions associated with purchased goods and services were expected to make a significant contribution to NRW's overall scope 3 emissions, we opted for the least specific spend-based method to report on all category 1 emissions (with the exception of water supply). It was felt that in this base year, the priority for emissions reporting in this category should be to gain an overview of all upstream emissions associated with our supply chain, through a blanket spend-based analysis. Gaining an overview of emissions impact across all spend was thought to be particularly important given that NRW is a relatively new organisation with a significant annual spend over a broad range of good and services, reflecting the organisation's broad remit. This initial base year analysis would be carried out with the intention of using the results to estimate key emissions hotspots for which estimates could be refined using a more supplier specific approach in future. This spend-based analysis approach was therefore seen as a first attempt at estimating supply chain emissions against which future improvements could be made.

The spend-based method involves collecting data on organisation-wide spend per category of purchased goods and services in the footprint year and multiplying this by a relevant EF per unit of economic value i.e. kg CO_2e/£ spent. Such EFs are provided for an economic area through environmentally-extended input output (EEIO) models. These models are typically based on data from national accounts and environmental accounts, allocating economy wide production process emissions to groups of finished products according to economic flows (Barrow *et al*., 2013; ISA and CenSA, 2010). The outputs of which are estimates of quantities of GHG emitted per £ of revenue generated from industrial sectors. Using these sector average EFs allows for a comprehensive estimate of an organisation's upstream emissions, albeit with high levels of uncertainty. It must be acknowledged that because these are sector average EFs, this approach does not reflect the emissions associated with the production processes of specific products or suppliers. As a result, estimates will not reflect any efforts made to reduce emissions through efficiencies in the supply chain e.g. through choosing an energy efficient supplier or working with suppliers to reduce material use. This accounting method does not therefore lend itself to setting targets and measuring emission reduction efforts.

We followed the supply chain method set out in Annex E of the DEFRA Environmental Reporting Guidelines (2013). This presents the results of an EEIO analysis conducted by the Centre for Sustainability Accounting (CenSA), providing cradle-to-consumer emissions data for 75 product and service groups. This CenSA EEIOA is listed as GHG protocol compliant, in their directory of third party life cycle emissions databases (GHG Protocol, 2012b). We undertook the following steps to estimate the organisation's upstream emissions from goods and services using this method:

1. We were given access to a master list of the organisation’s procurement account codes. All NRW spend is reported against these account codes whether paid via invoice, direct debit, fuel card, purchase card etc. The account codes represent broad categories of products and services purchased such as 21001: translation fees; 21017: contractors; 22000: computer hardware; 23003: fleet spares and parts; 24002: furniture and fittings etc. Most of the account codes are subdivided into product codes to enable reporting of the purchase of specific products within that broad category e.g. within 21017, contractor services are subdivided into a long list of product codes including 21017-0001 “IT contractors”; 21017-0008 “Web design”; 21017-0014 “Stonewalling”; 21017-0018 “Asset maintenance – hard and soft engineering services”.
2. Account code categories that represent non-upstream spend such as staff pay, overtime, national insurance contributions, staff relocation costs and internal charges (e.g. staff time to another project) were taken out of the master list, see Table A.1 in Appendix A for a full list of exclusions. These spend categories were not considered to represent goods and services procured by the organisation.
3. Account code categories that represent the purchase of goods and services for which primary activity data were available were also taken out of this master list: electricity, heating fuel, business travel, vehicle fuel and lubricants, waste management, sewage charges. See Table A.2 in Appendix A for a full list of exclusions. We were careful to avoid double counting of our upstream emissions between the spend-based and primary data approaches. In some cases, this was problematic e.g. the travel account code 12009 relates to “other domestic travel” with no further detail on what is categorised here. It is possible that a small amount of travel accounted for using primary activity data could be double counted by also including this category in the spend analysis. However, any double counting will be minimal given that most codes are already sufficiently detailed to accurately extract categories of interest. The introduction of more product codes in future under some account codes would provide greater detail in our accounts and ensure that any double counting is avoided.
4. We then created a spreadsheet of all remaining account codes with a new column mapping each to the most appropriate of the 75 DEFRA product group categories. This manual mapping process was problematic because there is little supporting explanation on the 75 product categories and what types of product / service are included / excluded from each. DEFRA (2013) state that the categories are based on the standard industrial classification (SIC) of economic activities from 2003 (National Statistics, 2003). Therefore, where we were unclear on how to categorise an account code, we sought further detail from the SIC. This typically provided enough information to categorise an account code in question but was not always definitive because not all SIC codes have a DEFRA product code. One example of where we needed to refer back to the SIC for clarification was to map account codes associated with outsourced forest harvesting and thinning activities. DEFRA (2013) states that product category UK-2 forestry products includes “Forestry products: Wood in the rough, other forestry products”. When we referred to the given SIC code for the category, logging and other forestry related services activities were also listed, suggesting that this product code could also be used for forestry contractor services. See lessons learned below for further discussion on the difficulties around applying this approach.
5. Some account code categories were found to be very broad, potentially including products and services that should be mapped to different DEFRA product

categories e.g. one account code for all consultant services procured (21018) covering ICT, financial, land management consultancy etc. We therefore mapped individual product codes (under broad account codes) to DEFRA categories where necessary. Some NRW product codes combine groups of products that should be mapped to separate DEFRA product categories but cannot be further disaggregated. For example, the NRW product code 14001-0001 refers to “mobile telephone costs including hardware”. Based on our interpretation of the DEFRA product codes, and supporting SIC descriptions, telephone hardware manufacture should be mapped to UK-42 “radio, television and communications” whilst telecommunications should be mapped to UK-60 “post and telecommunications”. Without being able to disaggregate the two, all spend against this product code was mapped to the latter category. We received external advice that suggested the spend based analysis is such a broad-brush approach that issues such as this will have limited impact on the overall accuracy of the results. Table A.3 in Appendix A gives a range of examples of how NRW product and account codes were mapped to the 75 DEFRA product group categories.

6. Some account and product codes used within NRW lacked a detailed description which also made mapping to DEFRA product codes problematic. Clarification on a number of codes was sought from procurement and accounting teams. Because of the size of the organisation and its broad range of functions reflecting those of three legacy bodies, finding a finance contact with an overview of all codes was problematic.
7. Once all account and product codes had been mapped to a DEFRA product group we requested spend data for each product and account code of interest inclusive of VAT from our finance team. Three problems were encountered with the provision of these data, as discussed and addressed in the points below:

- At the time of estimation only 9 months’ worth of spend data were available for reporting for the base year. These figures were extrapolated to 12 months, with a view to updating the analysis once year-end data became available should time allow. Unfortunately, this was not possible, and this spend-based analysis for the base year is therefore based on an assumption that spend in the final quarter of the year was equal to the average of the first three quarters. At the time of writing NRW accounts for the financial year 2015/16 had not been published. When revisited in future years this exercise should be carried out once year-end accounts data have been finalised for reporting.
- Whilst the accounts team were easily able to produce reports of total spend via all routes (invoice, card, direct debit etc.) against all requested account codes, they were unable to report on spend against product codes. It became clear that product codes are used by the procurement team only and are not used for organisational financial reporting purposes. We therefore requested spend data against product codes from the procurement team and spend against account codes from the accounting team. Because of a time-lag between purchase order placement and payments being made, figures reported from the two ends of the accounting system didn’t match up for the period. It was felt that for continuity with financial reporting, figures from the accounts team should be used. Spend against broad account codes was allocated pro rata between product codes based on the proportional spend on each as indicated by the procurement spend data, in order to reconcile the two sets of data.
- Accounts data do not typically include VAT, however DEFRA (2013) state that spend data used in this analysis should be VAT inclusive. An additional procedure was developed internally to estimate VAT spend for account codes in Agresso:

1. Open general ledger transaction browser report.
2. Add search criteria for appropriate period and required account codes via list.
3. Copy and paste results to Excel.
4. Summarise by account code via pivot table.
5. Open VAT Transaction Listing report within Tax Reporting.
6. Select appropriate periods and run report.
7. Copy and paste in Excel.
8. Summarise net, VAT and gross amounts by account code via pivot table.
9. Combine net amounts from transaction report pivot table and VAT amounts from VAT report pivot table.
10. The total VAT inclusive spend figure will reflect all general ledger transactions and VAT.
11. Totals will only reflect the net impact of accounting adjustments, as VAT is not accounted for beyond initial VAT procedures upon receipt of invoices etc.
12. Totals will not agree to management accounts, financials accounts, or other financial reports, which are net of VAT.

8. Spend against each account or product code was then multiplied by the product category EF to give total upstream emissions per category.
9. Account codes and product codes were then re-grouped for reporting under NRW relevant categories to make the data accessible to staff e.g. contractor work under headings such as forest thinning, forest harvesting, marine services, flood related services etc.

Table 4.8. Summary of purchased goods and services emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Purchased goods and services (excluding services paid for under services level agreements, reservoir operating agreements and water supply)	3 (category 1)	NRW spend data against account and product codes for 2015/16	NRW accounts team	9 months data extrapolated to 12 months; final spend reported by accounts split pro rata between product codes based on proportional spend from purchase order spend; VAT estimated for this exercise	kg CO_2e/ £ spent on 75 product categories (CenSA EEIO)	DEFRA (2013)

Lessons learned, caveats and suggested future improvements:

- This spend-based method relies on the availability of spend data inclusive of VAT, which is not consistent which NRW financial reporting. A methodology to estimate VAT associated with spend against account codes was therefore developed for this exercise. This method is recorded above for future reference, should the net carbon status calculation be revisited.
- As discussed above, matching NRW account codes to one of the 75 product categories was sometimes problematic. Land management services contracted out were often difficult to categorise, e.g. marine and terrestrial survey work; fencing work. Referring to the SIC documentation (National Statistics, 2003) was crucial to identify the full range of activities included within a product category e.g. the “legal, consultancy and business activities” product category was found to include technical surveying activities. Although

varied in nature most consultancy work was categorised under the same broad heading, highlighting the crudeness of this approach. Options for improving upon this approach in any future net carbon status calculations include exploring opportunities to use a more refined EEIO with EFs for a greater number of product and service categories, and working to develop more specific emissions estimation methods for key categories of emissions.

- DEFRA's introduction to using the 75 category spend-based method states that "*The estimates do not incorporate any allowance for emissions relating to the formation of capital assets*", which we have interpreted to mean that, the EFs do not include the formation of capital assets used in the supply chain to deliver the goods and services purchased. The 75 product category descriptions do include capital goods such as office computers and motor vehicles. We have therefore included the organisation's spend on capital goods within the analysis.
- This analysis relies upon the correct coding of spend by staff. In the process of completing this exercise a number of staff in different departments indicated that account code selection is often inconsistent. One example given was that contractor spend on maintenance activities on the woodland estate such as grass cutting and fence erection are recorded under a range of codes, with little consistency even within a regional team. Work is being done internally within NRW to revise and streamline account and product codes. This should help to rationalise codes and encourage accurate and consistent coding of spend.
- The internal revision of account codes will also mean that new NRW account codes will need to be re-mapped to the DEFRA product groups should the organisation wish to estimate its supply chain emissions following this procedure in future years. Ideally these new account codes should be developed to easily map across to the 75 DEFRA product groups.
- To allow the net carbon status calculation to be repeated in future years, a set procedure should be developed within the organisation for sharing spend data between procurement and accounts teams and those carrying out the calculation. This could involve making members of staff within the procurement and accounts teams responsible for reporting end of year spend against the account codes of interest. As part of the procedure those carrying out any future calculation would need to be made aware of new account codes each year so that these could be mapped to the DEFRA product groups.
- The GHG protocol (Barrow *et al*., 2013) suggests using a spend based method as a means of screening significant emissions sources, helping to prioritise further data collection efforts. The results of the spend based analysis for NRW have highlighted emissions hotspots in the supply chain, where improved data collection methods should be employed in future to improve the accuracy of these estimates and help target emission reduction efforts. This would involve moving away from spend based emissions estimates to using industry average emissions data per relevant unit of product purchased e.g. mass of materials, or for greatest accuracy, working with suppliers to estimate or gain access to supplier specific emissions estimates for their good or services. Using a mixture of spend based and supplier specific methods to estimate emissions associated with purchased goods and services will only be possible if spend data can be disaggregated sufficiently to avoid double counting between methods.
- To demonstrate / trial the approach of refining emission estimates for hotspots, we carried out a case study to better understand emissions associated with forestry

services on the WGWE (managed by and under the operational control of NRW). Several types of forestry operation carried out by contractors were amongst NRW's top 15 emissions hotspots identified through the spend analysis. These include forest harvesting, haulage, restocking and road maintenance. The rationale for, methodology, results and next steps of this case study are detailed in Appendix B.

4.6.1.3. Purchased goods and services - Service Level Agreements and Reservoir Operating Agreements (upstream category 1)

Emissions associated with the work done for NRW by external organisations under Service Level Agreements (SLAs) and Reservoir Operating Agreements (ROAs) were also considered to be supply chain emissions categorised within upstream scope 3, category 1. These agreements cover a breadth of services ranging from hands-on land management to desk-based studies, making applying a single EF to this category problematic. In the region of £18 million were spent on these agreements in the base year, representing a potentially significant source of upstream emissions for the organisation.

No additional activity data beyond total spend was available to us at the time of calculation. Two possible approaches to emissions calculation were considered:

1. Applying a spend based EF for consultancy work, consistent with the approach for other purchased goods and services as detailed in the previous section (4.6.1.2). The EF for consultancy work given in DEFRA (2013) is 0.17 kg CO_2e/kg.
2. Estimating and applying a proxy EF based on NRW's own emissions per £ of income. This would require an assumption that organisations completing work under SLAs and ROAs have a similar operational structure, and emissions intensity per unit of income to NRW. This approach was trialled whilst our calculations were being developed in July 2016. At the time, NRW's total income from the previous year's accounts was divided by our working emissions total for the organisation, giving an organisational EF per £ of income. The indicative result was an EF of 0.17 kg CO_2e emitted by NRW per £ of income.

Given that the EF estimated using working totals via the second approach was consistent with the spend based EF, we decided to opt for the first approach. Total spend on SLAs and ROAs in the base year was multiplied by the consultancy spend based EF (DEFRA, 2013). This spend based approach had the benefit of being consistent with emissions calculations for other purchased goods and services, and did not need all other emissions calculations for the organisation to be complete before it could be calculated, as would have been the case with a final proxy EF approach.

Table 4.9. Summary of SLA and ROA emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Services provided to under Service Level Agreements and Reservoir Operating Agreements (purchased goods and services)	3 (category 1)	NRW spend data against SLA and ROA account codes for 2015/16	NRW accounts team	9 months data extrapolated to 12 month	0.17 kg CO_2e/ £ spent on Legal, consultancy and other business services (UK-68)	DEFRA (2013)

Lessons learned, caveats and suggested future improvements:

- We received external advice on the spend based analysis approach that included a recommendation to cross check the reasonableness of spend based EFs with other activity where possible. The process of estimating a proxy EF for SLAs and ROAs based on NRW's own emissions helped to prove the validity of adopting the generic spend based EF.

4.6.2. Category 2 – Capital goods

Upstream emissions associated with the manufacture of capital good purchased by the organisation in the base year were included in the spend analysis of purchased goods and services, as outlined in Section 4.6.1.2.

4.6.3. Category 3 - Extraction, production & transportation of fuel & energy used

4.6.3.1. Category 3A upstream emissions of purchased heating fuels

Emissions associated with the extraction, refining and transportation of heating fuels consumed in buildings under NRW's operational control are categorised as upstream scope 3, category 3A emissions. These upstream emissions are in addition to those arising directly from fuel combustion in NRW boilers, accounted for in scope 1 calculations. For each type of heating fuel the activity data described in Section 4.4.1 (scope 1 heating fuels) i.e. kWh of natural gas, kerosene, LPG and biomass used were also used to estimate upstream emissions arising before the point of arrival at NRW owned and managed buildings. Total heating fuel use in the base year was multiplied by fuel specific scope 3 EFs from the UK Government conversion factors for Company Reporting spreadsheet, referred to as "well to tank" EFs.

Table 4.10. Summary of upstream heating fuel emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Natural gas upstream emissions	3 (category 3a)	Gas used in NRW owned and managed buildings (kWh)	Monthly meter readings from EMS site returns	Gas volume (m^3) used converted to kWh using standard correction factors and calorific value by EMS team	0.02483 kg CO_2e/kWh natural gas (gross calorific value)	Ricardo-AEA and Carbon Smart (2015)
Kerosene upstream emissions	3 (category 3a)	Kerosene used in NRW owned and managed buildings (kWh)	Monthly meter readings and delivery records from EMS site returns	Kerosene volume (litres) converted to kWh using standard fuel conversion factor by EMS team	0.05105 kg CO_2e/kWh burning oil (gross calorific value)	Ricardo-AEA and Carbon Smart (2015)
LPG upstream emissions	3 (category 3a)	LPG used in NRW owned and managed buildings (kWh)	Bulk fuel and cylinder delivery records from EMS site returns	LPG volume (litres) or weight (kg) converted to kWh using standard fuel conversion factors by EMS team	0.02697 kg CO_2e/kWh LPG (gross calorific value)	Ricardo-AEA and Carbon Smart (2015)
Biomass upstream emissions	3 (category 3a)	Wood chips, pellets and logs used in NRW owned and managed buildings (kWh)	Site records entered into EMS site returns	Biomass volume (m^3) or weight (t) converted to kWh using standard fuel conversion	0.01662 kg CO_2e/kWh wood chips; 0.03217 kg	Ricardo-AEA and Carbon Smart (2015)

				factors by EMS team	CO_2e/kWh wood pellets; 0.01277 kg CO_2e/kWh wood logs	

Lessons learned, caveats and suggested future improvements:

- The organisation's GHG inventory may feature a small amount of double counting of emissions associated with the production of a small quantity of logs as biomass fuel. At the time of calculation, all biomass fuel was thought to be purchased and therefore scope 3 emissions associated with upstream production and transport were applied to all biomass fuel used. However, it has been suggested that a small quantity of logs at one office were harvested on-site and therefore associated production emissions would already be accounted for in scope 1 fuel combustion emissions. This is a small amount and will have minimal impact on overall emissions.

4.6.3.2. Category 3A upstream emissions of fuel used in owned vehicles, plant and equipment

Emissions associated with the extraction, refining and transportation of transport fuels consumed in vehicles, plant and equipment under NRW's operational control are categorised as upstream scope 3, category 3A emissions. These upstream emissions are in addition to those arising directly from fuel combustion accounted for in scope 1 calculations. For each type of transport fuel, the activity data described in Section 4.4.3. (scope 1) i.e. litres of diesel, petrol, un-allocated fuel and gas oil were also used to estimate upstream emissions arising before the point of arrival at the petrol station forecourt or NRW depots. Total transport fuel use in the base year was multiplied by fuel specific scope 3 EFs from the UK Government conversion factors for Company Reporting spreadsheet, referred to as "well to tank" EFs.

Table 4.11. Summary of upstream vehicle fuel emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Diesel, petrol and un-categorised fuel	3 (category 3a)	Diesel and petrol used in NRW owned road vehicles, equipment and marine units (litres); Charge card spend on vehicle fuels (£s)	Fleet fuel card reports; EMS analysis of charge card spend on vehicle fuel	All charge card spend categorised as "Fleet Fuel & Oil & Lubricants" assumed to be diesel fuel; diesel EF applied to both diesel and premium diesel; petrol EF applied to premium unleaded, unleaded, super unleaded and lead replacement petrol	0.5811 kg CO_2e/litre average biofuel blend diesel; 0.4616 kg CO_2e/litre average biofuel blend petrol	Ricardo-AEA and Carbon Smart (2015)
Gas oil (red diesel)	3 (category 3a)	Gas oil delivered to NRW depots (litres); Charge card spend on gas oil (£s)	Fleet team bulk fuel delivery records; EMS analysis of charge card spend on gas oil	All charge card spend categorised as "Fuel oil" advised to be gas oil by EMS team	0.5847 kg CO_2e/litre gas oil	Ricardo-AEA and Carbon Smart (2015)

4.6.3.3. Categories 3B and C upstream emissions of purchased electricity

Emissions associated with the extraction, production and transport of fuels used in the generation of electricity purchased by the organisation are categorised as upstream scope 3, category 3b; and emissions arising from losses in transmission and distribution (T & D) associated with the electricity purchased by the organisation as category 3c. These upstream emissions are in addition to the scope 2 combustion emissions from purchased electricity. For all electricity purchased by the organisation from non-renewable sources, we applied scope 3 well to tank and T & D loss EFs from the UK Government conversion factors for Company Reporting spreadsheet.

Table 4.12. Summary of upstream electricity emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Upstream emissions of grid electricity use (non-renewable supply only)	3 (category 3b)	Electricity used in NRW owned and managed buildings and assets (excluding renewable supply) (kWh)	Monthly meter readings from EMS site returns for manned sites, invoices for unmanned sites		0.06888 kg CO_2e/kWh purchased	Ricardo-AEA and Carbon Smart (2015)
Emissions arising from T & D losses associated with electricity use	3 (category 3c)	Electricity used in NRW owned and managed buildings and assets (excluding renewable supply) (kWh)	Monthly meter readings from EMS site returns for manned sites, invoices for unmanned sites		0.03816 kg CO_2e/kWh purchased (T & D losses); 0.00569 kg CO_2e/kWh purchased (upstream emissions of T & D losses)	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- No upstream or T & D emissions have been estimated for the renewable electricity purchased via the grid.

4.6.4. Category 4 – Upstream transportation & distribution

Emissions arising from the transport of products and from transport services (logistics) purchased by the organisation are classed as upstream scope 3, category 4 emissions. For most goods purchased by the organisation delivery is included in the purchase price and is therefore captured in the supply chain spend analysis of emissions associated with purchased goods and services i.e. category 1 (Section 4.6.1.2). It was not possible to separate out the transport element of purchase prices to be reported separately in category 4. For upstream transport services with discrete account and product codes such as lorry hire, haulage services, delivery charges and courier services, we followed the supply chain methodology as for category 1, reporting the results separately under category 4.

Table 4.13. Summary of upstream transportation and distribution emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Emissions associated with the transport of purchased products	3 (category 4, but reported with category 1)	NRW spend on goods	NRW accounts team	Included in scope 3 category 1 calculations	kg CO_2e/ £ spent on 75 product categories (CenSA EEIO)	DEFRA (2013)
Emissions associated with transport services purchased by NRW	3 (category 4)	NRW spend data against haulage and courier account codes for 2015/16	NRW accounts team	9 months data extrapolated to 12 months; final spend reported by accounts split pro rata between product codes based on proportional spend from purchase order spend; VAT estimated for this exercise (see Section 4.6.1.2)	0.41 kg CO_2e/ £ spent on post and telecommunications (includes courier services); 0.95 kg CO_2e/ £ spent on road transport (CenSA EEIO)	DEFRA (2013)

Lessons learned, caveats and suggested future improvements:

- Category 4 emissions do not reflect all upstream transport purchased by NRW due to the lack of separate spend data on the purchase and delivery of goods.
- Category 4 estimates include emissions associated with the haulage of timber felled on the WGWE by contractors for NRW, calculated using the spend-based method. The forestry emissions case study conducted provides a more detailed estimate based on more specific activity and emissions data (see Appendix B). However, it is not possible to replace the timber haulage estimates from the spend analysis with this improved estimate at this time, because haulage spend data cannot be disaggregated sufficiently to accurately remove timber related haulage only.
- Ideally, we would recommend using the improved timber haulage estimates alongside the spend based estimates for all other upstream transport in a combined methods approach to increase the precision of the organisation’s scope 3 calculations. In future, working with the procurement team to amend account and product codes to provide greater detail on the specific nature of haulage spend would enable disaggregation to allow this element of the inventory to be refined with the improved data.

4.6.5. Category 5 – Waste generated in operations

Emissions arising from the disposal and treatment of waste generated in operations under NRW’s control are classed as upstream scope 3, category 5 emissions. NRW generates conventional office waste such as paper, packaging, batteries and staff kitchen waste; alongside less conventional waste products associated with land management operations such as wood, chemical and construction waste. Alongside waste generated by the organisation, NRW also disposes of waste fly tipped on NRW owned or managed land. Although this is not waste generated by the organisation it is disposed of as part of our land management remit. All fly tipped waste is disposed of via an NRW depot or office and is therefore recorded within EMS returns. On the basis that removing this waste is part of NRW’s land management remit, emissions associated with fly tipped waste are included within the organisation’s category 5 emissions.

Waste disposals are recorded as part of the EMS spreadsheet filled in monthly by facilities staff in each building to record key environmental performance data. These records detail the weight of different waste streams disposed of and treatment method e.g. reuse, recycle, combustion or landfill. This spreadsheet has recently been improved to collect detailed data on different waste streams by waste type, and significant work was done by the EMS team in the base year to improve the quality of data input by facilities staff. It is anticipated that waste data accuracy will improve greatly between the base year 2015/16 and the following reporting year 2016/17. Currently emissions associated with waste disposal are estimated by the EMS team using an average data method i.e. applying an average EF for all waste disposed of via a specific method. Given that significant improvements were made to data collection processes in the base year we did not seek to improve the calculation method to use waste specific EFs for the base year, however this should be pursued in future years as the quality of activity data improves. The organisation's total waste disposals in the base year (242 t landfilled, 416 t recycled, and 133 t combusted) were multiplied by municipal waste EFs per tonne disposed of through each method (Ricardo-AEA and Carbon Smart, 2015). A municipal rather than commercial waste EF was applied to reflect that the organisation's waste includes kitchen waste, deer carcasses etc. In addition to the waste streams recorded via individual office/depot returns, the EMS team also collated data on IT equipment disposals via a recycling contract in the base year. IT equipment sent for recycling in the base year (3.98 t) was multiplied by an EF for mixed electrical item recycling (open loop). The EFs applied include collection, transport and landfill emissions for landfilled waste; and transport only for waste combusted or recycled (Ricardo-AEA and Carbon Smart, 2015). The GHG protocol technical scope 3 guidelines (Barrow *et al*., 2013) indicate that emissions from the transportation of waste should be reported in scope 3 category 4 upstream transportation and distribution emissions, however it was not possible to break down the waste EFs to enable waste emissions to be sub-categorised in this way.

Emissions associated with the treatment of waste water discarded by NRW are also reported in this category as per the GHG protocol, although the calculation methodology is outlined in Section 4.6.1.1 alongside water supply emissions.

Table 4.14. Summary of waste emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
"Municipal" waste disposal	3 (category 5)	All categories of waste disposed of at NRW offices and depots (t)	Monthly data returns by facilities staff to EMS	Includes fly tipped waste	459 kg CO_2e/t municipal waste landfilled; 21 kg CO_2e/t municipal waste combusted; 21 kg CO_2e/t municipal waste recycled (open or closed loop)	Ricardo-AEA and Carbon Smart (2015)
IT equipment recycling	3 (category 5)	All IT waste sent for recycling	E-mails sent by facilities staff reporting disposals via IT recycling company to EMS		21 kg CO_2e/t mixed electrical waste recycled (open loop)	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- The accuracy of the waste emissions calculations may be low for 2015/16. In future, this can be significantly improved upon, following work done in the base year by the EMS team to improve recording and accuracy of activity data. In future, more detailed EFs by waste type should be applied to the improved activity data. To facilitate this, the waste categories in the EMS data collection spreadsheet could be updated to align more closely with waste emissions categories given in the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015). This will improve the calculation methodology from the average data to the waste type specific method outlined in the GHG Protocol (Barrow *et al*., 2013).
- The base year was the first year for which IT disposal data were recorded. This appears to have been on an ad-hoc basis and therefore may not be comprehensive. Putting a requirement in place for the disposal company used by NRW to provide an annual report of all equipment disposed of to the EMS team would improve the accuracy of this emissions estimates in any future net carbon status calculation.
- To avoid double counting of waste disposal service emissions between the supply chain spend analysis outlined in scope 3 category 1, and the primary data method outlined above, waste related account codes were removed from the spend analysis e.g. 24003 office waste recycled and 24004 office waste non-recycled.
- As explained in Section 4.6.1.1, emissions associated with the treatment of water from sites with septic or sealed tanks are not accounted for in this base year GHG inventory for the organisation.

4.6.6. Category 6 – Business travel

Emissions associated with business travel in vehicles not owned, operated or leased by NRW are classed as scope 3, category 6 business travel emissions. This includes travel via public transport, hire cars and employee-owned vehicles for NRW business purposes, excluding employing commuting. The EMS team estimates business miles travelled each year using a mix of distance and spend based estimation methods. Details of the activity data used, and emissions estimation method followed for each category of travel undertaken for NRW business purposes are given below. For each mode of travel the EFs applied are combined EFs, including both fuel combustion emissions and those associated with the extraction, refinement and transportation of the fuel, i.e. they are lifecycle EFs as advised by the GHG Protocol technical guidance on energy EFs in scope 3 accounting (Barrow *et al*., 2013)).

Hire car travel - NRW's fleet team receives reports from each hire car provider used by the business detailing either mileage by each individual hire event, or total hire mileage. Mileage details are aggregated across the providers to give an annual hire mileage for NRW. Almost one fifth of all car rentals (determined by spend) were paid for directly by staff using charge cards in the base year. These were captured by the EMS team by extracting spend categorised as "fleet, hire, lease and haulage" from charge card reports and using the average hire cost per mile (across all of the aforementioned hire car reports) to convert spend to mileage (£0.28769 / hire car mile). This grouped spend category was all assumed to be on hire cars in the absence of more accurate data. The organisation's total mileage travelled in hire cars in the base year (256,654 miles) was multiplied by an EF per mile travelled by an average sized car of unknown fuel type from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015).

Employee-owned car travel (referred to as grey mileage within NRW) - The best activity data currently available to calculate emissions associated with employee-owned car travel is total estimated mileage. This is estimated by the fleet team by extracting all expense claims made by staff for fuel use in own cars from the finance system. The total expense claim for fuel in employee-owned cars is converted to mileage using standard mileage claim rates (pence per mile) as set out by HMRC. The organisation's total employee-owned car mileage for business purposes in the base year (552,343 miles) was multiplied by a standard EF per mile travelled by an average sized car of unknown fuel type from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015).

Air travel - NRW travel policy discourages flying for business purposes. All journeys require executive team level permission, limiting air travel within the organisation. Journeys made by air by ex-Environment Agency Wales (EAW) staff are booked through a travel management company who report journey details to the NRW facilities team. The EMS team utilises this report, alongside details of flight transactions paid for by card, extracted from charge card reports. Journey miles are estimated by the EMS team based on journey start and end point details of each flight made. All flights made in the base year were within Europe. The organisation's total air miles in the base year (18,898 miles) were multiplied by an EF per passenger kilometre travelled by the average passenger on a short haul-flight from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015). The combined EF used incorporates combustion and upstream emissions associated with fuel use, in addition to the impact of radiative forcing.

Train travel - As with air travel, train journeys by air by ex-EAW staff are booked through a travel management company who report journey details including distances to the NRW facilities team. The EMS team utilises these journey distances, in addition to details of train ticket transactions paid for by card, extracted from charge card reports, to derive total train mileage for the year for all staff. All charge card spend on train travel is converted to mileage using the average cost per journey mile from the travel management company train journey data (£0.25377/mile). The organisation's total train miles in the base year (866,267 miles) were multiplied by an EF per passenger kilometre travelled on national rail from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015).

Motorcycle travel - Again, expense claims made by staff, extracted from the finance system by the NRW fleet team is the activity data source for motorcycle travel. The total motorcycle claim on fuel is converted to mileage using standard mileage claim rates (pence per mile) as set out by HMRC. The organisation's total motorcycle business mileage (4,475 miles) was multiplied by a standard EF per mile travelled by an average sized motorbike from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015).

Bicycle travel - No emissions were estimated in association with the 1,944 miles of business travel by bicycle.

Unspecified business travel - No primary activity data relating to business travel via other modes such as buses, taxis and ferries are currently recorded within the organisation, or reported by the EMS team. However, one NRW travel and subsistence account code in the finance system, described as “Other domestic travel” captures spend on buses and taxis and possibly other modes of business travel. It was not possible to disaggregate this category of spend further in the accounts system. For completeness, we had the option of accounting for this category, in terms of spend, in the scope 3 spend analysis (fully described in the Section 4.6.1.2 Purchased goods and services (upstream category 1)). However, because of lack of detail on what is covered by each travel related account code category, and because of the possibility of inaccurate coding of spend, we cannot be certain that this approach would not result in the double counting of some business travel related emissions between the primary data calculations above and the spend analysis. Separate, specific account codes do exist for train travel, air travel, mileage claims, and vehicle hire, which should limit any double counting through this approach. All spend on “other domestic travel” was therefore multiplied by the DEFRA UK-56 EF per £ spent on “Road transport” which includes spend on public transport.

Hotel stays - The GHG Protocol scope 3 technical guidance (Barrow *et al*., 2013) states that emissions associated with business travellers staying in hotels can be optionally reported within category 6. We were limited to using spend categorised as accommodation within the finance system as activity data, and therefore hotel related emissions are captured within the spend based analysis of emissions associated with purchased goods and services (scope 3, category 1).

Table 4.15. Summary of business travel emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Hire car travel	3 (category 6)	Hire car mileage; Charge card spend on car hire (£)	Hire car provider reports to NRW fleet team; EMS analysis of charge card spend on car hire	All charge card spend categorised as “Fleet, hire, lease and haulage” assumed to be car hire; Charge card spend converted to mileage based on cost of £0.29 per mile	0.299901 kg CO_2e/mile (combustion only); 0.061734 kg CO_2e/mile (fuel extraction, refinement and transport) in an average sized car of unknown fuel type	Ricardo-AEA and Carbon Smart (2015)
Employee-owned car travel (excludes commuting)	3 (category 6)	Employee-owned car business mileage expense claims	Fleet team extraction of fuel expense claims for employee-owned cars from the finance system	Total expense claims converted to mileage using standard HMRC mileage claim rates (pence per mile).	0.299901 kg CO_2e/mile (combustion only); 0.061734 kg CO_2e/mile (fuel extraction, refinement and transport) in an average sized car of unknown fuel type	Ricardo-AEA and Carbon Smart (2015)
Air travel	3 (category 6)	Flight start and end point for each journey	Travel management company report to facilities team; EMS analysis of charge card spend on flights	Flight distances estimated by EMS team using the website http://www.worldatlas.com/travelaids/flight_distance.htm	0.16972 kg CO_2e/passenger km (fuel combustion and radiative forcing); 0.0185 kg CO_2e/passenger km (fuel extraction, refinement and transport)	Ricardo-AEA and Carbon Smart (2015)

					travelling short haul to/from UK, average class	
Train travel	3 (category 6)	Train mileage for ex EAW staff journeys, Charge card spend on train tickets (£)	Travel management company report to facilities team; EMS analysis of charge card spend on train travel	Charge card spend converted to mileage based on cost of £0.25 per mile	0.045057 kg CO_2e/passenger km (fuel combustion); 0.00816 kg CO_2e/passenger km (fuel extraction, refinement and transport) on national rail	Ricardo-AEA and Carbon Smart (2015)
Motorcycle travel	3 (category 6)	Staff motorcycle business mileage expense claims	Fleet team extraction of fuel expense claims for motorcycle travel from the finance system	Total expense claims converted to mileage using standard HMRC mileage claim rates (pence per mile).	0.192574 kg CO_2e/mile (combustion only); 0.036902 kg CO_2e/mile (fuel extraction, refinement and transport) in an average sized motorbike	Ricardo-AEA and Carbon Smart (2015)
Unspecified business travel including bus and taxi journeys	3 (category 6)	NRW spend data against the "other domestic travel" account code	Extracted from the spend data shared by the NRW accounts team	All "other domestic travel" assumed to be road travel	0.95 kg CO_2e/ £ spent on road transport (EF UK-56 from CenSA EEIO)	DEFRA (2013)

Lessons learned, caveats and suggested future improvements:

- All spend recorded as "fleet, hire, lease and haulage" from charge card reports is assumed to be on car hire. This approach should be revisited in future to develop a methodology to more accurately capture and categorise hire car spend via charge cards.
- Hire car emissions are currently estimated using a broad-brush EF for mileage in an average sized car of unknown fuel type. In future, it may be possible to use more targeted EFs if mileage could be categorised by car and fuel type from hire car reports and if charge card spend on hire cars can be more accurately recorded. Improved recording could also be put in place to capture additional details for business travel in employee-owned cars, allowing the use of more refined EFs.
- Air and train journeys of ex-EAW staff are booked through a travel management company who report journey details back to NRW, providing reliable primary activity data for estimating emissions associated with these journeys. No central records of the journeys of other staff exist and we are reliant on spend based activity data to estimate emissions associated with these. We recommend that the organisation puts in place improved data collection procedures in future reporting years for the capture of business travel data, to improve the accuracy of emissions estimates e.g. through expanding the use of the travel management company.
- It should be noted that using two different approaches to fully account for business travel emissions in this way (primary data based and spend based) means that two different sets of EFs have been applied. The EFs applied to primary activity data (mileage) account for fuel extraction, refinement, transport and combustion while the

spend based EFs are described as “cradle to consumer” and may therefore also account for some of the operating emissions of the company providing the service. In future the organisation should look at putting in place data collection procedures to gather primary activity data on all modes of travel (i.e. including buses, taxis, ferries) to enable consistent accounting of business travel emissions.

- Most travel related account codes were excluded from the supply chain spend analysis to avoid double counting of travel emissions with primary data methods / estimates based on charge card spend by the EMS team. For example, train travel and air travel account codes were excluded from the supply chain spend analysis. Some account codes were excluded because they encompass fuel spend used by the EMS team, however, due to lack of staff resource it was not possible for the EMS team to give an accurate record of spend included and excluded from their analysis within each account code. This may mean that that non-fuel elements of some account codes such as boat hire have been omitted from our calculations. In future, further work is needed to clarify which elements of spend fall within and outside of the EMS analysis, and to improve the alignment of the primary data and spend based supply chain analyses.

4.6.7. Category 7 - Employee commuting & homeworking

4.6.7.1. Employee commuting

Emission arising from employee commuting are categorised as upstream scope 3 because they do not arise directly from the organisation but are considered a consequence of its activities. These emissions fall within category 7 of scope 3 emissions outlined in the GHG protocol and cover the transport of employees between their homes and places of work in vehicles not owned or operated by NRW (Barrow *et al*., 2013). NRW employed 1900 staff in 2015/16 in offices across Wales, many of which are fairly in rural locations, giving rise to potentially significant commute related emissions.

NRW does not currently hold information on the distance, frequency and mode by which staff travel to work. However, the Organisational Development and People Management Directorate holds home and office post codes for all staff; details of the full time equivalent working hours of each staff member; and details of staff contracted to work from home. Initially we were unable to access these data due to data protection concerns internally. After clarifying that we only needed access to postcode data with no further identifying details, we were provided with a list of home and office postcode for each staff member. No further information relating to mode of travel or frequency of travel was available therefore we had to rely on average data form the literature in our initial estimations. This meant that emissions were estimated following a hybrid of the “distance-based” and “average-data” methods outlined for employee commuting in the GHG Protocol (Barrow *et al*., 2013).

The following steps were undertaken to estimate emissions:

1. To calculate driving distances between home and office postcodes for each staff member without having to manually enter postcodes into an on-line tool such as Google maps, we temporarily copied and paste the list of home and office postcodes into Google spreadsheets and used the following formula to interface with Google maps.
   importxml("http://maps.googleapis.com/maps/api/directions/xml?origin=" & A2 & "&destination=" & B2 & "&sensor=false&alternatives=false","//leg/distance/value")/1000

2. By putting home postcodes in column A and office postcodes in column B, with each row representing one staff member, entering the above formula in column C automatically returned driving distances in km between each pair of postcodes. Dragging the formula down to cover more than around 100 rows often returned an error message (#VALUE), therefore we estimated the distances between batches of >100 pairs of home and office post codes each time. The distances were doubled to reflect a return journey each day.
3. Total commute mileage for NRW staff for the year were estimated based on the following assumptions: There were assumed to be no commute emissions for staff contracted to work from home. No data were available on the number of days spent in the office / homeworking for those not contracted to work from home. Staff with a commute of >80 miles one way were assumed to work from home with 2 office visits per month (i.e. 24 office visits a year). All staff with a commute of <80 miles were assumed to visit the office 4 days a week. These are somewhat arbitrary, although probable assumptions, and because of this our estimates should be considered a first attempt at accounting for NRW staff commute emissions. A full-time member of staff was assumed to work 222 days.
4. In the absence of any NRW data on the mode of staff travel, we adopted national average data on usual mode of travel to work for the Welsh workforce. The Labour Force Survey undertaken by the Office of National Statistics reported that the usual method of travel to work for respondents in Wales was by car for 83%, bicycle 2%, bus/coach 3%, national rail 2% and walking 8% (DFT, 2015). No mode was given for 0.8%, and no figure was given for travel by motorcycle. On the basis of external advice, we assumed that for this 0.8% the usual mode of travel was via motorcycle (an alternative approach could have been to apply a weighted EF of all other modes to the unallocated 0.8%). To apply these national statistics to the organisation, we assumed that the proportion of the NRW commute distance by each mode was equal to the proportion of respondents who usually travel to work by each mode i.e. we assumed that 83% of NRW's commute distance was done by car. (This approach therefore has the caveat that it does not account for differences in mode of travel according to commute distance).
5. For travel by car this estimated distance travelled was revised downwards to reflect car sharing on the work commute. Based on the most recent data available, car occupancy rates for commuting in Great Britain in 2012 were 1.2 occupants per journey (DFT, 2013). On this basis only 83% of car kilometres were attribute to NRW staff ((1 ÷ 1.2) x 100).
6. Once annual commute distances by mode were estimated, we applied standard industry EFs per vehicle km or passenger km travelled as appropriate to estimate total emissions by mode. We combined the combustion and well to tank EFs for each mode to provide an overall EF per km travelled (i.e. including the extraction, processing, transport and use of the fuel). For car travel we applied an EF for average sized cars with unknown fuel type; for bus/coach travel we applied an EF for an average local bus; for rail travel a national rail EF; and for the unallocated 0.8% an EF for average sized motorbikes, all from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015).

Table 4.16. Summary of employee commute emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Staff commute	3	Commute distance between home and office postcodes for all staff (km as estimated using Google maps)	Postcode pairs provided by NRW's Organisational Development and People Management Directorate	Staff with a commute of >80 miles work from home with 2 office visits per month; Staff with a commute of <80 miles visit the office 4 days a week; Full time = 222 days/year; Mode of travel based on Welsh results from the Labour Force Survey; Car occupancy rates for commuting = 1.2.	Average size car 0.22471 kg CO_2e/ vehicle km; Average local bus 0.12205 kg CO_2e/ passenger km; National rail 0.053217182 kg CO_2e/ passenger km; Average size motorbike 0.14259 kg CO_2e/ vehicle km.	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- Make clear internally that no personal identifying information is needed alongside home and office postcodes, to avoid data protection concerns.
- Use of the Google spreadsheets formula given above to estimate distances between multiple postcode pairs simultaneously returns errors when used on batches of >100 or so.
- The "getdistance" formula in Excel is an alternative option for estimate distances between multiple postcode pairs simultaneously. We were unable to get this method working, possibly because we were accessing the internet via a proxy server rather than via a direct connection as is likely to be the case in many organisations.
- The reported results will be heavily reliant upon the assumptions around number of days spent working from home for staff with commute distances under and over 80 miles. The cut off between the travel / work from home habits of staff travelling under and over 80 miles is arbitrary. Sensitivity analyses could be used to determine the impact of key assumptions on the overall result. Any future improvements in data collection and therefore calculation accuracy may significantly impact the reported results.
- Assessing the relative contribution of commute emissions to the overall scope 3 total will help to determine how much work the organisation should put into improving data collection and calculation methodologies in future. Sensitivity analyses around key assumptions will help to shape the balance between improving data collection methods and potential improvements in accuracy. A staff travel survey of distance, mode and frequency of travel is ideally needed to provide an accurate estimation of staff commute emissions. However, it may be possible to integrate questions on staff travel into existing data management systems e.g. inserting work location questions into any existing timesheets.

Additional useful resources:

- Google docs discussion forum on estimate distances between multiple postcode pairs
- Monmouthshire County Council's 2009 case study of staff travel emissions http://www.wlga.gov.uk/download.php?id=3511&l=1

- Transport statistics for Great Britain
  https://www.gov.uk/government/collections/transport-statistics-great-britain

4.6.7.2. Employee homeworking

Employee homeworking i.e. teleworking emissions are categorised as upstream scope 3 because they do not arise directly from the organisation but are considered a consequence of its activities. Reporting these emissions is an optional element of employee commute emissions reporting in category 7 of the GHG protocol (Barrow *et al*., 2013). Employee teleworking emissions are associated with additional energy use when working from home e.g. electricity and gas use. As NRW is restructured and office space is reduced it is possible that there may be an increase in staff teleworking. It was therefore felt to be important to improve our knowledge of the organisation's teleworking emissions.

As a result of the estimation of NRW employee commute emissions, we have data available on the number of staff contracted to work from home and their full time equivalent hours. The organisation does not currently centrally record the hours that other staff work from home, as this is typically agreed on a case by case basis between staff and managers. In order to estimate employee commute emissions, we made assumptions on the number of days that other staff work from home based on their commute distance to the office. Using both the available data and this same set of assumptions, we estimated the total number of days worked from home by NRW employees per year. Homeworking emissions were then estimated using a Carbon Trust EF which accounts for the average increase in electricity and heating associated with homeworking. The EF used assumes that the average employee heats just their home office for an extra four hours a day when working from home.

Table 4.17. Summary of employee homeworking emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Staff homeworking	3	Number of staff contracted to work from home and FTE hours; Estimates of days worked from home by other staff as per employee commute methodology	NRW's Organisational Development and People Management Directorate	Staff with a commute of >80 miles work from home with 2 office visits per month; Staff with a commute of <80 miles visit the office 4 days a week; Full time = 222 days/year; The average homeworker heats just their home office for an extra four hours a day	450 Kg CO_2e/homeworker/ year (if working from home 5 days a week and heating just their home office for an extra four hours a day)	Swift and Stephens (2014)

Lessons learned, caveats and suggested future improvements:

- As with staff commute emissions, estimates of our staff teleworking emissions are based on assumptions relating to the number of days working from home and should therefore be considered a first attempt at accounting for these emissions.
- The relative contribution of homeworking emissions to the overall scope 3 total will help to determine how much effort should be made to improve data collection and calculation

methods in future. Central recording of hours worked from home is ideally needed to allow accurate estimation of the organisation's teleworking.

- The Carbon Trust EF adopted for homeworking emissions assumes that an average employee heats just their home office for an extra four hours a day (Swift and Stephens, 2014). Factors such as whether the house is normally occupied during the day and whether just the office or the whole house is heated can significantly influence home energy consumption and therefore teleworking emissions. The most accurate methodology outlined for estimating teleworking emissions in the GHG protocol suggests questioning staff about home energy use as part of a survey on commuting (Barrow *et al*., 2013).
- External advice on our homeworking emissions calculations suggested that the Carbon Trust EF seems low for a central heating system. We have utilised the Carbon Trust figures in the absence of other data, however, we have been advised to verify the figure and underlying assumptions with the Carbon Trust. This should be followed up in any future work to improve the accuracy of the organisation's emissions calculation.

4.6.8. Category 8 – Upstream leased assets

As set out in Figure 4.1, leased buildings are categorised as being within the NRW organisational boundary for emissions accounting, meaning that emissions associated with their operation (i.e. from fuel and electricity use) are accounted for in scopes 1 and 2. Leased vehicles, however, are considered to be outside of the organisation's operational control and therefore outside of the organisational boundary, as explained in Section 4.1. The GHG protocol technical guidance on calculating scope 3 emissions (Barrow *et al*., 2013) states that "*emissions from leased vehicles operated by the reporting company not included in scope 1 or scope 2 are accounted for in scope 3, category 8*". Emissions associated with lease cars subsequently relinquished could make a significant contribution to the NRW emissions total in the base year. The best activity data currently available for estimating emissions associated with lease car fuel combustion is total lease car mileage. This is estimated by the fleet team by extracting all expense claims made by staff for fuel use in lease cars from the finance system. The total expense claim on lease car fuel is converted to mileage using standard mileage claim rates (pence per mile) as set out by HMRC. The organisation's total lease car mileage in the base year (1,649,345 miles) was multiplied by a standard EF per mile travelled by an average sized car of unknown fuel type from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015). As for business travel emissions, this is a combined lifecycle EF accounting for fuel combustion and upstream emissions.

Table 4.18. Summary of leased vehicle emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Lease car fuel	3	Lease car mileage	Fleet team extraction of fuel expense claims for lease cars from the finance system	Total expense claim converted to mileage using standard HMRC mileage claim rates (pence per mile).	0.299901 kg CO_2e/mile (combustion only); 0.061734 kg CO_2e/mile (fuel extraction, refinement and transport) in an average sized car of unknown fuel type	Ricardo-AEA and Carbon Smart (2015)

Lessons learned, caveats and suggested future improvements:

- Emissions are currently estimated using a broad-brush EF for mileage in an average sized car of unknown fuel type. In future it may be possible to use more targeted EFs if claims could be categorised by car and fuel type. This could be possible if some additional analysis were carried out on the finance system data to match claimants with the type of car that they have. This is, however, likely to be less of a priority in future years given the significant reduction in lease car vehicle numbers within the organisation.

4.6.9. Category 9 – Downstream transportation & distribution

Emissions arising from the transportation of products sold by the organisation (in vehicles not owned or paid for by the organisation), arising at any point between the organisation and end consumer are classed as downstream scope 3, category 9. The distinction between upstream (category 4) and downstream (category 9) transport emissions is that the upstream transport is paid for by the organisation whilst downstream transport arises after the point of sale (Barrow *et al*., 2013). Sold products arising from operations within the NRW organisational boundary are standing trees and harvested timber. Data on the volume of timber harvested in the base year and NRW's harvesting and sale model were obtained from the Wales Harvesting and Marketing team within NRW. In the base year, 55% of timber harvested on the WGWE was sold standing, with the buyer responsible for harvesting and transporting the timber. Emissions associated with transport of the harvested timber to mill are therefore downstream of the organisation. The remaining 45% of harvested timber is hauled by contractors paid for by NRW i.e. these are upstream transport emissions accounted for in category 4. The total volume of timber hauled following standing sales in the base year was multiplied by an NRW derived EF for timber haulage to mill, based on fuel only emissions per m^3 of timber hauled, as described in the forestry emissions case study in Appendix B. Emissions associated with the transport of timber from the mill to further processors, retailers and consumers were not estimated and are therefore excluded from the organisation's GHG account.

Emissions associated with customer travel to owned and operated facilities can be accounted for and reported in this category. NRW owns and manages numerous outdoor recreation sites with visitor car parks and visitor centres. In this base year it was not possible to account for these emissions. Although some activity data are available on the number of vehicles visiting some sites no further information on vehicle type or journey details were available.

Table 4.19. Summary of downstream timber transport emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Downstream transport of standing sales timber to the mill	3 (category 9)	Total volume of timber felled on the WGWE in 2015/16 (m^3 over bark standing); percentage of timber sold through standing sales (%)	NRW Wales harvesting and Marketing team end of year PR6 report	EF estimated based on fuel use in NRW forestry emissions case study (Appendix B)	10.44 kg CO_2e / m^3 obs of timber harvested	NRW forestry emissions case study (Appendix B)

Lessons learned, caveats and suggested future improvements:

- The EF used per m^3 of timber hauled was derived by NRW based on the number of full time equivalent lorries needed to haul the annual timber harvest, average timber load and average fuel use per day as indicated by timber hauliers working in the South West region of the NRW estate. By applying standard combustion EFs per litre of standard forecourt diesel from the UK Government conversion factors for Company Reporting spreadsheet (Ricardo-AEA and Carbon Smart, 2015), we estimated total haulage emissions in the South West and subsequently emissions per m^3 of timber harvested and hauled. This is therefore an NRW specific, average fuel use only emissions EF, not derived in the same way as those sourced from standard databases. The activity data and emissions data used to estimate timber haulage emissions in this category are therefore not consistent with those used to estimate upstream timber haulage emissions in category 4 (see category 4 for full explanation).

- Emissions associated with timber transport beyond the mill have been excluded from the calculation in this base year. Although this category of emissions could be added to the footprint in future years, NRW are likely to have limited, if any control or influence over it, meaning that it is unlikely to be worth investing the resources that would be needed to derive activity data for its estimation. Obtaining activity data for downstream transport beyond initial processing at the mill would be problematic given that NRW is not involved in this part of the timber supply chain.
- Visitor travel to NRW sites could be a significant source of emissions and could therefore be accounted for in future iterations of the organisation's footprint calculations. To facilitate this, primary data collection would be needed on number of visitors, mode of travel and other journey details such as whether their journey was solely to visit the NRW site or whether they were also visiting somewhere else. These data could be collected through visitor surveys at major visitor sites or a representative sample of sites to enable scale up to all NRW visitor sites. However, NRW arguably has limited influence over these emissions, particularly given that mode of travel is constrained by the rural nature of the sites. As with post-mill timber transport, it may not be worth investing the resources that would be needed to derive activity data for its estimation.

4.6.10. Category 10 - Processing of sold products

Emissions associated with the processing of intermediate products sold by the organisation (that occur after the point of sale but before end use by the consumer) are classed as downstream scope 3, category 10 emissions. As outlined in category 9 above, NRW products that require further processing before use are trees sold standing and harvested timber. Processing emissions downstream of NRW therefore include those arising from the harvest of timber sold standing, those arising from the mill and any alternative processing into final products. Sixty percent of the total stem wood cut from the estate goes to sawmills, with the main products by weight being chips for board and sawn fencing. The majority of roundwood harvested goes into the board industry.

For the 55% of timber harvested on the WGWE sold standing, the buyers' harvesting emissions are classed as processing of a sold product i.e. category 10 emissions. The total volume of timber harvested by buyers in the base year was multiplied by an NRW derived EF for harvesting, based on fuel only emissions per m^3 of timber harvested (using harvester/forwarder units; skyline units and skidder units), as described in the forestry emissions case study in Appendix B.

Due to a lack of activity and emissions data, emissions associated with mill or alternative processing into final products were not estimate for the base year, and are therefore excluded from the organisation's GHG account.

Table 4.20. Summary of downstream timber harvesting emissions calculations.

Emissions category	Scope	Activity data	Source of activity data	Conversions / Assumptions	Emission factors	Reference
Downstream harvesting of trees sold standing	3 (category 10)	Total volume of timber felled on the WGWE in 2015/16 (m^3 over bark standing); percentage of timber sold through standing sales (%)	NRW Wales harvesting and Marketing team end of year PR6 report	EF estimated based on fuel use in NRW forestry emissions case study (Appendix B)	3.48 kg CO_2e / m^3 obs of timber harvested	NRW forestry emissions case study Appendix B

Lessons learned, caveats and suggested future improvements:

- Within NRW's GHG accounting and reporting, a proportion of emissions associated with timber harvesting feature in 3 different reporting categories of the footprint, determined by where the activity falls in relation to the organisational boundary: emissions associated with the 2% of timber harvested in-house are accounted for within scope 1 fuel calculations, emissions associated with the 43% of timber harvested by contractors are accounted for in scope 3, category 1 (purchased goods and services) based on spend on forestry contractors; emissions associated with the harvest of the 55% of timber sold standing are accounted for in scope 3, category 10 based on estimated fuel use per m^3 harvested. Using three separate calculations approaches for the same source of emissions is not ideal, however this was necessary to produce estimates that fit in within each emission reporting category. Future refinement of account codes could enable forestry contractor related emissions based on spend data to be reliably replaced by the more specific case study based emissions estimates.
- Emissions associated with timber processing at the mill and other facilities have been excluded from the organisation's GHG calculation in this base year. Although this category of emissions could be added to the footprint in future years, NRW are likely to have limited, if any control or influence over it, meaning that it may not be worth investing the resources that would be needed to derive activity data for its estimation. Obtaining activity data for downstream processing would be time consuming given the range of wood product streams supplied. A high-level estimate of processing emissions could be made initially to determine the scale and significance of this category of emissions in relation to other scope 3 categories. The result would then inform a decision on putting further resources into more accurately estimating emissions from this source.

4.6.11. Category 11 – Use of sold products

Emissions associated with the use of products sold by NRW are classed as downstream scope 3, category 11. Whilst this category of emission reporting seems to be primarily aimed at products that consume energy during their use it also includes emissions arising from the fuel and feedstock products during their use phase (i.e. combustion). Combustion emissions associated with timber product that becomes fuel wood have not been accounted for in this base year. Again, it is likely that NRW has limited influence over this category of downstream emissions.

4.6.12. Category 12 – End of life treatment of sold products

Emissions associated with the disposal of products sold by NRW are classed as downstream scope 3, category 12. End-of-life emissions associated with NRW timber products have not been accounted for or reported within this category of the organisation's GHG account.

Carbon stored in wood products produced from the estate's timber is accounted for within the woodland carbon stock and sequestration modelling work carried out by Forest Research for the CPP (see section 5.2.3.1). Modelled estimates of carbon stock changes (i.e. sequestration) in harvested wood products (HWPs) take into account losses of carbon due to the decay of wood products that have reached the end of their expected lives. However, emissions associated with disposal method are not accounted for. The methodology and results are presented in the second half of this report on the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate.

4.6.13. Category 13 – Downstream leased assets

Emissions associated with the operation of assets owned by NRW but leased to other organisations are classed as scope 3, category 13 emissions providing the asset lies outside of the organisational boundary (i.e. the emissions are not accounted for in scope 1 or 2). As outlined in Section 4.1 (Setting organisational and operational boundaries), land leased to and managed by external organisations (e.g. Skomer island) is outside of NRW's organisational boundary, therefore any emissions associated with the management of this land would be reported under category 13. However, in this base year these emissions have not been accounted for, due to the difficulty of obtaining data from external organisations, and the need to focus available resources on emissions sources over which the organisation has influence.

4.6.14. Category 14 – Franchises

NRW does not operate any franchises therefore this category of emissions is not relevant to the organisation.

4.6.15. Category 15 – Investments

Emissions associated with the investments made by an organisation are classed as scope 3, category 15 emissions. This emissions category is primarily aimed at private finance and is not relevant to NRW. Amongst the optional investments that can be reported under this category are pension investments and all other type of investments, although they have not been estimated for the organisation for the base year. It is unclear whether the impact of emissions associated with grant funding provided by the organisation could be accounted for within this category. We do not currently have any activity data to allow us to estimate emissions associated with external projects funded by the organisation. However, we sought external advice on how NRW could work to influence emissions arising from grant funded activities through requirements in grant applications. Since receiving this advice, NRW's application form for grants over £25,000 has been updated to require qualitative details of project impacts on sustainability indicators including travel, use of consumables, building materials and energy.

5. Estimating carbon sequestration and stocks in habitats on the NRW estate

The GHG Protocol Corporate Standard (Ranganathan *et al*., 2004), followed by the CPP for emissions reporting, recognises the need for some organisations to account for sequestered atmospheric carbon to provide a complete and accurate picture of their GHG impacts. No set methodology is provided but applying and adapting the approach of setting organisational and operational boundaries as in emissions reporting is suggested. The standard states that sequestration estimates should be reported separately from the organisation's GHG inventory.

In order to comprehensively evaluate NRW's carbon status, alongside calculation of the organisation's GHG emissions, the CPP has produced a high-level estimate of how much carbon was sequestered in habitats and wood products from the estate in 2015/16. The balance of emissions and sequestration will indicate whether the organisation was a net emitter or net sequesterer in the base year. Existing carbon stocks were also considered to be an important element of the organisation's carbon impact, with protection of stocks paramount to avoid accelerated GHG emissions associated with the organisation's activities. We have also therefore estimated the extent of carbon currently stored in the full range of habitats on the estate.

In the absence of guidelines on accounting for corporate sequestration, we adopted and developed habitat specific calculation methodologies, where possible following the broad principles of the GHG Protocol Corporate Standard for emissions accounting. For each habitat type on the estate we set out with the aim of estimating the following:

- Total annual carbon sequestration in vegetation and soils across the habitat area in the base year 2015/16,
- Total existing carbon stocks in vegetation and soils across the habitat area in the base year 2015/16.

5.1. Setting organisational and operational boundaries

Echoing the approach adopted for GHG emissions accounting, the organisation's direct impact on carbon stocks and sequestration are estimated within an organisational boundary defined as assets and operations under NRW's operational control. This equates to carbon stocks and sequestration in the vegetation and soils of land manged day to day by NRW, whether owned or leased. Land owned by NRW but considered to be under the operational control of other organisations through lease, agreement or farm business tenancy has been excluded from the calculations e.g. Skomer Island leased long term by the Wildlife Trust South and West Wales. Some small parcels of NRW owned land managed by others were not digitised and therefore it was not possible to exclude them from the stocks and sequestration accounts at this time. Land owned and managed by NRW for conservation purposes but grazed by an external organisation or farmer were considered to be within NRW's operational control and are therefore included within the calculation boundary. There are a small number of parcels of land that NRW does not own or lease but manages in partnership with another organisation. These parcels of land are not currently digitised and the extent of NRW's involvement in each is not centrally recorded, these parcels are therefore assumed to be outside of NRW's operational control and are not included in stock and sequestration accounts. Any land leased to and managed by NRW has been included within the organisational boundary e.g. the WGWE, with no cut off in terms of lease length. As explained in Section 4.1, windfarms developed on the WGWE lie outside of NRW's operational control, therefore associated emissions have not been accounted for within the organisational boundary. The land on which these developments sit should also therefore be excluded from our carbon sequestration and stock calculations, however lack of a centralised digitised map showing these boundaries meant that it was not possible to exclude it from the stocks and sequestration accounts at this time.

The results should therefore be considered a snapshot of NRW's carbon sequestration and stocks according to the organisational boundary, with some land mapping related deviations, in 2015/16. A number of NNR leases will expire over the next 10 years, the majority of which have been continually renewed over a long period of time and are likely to be renewed going forward. However, as internal reviews of NRW's operations and assets progress, the composition and extent of the NRW owned and managed estate is likely to change. As such, updates to the CPP calculations will be needed to capture emissions and sequestration associated with future altered organisational boundaries.

The operational boundary applied in emissions accounting determines which scopes are estimated for assets and operations within the organisational boundary and which indirect emissions categories will be accounted for in scope 3 calculations. Applying this type of thinking around accounting for direct and indirect emissions to stock and sequestration calculations; indirect stocks and sequestration that could be accounted for include those associated with NRW land leased to and managed by others, and stocks in timber produced on the estate and sold to others. However, as with emissions associated with the management of NRW land under the operational control of others, sequestration and stocks in these habitats is not accounted for here. Alongside vegetation and soil carbon pools, for the woodland estate, HWPs represent a potentially significant pool. Applying organisational and operational boundaries to sequestration and stocks in HWP is problematic, because ownership of the carbon could be considered to transfer along the supply chain as timber / standing trees are sold, transported, processed and used (Ranganathan *et al*., 2004). For GHG emissions accounting purposes, the GHG protocol classes emissions associated with purchased products as upstream scope 3 and emissions associated with sold products as downstream scope 3 relative to the operational control organisational boundary. Applying a similar approach, all stocks and sequestration associated with HWP from the NRW managed woodland estate could be accounted for as a downstream benefit following sale as standing trees or timber. Our sequestration and stock estimates include all HWPs arising from the woodland estate, with all results reported together. However, HWP result could technically be considered a downstream benefit rather than one occurring within the organisational boundary.

The carbon pools and GHGs accounted for within the calculation boundary differ between habitat types based on the calculation method considered most appropriate for each based on: whether the habitat was deemed a priority for detailed assessment, the availability of management data for the habitat type across the NRW estate, current scientific understanding of the GHG emissions and removals associated with each land use type.

5.2. Calculation methods

We followed the broad steps outlined below to produce whole estate estimates:

- **Mapping the NRW owned and managed estate** to match the organisational boundary of operational control outlined in our GHG emissions inventory reporting (Section 4.1).
- **Determining the type and extent of habitat types on the estate** by overlaying the estate map with a Phase 1 survey map of habitat categories.
- **Developing and applying habitat specific calculation approaches** for each individual habitat category based on priority level, available management data and calculation guidelines, calculating the carbon stocks and sequestration of each habitat type across its extent on the NRW estate, accounting for vegetation and soil carbon pools as a minimum.

- **Summing the net sequestration and totals stocks of all habitat types** to produce a net sequestration estimate for the NRW owned and managed estate.

5.2.1. Mapping the NRW owned and managed estate

Existing digitised maps of the NRW estate were modified to create a bespoke map for the CPP matching the selected organisational boundary of land under the operational control i.e. day to day management of NRW, as set out in Section 4.1. This process involved working with our estates team and GIS mapping teams to update and verify existing maps including: updating information on land leased to and from NRW; addressing obvious anomalies such as newly acquired parcels of land not digitised and those no longer managed by NRW; removing parcels of land where NRW has rights such as access but no management role; clarifying who has operational control of parcels of land at a regional level with NRW land agents.

5.2.2. Determining the type and extent of habitat types on the estate

The extent of each habitat type on the NRW estate was defined using Phase 1 habitat classification maps held by NRW, within our organisational boundary of owned and managed land. Phase 1 survey maps were used as a basis for calculations because they were based on a consistent approach to habitat classification across habitat types and over the full extent of the estate. One disadvantage to this data set is that the surveys were carried out in the late 80s, and therefore the maps will not capture any land use changes that have occurred in the intervening period.

When developing the calculation approaches for individual habitat categories we found more detailed data sets were available for some habitats that would allow more accurate estimates of habitat sequestration and stocks to be produced. These datasets were either more recent or at a finer spatial scale than the Phase 1 data. This was the case for saltmarshes, eroded and restored deep peat and woodland habitats on the estate. These habitat extents were defined using the more detailed data sets in calculations, but both saltmarsh and deep peat areas were mapped back to the original Phase 1 categories to integrate them into whole estate calculations. This resulted in some Phase 1 habitat areas being re-categorised into different habitat categories e.g. Phase 1 grassland being re-categorised as saltmarsh or re-wetted bog based on the newer data sets. Where the newer data sets indicated that a habitat category had a smaller extent than indicated by the Phase 1 maps this meant that we were left with areas of land with no habitat categorisation, these were re-categorised as “unknown” for the purposes of producing comprehensive estimates for the whole estate.

The most significant example of this is woodland habitats. Woodland extent was defined in calculations using the forest sub-compartment database (SCDB) for the commercially managed forest, and according to the woodland categories within the National Forest Inventory for non-commercial woodland areas (outside of the SCDB but within the organisational boundary). Because of the level of spatial detail in the SCDB for individual forest blocks it was not possible to map woodland areas back to Phase 1 habitat classifications, but it was assumed that all woodland habitats defined using these more detailed data sets were classed as either woodland or scrub under Phase 1 categorisation. Using the more detailed data sets gave a figure of 108,113 ha for the extent of the woodland estate, which is 8,000 ha less than the Phase 1 extent for the same habitat type. This resulted in over 8,000 ha of land being re-categorised as “unknown” for calculation purposes. Table 5.1 details the changes made to the Phase 1 habitat categories and extents for calculation purposes. Results are reported for these re-categorised habitat extents rather than the original Phase 1 extents.

Table 5.1. Area of each habitat category on the NRW owned and managed estate according to Phase 1 habitat maps, and habitats areas used in calculations following re-categorisation with habitat specific datasets.

Habitat category	Area on the NRW estate based on Phase 1 habitat surveys (ha)	Area used in calculations (ha) (after habitat re-categorisation)
Woodland and scrub	116,276.37	108,112.85
Grassland and marsh	5,205.82	5,189.59
Heathland	4,185.59	4,185.59
Mire[α]	3,534.34	3,592.60
Other (includes unknown)*	3,071.29	11,352.71
Coastland	8,360.70	8,246.67
Tall herb and fern	1,208.13	1,208.13
Open water	436.30	429.89
Miscellaneous	422.83	420.90
Rock exposure and waste	314.81	314.81
Swamp, marginal and inundation	283.45	245.89
Total	**143,299.62**	**143,299.62**

α Mire is a Phase 1 survey habitat grouping that includes bog, fen, flush, spring and mire habitat codes.
* The area of other habitats has increased from 3,071 ha using Phase 1 maps alone to 11,353 ha when the more detailed, habitat specific datasets are integrated. This reflects the re-categorisation of over 8,000 ha of woodland and scrub habitat in Phase 1 habitat maps to “unknown”.

The use of multiple digitised land use data sets for the estate highlighted issues around boundary digitisation discrepancies e.g. the boundary of a parcel of woodland mapped in the SCDB often did not match exactly to the boundary of the same parcel on NRW land ownership. This reflects differences in digitisation techniques between digitised map layers and datasets and was problematic in producing a definitive map of the estate for the CPP. The area figures presented here are therefore the best possible estimates from a desk based study, without further work to ground truth boundaries and re-survey habitats.

In 2015/16 the NRW estate encompassed over 143,000 ha of land, including over 106,000 ha of commercial WGWE, leased and managed by NRW. The estate also encompassed over 8,000 ha of coastal habitat, 5,000 ha of grassland, 4,000 ha of heathland, 3,500 ha of mire including 1,000 ha of blanket bog.

5.2.3. Developing and applying habitat specific calculation approaches

The GHG Protocol Corporate Standard suggests adapting the IPCC guidelines for calculating national GHG inventories to estimate sequestered carbon at the organisational level. Volume 4 of the 2006 IPCC guidelines for “Agriculture, Forestry and Other Land Use” (AFOLU) (IPCC, 2006) provides guidance on estimating emissions and carbon removals in six land use categories including forests, grasslands and wetlands. Default equations are provided for the estimation of carbon stocks and changes, in each land use category over the calculation period, reflecting input data on land use and management practices. Three tiers of calculation methods are presented – with tier 1 equations being the simplest, drawing on default emissions data and coarse land use data; tier 2 applies country specific emissions data and information, whilst tier 3 involves a more tailored approach to estimation and often involves the use of detailed models. The level of certainty and accuracy in carbon stock and change estimates increase through the tiers, alongside the level of detail needed in input land management and emissions data. Separate equations are presented for stocks and changes in soil, biomass and dead organic matter carbon pools. The level of detail needed in land management and emissions input data may prevent many organisations from fully adopting IPCC equations, but the concept of matching tier to the significance of the land use category and pool was helpful to us to target resources.

We set out with the aim of producing a comprehensive estimate of existing carbon stocks and annual sequestration rates for all habitats on the estate considering the influence of key factors including previous land use, habitat management and condition, soil type. As we started to explore methodologies for each habitat type, it became apparent that our ambition would be constrained by data availability, both in terms of scientific evidence on the impact of the aforementioned factors but also in terms of our internal data availability on the past and present management of our habitats. For the majority of habitats no central, comprehensive record of current and past management exists. It was therefore necessary to prioritise habitats for which we would produce more detailed calculation estimates, based on the anticipated carbon significance of habitats in terms of contribution to the estate totals, and fall back on default values for other habitats. We prioritised: woodland habitats which are 81% of the total estate area and will therefore play a crucial role in its carbon balance; bog and fen habitats on the estate given that these habitats can represent a significant carbon store and that in poor condition they can be a significant source of emissions. We were also keen to understand how other habitats on deep peat soils contributed to the estate's carbon status. For all woodland habitats and all habitats on deep peat soils this meant contracting external organisations specialising in these areas to model stocks and sequestration using best available evidence and methodologies. We have therefore adopted a range of carbon stock and sequestration estimation methodologies as appropriate to the habitat category. These are not necessarily consistent and compatible within or across habitat categories but reflect the best data currently available for use. Estimates include stocks and sequestration in soil and vegetation pools as a minimum. For some habitats, the sequestration estimates are GHG fluxes (including CO_2, CH_4 and N_2O), for others they are based on CO_2 exchanges only.

5.2.3.1. Woodland habitats (all soils)

Given the extent of the woodland estate (both commercial and non-commercial) and the potential for significant annual sequestration in tree biomass and soils, it was felt that accurately estimating carbon stocks and sequestration in woodland habitats was crucial to provide an accurate estimate for the whole NRW estate. As such we contracted Forest Research (FR) to model carbon stocks and sequestration in both commercial and non-commercial woodlands on the estate using their well-established CARBINE carbon accounting model. This is the model used to estimate net carbon stock changes in forest trees, soils and HWPs for UK GHG inventory reporting in the land use, land use change and forestry sector. CARBINE models carbon exchanges between the atmosphere, forest ecosystem and HWP at a stand or forest level, accounting for CO_2 losses and removals only. The model combined detailed land management data provided by NRW on species, area, age-class, soil type and management regime with UK derived estimates of stand structure, growth and carbon content to estimate current and projected carbon stocks in soils, biomass, dead organic matter and HWP pools. Detailed input data for modelling the commercial estate came from the NRW forest SCDB and NRW's Forest Design Plan, with high level assumptions on production taken from NRW's Timber Marketing Plan. Input data on non-commercial woodlands was provided by NRW conservation management staff. Calculation of carbon stocks in afforested peat soils was based on the deep-peat resource on the estate as defined by the Wales unified peat map. Base year stocks represent modelled stocks as of 31st March 2015 and sequestration is the net projected change in stock based on growth and management over the year 2015-16. Soil carbon stocks were estimated to a depth of 1 meter. See Appendix C for a summary of the methodology (including diagram of the system boundary of calculations) and results, and Matthews *et al*. (2017) for the full report[11]. This can be considered a tier 3 approach to estimation of CO_2 exchanges, reflecting the best available data for UK woodlands.

CARBINE provided the CO_2 emissions / removals balance for mineral and organic soils under woodland on the estate but does not account for fluxes of CH_4 and N_2O from woodland soils. Given its extent, it was felt that the net sequestration estimates for this habitat should be a full GHG account, including soil CH_4 and N_2O fluxes. As part of the estimates of stocks and sequestration for habitats on deep peat soils (see Section 5.2.3.2 below) the Centre for Ecology and Hydrology (CEH) provided us with an EF for GHG fluxes form afforested deep-peat soils. This is from a recent review of UK relevant data aiming to update peat EFs to Tier 2 in the UK GHG inventory, and therefore represent the best data currently available. We extracted and applied the CH_4 and N_2O elements of this EF per hectare to the area of the woodland estate on deep peat soils. These estimates of the fluxes of each gas were derived in separate studies, therefore we were able to apply them separately and combine the results with the those for CO_2 exchanges from afforested organic soils estimated by CARBINE.

To calculate non-CO_2 emissions from mineral soils under woodland we sought advice from both FR and CEH on available methodologies and guidelines. In the absence of other data we defaulted to the IPCC tier 1 equations to estimate these emissions sources. The consensus of advice on CH_4 was that IPCC guidelines do not account for CH_4 emissions from aerobic soils. The IPCC wetlands supplement provides guidelines for estimating CH_4 emissions from afforested organic soils only but does not cover mineral aerobic soils. Our understanding is that mineral soils under forests may be a slight net sink of CH_4, and a recent review of published GHG flux data for British afforested mineral soils supports this (Morison *et al*., 2012). However, there are currently no IPCC guidelines on accounting for this. We have therefore assumed that there are no net CH_4 emissions from afforested mineral soils on the NRW estate. The consensus of advice on N_2O accounting was that the IPCC tier 1 guidelines are the best option for estimating these emissions given that any emissions were expected to be minimal. Chapter 4 of the 2006 IPCC Guidelines on Agriculture, Forestry and Other Land Use on forest land includes guidelines for the calculation of carbon stock changes and non-CO_2 gases from biomass burning only, stating that other non-CO_2 emissions are covered in Chapter 11 (Aalde *et al*., 2006).

[11] The full report can be accessed on the Project's webpages at https://naturalresources.wales/about-us/corporate-information/carbon-positive-project

Chapter 11 includes guidelines on calculating N_2O emissions from managed soils, with manged forest land includes in the definition of managed land (DeKlein *et al*., 2006). Calculations are based on emissions arising as a result of net nitrogen additions to soil such as application of fertiliser, manure or crop residues; or as result of the mineralisation of nitrogen in soil organic matter following drainage of organic soil or management of mineral soils. No fertiliser, organic nitrogen, dung or urine are applied to NRW managed woodlands; therefore, no ensuing emissions were calculated. There is no mention of forest residues in the section on crop residue nitrogen addition, therefore no N_2O emissions arising from mineral soils following forest residue inputs have been calculated. Losses of N_2O from soils due to mineralisation are estimated using a carbon-nitrogen ratio for soil organic matter, following any loss of soil carbon stocks resulting from land use change or land management practices. Using a tier calculation 1 approach an average annual loss of soil carbon is estimated for all land uses and management systems. On average, per hectare, afforested mineral soils on the NRW estate are a source of net carbon removals rather than losses in the base year. Therefore, N_2O emissions from afforested mineral soils due to mineralisation were estimated to be zero. Table 5.2 summaries the approach taken to estimate net sequestration and carbon stocks for woodland habitats on the estate.

Table 5.2. Summary of woodland sequestration (GHG balance) and carbon stock calculations.

NRW input data	For commercially managed woodlands: the forest SCDB recording information on individual forest stands including tree species, planting year, spacing and yield class; Forest Design Plans recording planned frequency and type of thinning and felling for stands in the SCDB; the NRW Timber Marketing Plan setting out volumes of harvested timber committed to market in future years; NRW timber use statistics from the Wales Harvesting and Marketing team. For non-commercial woodlands: information of typical tree species, ages and management provided by reserve managers.
Carbon pools accounted for	Soil, litter, trees, HWP
GHGs accounted for in net sequestration calculation	CO_2 for all pools; CH_4 and N_2O soils only
Soil carbon stock depth	1 meter
Methodology	Modelled tier 3 equivalent calculation of all woodland CO_2 exchanges and soil carbon stocks (FR CARBINE model); Area based, UK specific EF for afforested deep-peat soil N_2O and CH_4 emissions (new tier 2 EF CEH); Default IPCC tier 1 calculations for afforested mineral soil N_2O and CH_4 emissions.

5.2.3.2. Mires and all other habitats on deep peat soils

Alongside woodland habitats, it was felt that accurately estimating peatland carbon stocks and sequestration (or emissions) would be crucial to understand the estate's carbon status. This was based on the knowledge that peatlands can represent a significant carbon store and can continue to sequester over millennia, however peatland disturbance (e.g.

drainage) can turn peatlands into a significant source of GHGs. A recent project led by CEH mapped the extent and condition of Welsh peatlands, attaching the best available EFs to peatlands grouped by habitat type and condition (Evans *et al*., 2015). We contracted CEH to produce a similar condition based assessment of GHG emissions / sequestration in NRW peatland habitats, taking into account any available NRW data on peat erosion and drainage on the estate. See Appendix D for a summary of the methodology and results, and Williamson *et al*. (2016) for the full report[12].

The deep-peat resource on the estate was mapped using the Wales unified peat map (Evans *et al*., 2015). Habitats were categorised according to phase 1 data and their condition, assessed based on a digitised drainage ditch map for Wales held by CEH, NRW records of blocked ditches and areas of eroding peat. The most applicable EFs were then attached to each habitat-condition category combination, from a recent review of UK peat soil emissions data published by Artz *et al*. (2016). The applied EFs represent soil fluxes of CO_2, CH_4, N_2O and fluvial fluxes of carbon. Sequestration estimates therefore reflect the condition of the estate according to available digitised records for the NRW estate as of September 2016. This could be considered equivalent to a tier 2 IPCC approach, utilising habitat specific emissions data derived from empirical studies in the UK and reflecting habitat condition i.e. drainage.

Carbon stocks in the soils of habitats on deep peats on the NRW estate were modelled spatially by CEH as part of the same piece of work, based on a standard equation linking peat depth and slope. This equation was calibrated using data on field measurements of peat-depth held by CEH from across Wales, supplemented with all peat depth measurements held by NRW for the estate. The depth of the stock modelled therefore varies across and within habitat types based on elevation data to a maximum depth of 300 cm. Stock estimates were corrected to account for land use-change and drainage based on values from the literature. Carbon stocks in vegetation were also calculated by CEH using biomass data by habitat type from a recent Natural Environment Research Council project, as detailed and referenced in the CEH report prepared for NRW (Smart *et al*. cited in Williamson *et al*., 2016). Table 5.3 summaries the approach taken to estimating net sequestration and carbon stocks for habitats on deep peat soils on the estate.

Table 5.3. Summary of deep peat habitat sequestration (GHG balance) and carbon stock calculations.

NRW input data	Mapped ditches (open and blocked); mapped restored and bare peat; peat depth measurements
Carbon pools accounted for	Soil fluxes of GHGs, soil and biomass carbon stocks
GHGs accounted for in net sequestration calculation	CO_2, CH_4, N_2O, fluvial carbon fluxes
Soil carbon stock depth	Variable with slope, up to 3 meters
Methodology	UK specific EFs (new tier 2 EFs CEH)

[12] The full report can be accessed on the Project's webpages at https://naturalresources.wales/about-us/corporate-information/carbon-positive-project

5.2.3.3. All other habitats on non-deep peat soils

Carbon sequestration:

For habitats lacking management data and / or UK specific emissions data, IPCC tier 1 methodology was followed to estimate sequestration i.e. carbon stock change. Default IPCC tier 1 equations assume that after a change in land use, carbon stocks will reach equilibrium after 20 years i.e. there is no net sequestration (or emissions) in established habitats. For long established habitats, under consistent long-term management the assumption is that sequestration would be equal to zero. Only land in a transitional period between land use categories or having had a substantial change in management will therefore have emissions or sequestration values attached to them. i.e. robust data on land management history is needed to identify areas of land that are sequestering or emitting carbon. A large proportion of non-woodland habitats on the NRW estate were previously managed by the Countryside Council for Wales for conservation purposes and can therefore be considered to be long established and under stable management. For these habitats e.g. grasslands, it was assumed that there was no change in land use in the last 20 years and no change in management between the start and end of the base year i.e. having no net sequestration. For coastal, open water and swamp habitats we consulted relevant IPCC guidelines and wider literature to determine the most applicable estimation method for each habitat type.

Our base year calculations for non-woodland and peatland habitats do not therefore, currently take into account the impact of past positive and negative land use changes on carbon stocks e.g. conversion of agricultural land to less intensive agricultural land or even woodland (or vice versa). Any land use changes not captured in our calculations in non-woodland and peatland habitats are likely to have occurred over a very small area and have minimal impact on the estate sequestration estimates given the dominance of the woodland habitats. In future, more detailed assessments of stocks and sequestration in individual habitats on the NRW estate could be possible if data on past and present management were gathered centrally e.g. for grasslands. Table 5.4 details the approach followed to estimate sequestration in each broad habitat category, accounting for CO_2 exchanges only.

Carbon stocks:

Rather than adopting default carbon stock estimates by climatic region and habitat type from the IPCC 2006 guidelines we opted to use available Wales or UK specific data by habitat. The 2007 Countryside Survey (CS) surveyed UK natural resources including vegetation and soil properties to assess changes in the countryside since a previous survey in 1998. This included soil carbon density measurements to a depth of 15cm for 10 broad habitat categories (Emmett *et al*., 2010) surveyed. This is the most comprehensive, disaggregated, assessment of UK soil carbon density and the most consistent across habitats. Although the CS values do not reflect management, for many habitats there are Wales specific results. The CS soil carbon stock estimates have been adopted by default for all NRW habitats lacking management data (except for coastal and open water habitats which are not covered in CS soil reporting). To fill this gap for coastal and open water habitats, UK values were sought from the peer-reviewed literature (with the exception of saltmarsh for which we used a newly developed and freely available carbon stock predictor tool, see Table 5.4 for details). Carbon stocks in vegetation were estimated based on biomass data by habitat type from a recent Natural Environment Research Council project, as detailed and referenced in the CEH report prepared for NRW on peatland habitats (Smart *et al.* cited in Williamson *et al*., 2016). We were advised that these were not peat habitat specific, therefore the same values were utilised for vegetation on deep-peat and non-deep-peats soils. These values vary between 0.6 tonnes of carbon per hectare (tC/ha) of vegetation for basic flush habitats to 4.5 tC/ha for semi-improved grasslands. For comparison, Milne and Brown (1997) provided values for the carbon density of a range of British vegetation cover types including pasture, unimproved grass and heath which ranged from 1 to 2 tC/ha (excluding woodland), which are consistent in terms of magnitude with the values cited in Williamson *et al*. (2016).

Table 5.4 details the approach followed to estimate carbon stocks in each broad habitat category. Any values adopted in our calculations from published literature were from national scale datasets and may not therefore reflect emerging data from individual research studies. As improved carbon stock, emissions and sequestration data become available in future, NRW's carbon stock and sequestration calculations should be revisited and refined.

Table 5.4. Calculation methodologies for annual carbon sequestration and existing carbon stocks by habitat category.

Habitat	Annual sequestration	Carbon stocks
Grassland (mineral soils)	Based on IPCC Tier 1 methodology for grassland carbon emissions and removals (Chapter 6 of the 2006 IPCC Guidelines). Carbon pools included in IPCC estimations are: above ground and below ground biomass; dead organic matter and soils. There is currently no central comprehensive record of past and present grassland management within NRW or land use changes to/from grassland. NRW grasslands are primarily within our NNRs which have been under long term management for conservation. All NRW grasslands have therefore been categorised as "grassland remaining grassland" for the purpose of emissions / sequestration calculations. Tier 1 calculations for "grassland remaining grassland" assume that carbon stocks in grassland biomass and litter stocks are in equilibrium i.e. there is 0 net emissions or sequestration. Changes in mineral soil carbon stocks under grasslands are calculated according to changes in management regime. After a management regime change soil carbon stocks are assumed to reach equilibrium after 20 years with the change achieved linearly over the 20-year period. No changes in management regime were assumed for NRW grassland – with the majority of grassland thought to be in the nominally managed (non-degraded) category. Soil sequestration is therefore 0 tC/ha/yr based on the Tier 1 methodology. Estimates of the time to carbon equilibrium for grasslands in the wider literature vary e.g. depending on previous land use	Vegetation carbon density for all grassland habitats was based on the same biomass data used for grassland habitats on deep-peat soils (Smart *et al*. cited in Williamson *et al*., 2016). Soil carbon stock values were taken from Emmett *et al*. (2010) – the technical soils report from the 2007 CS. Wales specific values were used where available. The "acid grassland" figure was used for all categories of acid grassland; the "neutral grassland" figure for unimproved neutral grassland; and the "improved grassland" figure for improved grassland. The average of figures for improved and neutral grassland was used for semi-improved neutral grassland habitats. No values are given in Emmett *et al*. (2010) for calcareous grassland – an average of the values for improved and neutral grassland was therefore used for unimproved and semi-improved calcareous grassland habitats. Marshy grassland soil carbon stocks were based on the Great Britain value for fens, marshes and swamps. Soil carbon stock values relate to the top 15cm of the soil profile. Dead organic matter stocks were not estimated due to lack of data.

	and range from e.g. 30 to 150 years. Grasslands managed by NRW are typically managed for nature conservation because of their pre-existing habitat value and are therefore assumed to be at or approaching equilibrium.	
Heathland (mineral soils)	It is unclear where heathland falls within the IPCC guideline habitat categories. The grassland definition can include "*shrublands with high proportions of perennial woody biomass*" therefore the grassland guidelines have been followed for heath. Making the same assumptions as for grasslands, there are assumed to be zero net emissions / sequestration from NRW heathland biomass, dead organic matter and mineral soils. Evidence reviewed in the Natural England 2012 report on carbon storage by habitat also suggests there is no net sequestration in mature heathland habitats (Alonso *et al*., 2012).	For heathland vegetation, carbon density was taken from Smart *et al*. cited in Williamson *et al*. (2016). Soil carbon stocks used the figure for soil carbon density under dwarf shrub heath from Emmett *et al*. (2010). The same figure was used for all heathland habitats. Soil carbon stock values relate to the top 15cm of the soil profile. Dead organic matter stocks were not estimated due to lack of data.
Mire (mineral soils)*	For the small area of mire habitats classified as being on non-deep-peat soils (based on the Wales unified peat map) we assumed that these would be on organo-mineral soils for which the deep-peat sequestration estimates would be the most appropriate data available. I.e. the same sequestration or EFs per hectare were adopted for mires on deep peat and non-deep-peat soils, as estimated by CEH for each individual habitat category.	For consistency with the sequestration calculation approach for this habitat category we considered adopting the CEH carbon stock values, however, stock estimates were modelled spatially by CEH according to a 50-meter resolution digital elevation model. We therefore reverted to CS Great Britain average soil carbon stock estimates for bog soils and fen/marsh/swamp soils as appropriate. Soil carbon stock values relate to the top 15cm of the soil profile. Dead organic matter stocks were not estimated due to lack of data.
Coastal habitats	For coastal wetlands, the IPCC guidelines provide guidance on estimating emissions or sequestration from specific management activities such as salt production or dredging. In the absence of spatially detailed past and present management data we researched UK specific values for coastal habitats	As for sequestration, carbon stocks values per hectare for sand dunes were taken from Beaumont *et al*. (2014) by dividing their estimates of total Welsh carbon stocks in dune vegetation and soil pools by total dune area. Sand dune soil carbon stock values derived relate to the top 15cm of the soil profile.

	in the published literature, recognising that coastal habitats may take longer to reach carbon stock equilibrium than other habitats and that these are naturally more dynamic systems. We based sand dune and saltmarsh sequestration estimates on values referenced and reviewed in Beaumont *et al*. (2014), the first UK inventory of carbon stocks and sequestration in UK coastal habitats. Sand dune sequestration estimates are a UK area weighted average for dry and wet dune systems based on sequestration estimates for each habitat from Jones *et al*. (2008). This chronosequence study assessed soil development (and organic matter accumulation) in sand dune habitats over 140 years. The study suggests that an equilibrium state of no net sequestration can take up to 10,000 years to be reached. Salt marsh sequestration estimates are average UK values for “mature” marshes from Cannell *et al*. (1999), again as used in Beaumont *et al*., (2014). No useable data were found for intertidal habitats – although Alonso *et al*. (2012) identified a sequestration value of 16 g C/m^2/yr for intertidal habitats in their review of carbon storage by habitat, the original study referenced relates to a restoration project, therefore the value reflects a management change rather than being a typical value for intertidal habitats. Zero sequestration was assumed for maritime cliffs, slopes, shingle and boulders.	Soil carbon stock values in saltmarsh habitats were estimated using the saltmarsh carbon predictor tool (Skov *et al*., 2016). In response to a lack of empirical data on saltmarsh carbon stocks in the UK, the CBESS research consortium sampled Welsh and English saltmarshes to develop a method of predicting stocks for these habitats (Skov *et al*., 2016). The tool they produced can be used to predict carbon stocks in the top 10 cm of a saltmarsh soil using basic habitat data on vegetation composition and/or soil type. We downloaded their GIS map of Welsh saltmarsh carbon stocks (https://www.saltmarshapp.com/saltmarsh-tool/) and overlaid the NRW estate boundary over it, cookie cutting the saltmarsh layer to reflect the NRW owned and managed land estate boundary. For each mapped unit of saltmarsh habitat within the estate boundary we multiplied the area in hectares by the carbon stock estimate in tonnes per hectare, using the highest confidence predictor each time (i.e. where estimates of carbon stock were available based on both vegetation and soil type we used this value in preference over the predictions made using vegetation alone or soil alone (see Skov *et al*., 2016 for further explanation)). This approach means that confidence in the carbon stock prediction varies between habitat areas but that the most accurate values available are used in each case. Summing the predicted values for all habitat areas provided a total NRW saltmarsh carbon stock estimate for the base year in the top 10cm of the soil profile. Using this method, the average soil carbon density in the estate’s saltmarshes was estimated at 38.99 tC/ha (compared to 80.64 tC/ha in the top 15cm of the saltmarsh soil profile in Wales from Beaumont *et al*., 2014). Stocks in saltmarsh vegetation were estimated using the average per hectare value from Beaumont *et al*. (2014), derived by dividing their estimates

		of total carbon stocks in Welsh saltmarsh vegetation by total saltmarsh area. No literature published data were available at the UK or Wales level for intertidal carbon stock estimates. A value of zero was assumed for maritime cliff, slope, shingle and boulder habitats. Dead organic matter stocks were not estimated for any coastal habitats due to lack of data.
Other (mosaic, not accessed, unknown) (mineral soils)	Zero sequestration was assumed for these habitats, as is consistent with the assumptions made in our calculations for grasslands and heathland under long-term, stable management.	Vegetation carbon stock densities associated with blanket bog (heather dominated) were adopted by CEH for “other” habitats as part of the stock estimates for deep-peat habitats. For consistency, and recognising that vegetation carbon stocks are dwarfed by those in soils, we also adopted these values to estimate the vegetation carbon stocks in “other” habitats on mineral soils. The average soil carbon density value for all Welsh habitat types from Emmett *et al*., (2010) was adopted for all “other” habitats on mineral soils. Soil carbon stock values relate to the top 15cm of the soil profile. Dead organic matter stocks were not estimated due to lack of data. In addition to including habitats classified as “unknown” based on Phase 1 mapping in this category, 132 ha of habitat classified as saltmarsh in Phase 1 mapping were also re-classified as unknown for our calculations. This was necessary because saltmarsh maps used for soil carbon stock prediction in Skov *et al*. (2016) did not include these 132 ha, based on photography and vectorisation of saltmarsh extent completed by the Environment Agency. The same was true for just over 8000 ha of Phase 1 woodland not accounted for in the more detailed woodland data set used for modelling (as explained in Section 5.2.2).
Tall herb and fern (mineral soils)	Zero sequestration was assumed for these habitats, as is consistent with the assumptions	Vegetation carbon stock estimates associated with acid grasslands were adopted by CEH for tall herb and fern habitats as part of the stock estimates for deep-peat

	made in our calculations for grasslands and heathland under long-term, stable management.	habitats. For consistency, and recognising that vegetation carbon stocks are dwarfed by those in soils, we also adopted these values to estimate the vegetation carbon stocks in tall herb and fern habitats on mineral soils. The mean soil carbon stock value for British bracken habitats from Emmett *et al*. (2010) was adopted for bracken habitats on the estate. The same value was also adopted for other tall herb and fern habitats (ruderal and non-ruderal), with the exception of species rich ledges for which a soil carbon stock value of zero was assumed. Soil carbon stock values relate to the top 15cm of the soil profile. Dead organic matter stocks were not estimated due to lack of data.
Miscellaneous (mineral soils)	For arable land, there is currently no central comprehensive record of past and present land management within NRW or land use changes to/from this land use category. It is assumed that any arable land has been in this category long term, and that NRW (and the legacy bodies before that) would not have converted grassland or other land use types to arable. The small amount of arable land present has therefore been categorised as “cropland remaining cropland” i.e. it has not “not undergone any land use conversion for a period of at least 20 years”. Change in biomass carbon is only estimated for perennial woody crops. For annual crops no net change in biomass carbon stocks is assumed – all NRW arable land is assumed to fall within this category. Tier 1 calculations assume that deadwood carbon stocks are at equilibrium in croplands. Because management is assumed to be consistent from year to year no net soil carbon stock change is assumed for all arable land based	Vegetation carbon stock estimates associated with improved grasslands were adopted by CEH for arable habitats and amenity grasslands as part of the stock estimates for deep-peat habitats. For consistency, and recognising that vegetation carbon stocks are dwarfed by those in soils, we also adopted these values to estimate the vegetation carbon stocks in arable and amenity grassland habitats on mineral soils. The mean soil carbon density for Welsh arable and horticultural soils from Emmett *et al*. (2010) was adopted to estimate arable soil carbon stocks, and the Welsh improved grassland value for amenity grassland soil stocks. Soil carbon stock values relate to the top 15cm of the soil profile. Zero vegetation and soil carbon stocks were assumed for all other miscellaneous habitats as these are primarily buildings and tracks. Dead organic matter stocks were not estimated due to lack of data.

	on the Tier 1 calculation methodology. No net sequestration/emissions have therefore been assumed for arable land on the estate, when all carbon pools are considered. No change in management or land use was assumed for amenity grasslands in this category, resulting in an assumption of no net sequestration (as for other grassland habitats on the estate). Zero sequestration was assumed for all other miscellaneous habitats as they are primarily buildings and tracks.	
Open water	The IPCC wetland guidelines do not provide guidance on estimating emissions or removals from permanently flooded lands or from unmanaged wetlands. They do not therefore appear to be applicable to habitats classed as open water in phase 1 habitat surveys. Having explored the available published literature, carbon sequestration in sediments underlying open water habitats on the estate was not estimated due to limited available data. There are numerous studies on carbon flows through aquatic environments under different environmental conditions, and in different geographic locations in the peer-reviewed literature (e.g. Downing *et al*., 2008) but no figures were found for annual sequestration.	As with carbon sequestration, limited data on carbon stocks in open water environments were found in the published literature. Available data relate to a specific location or set of conditions, meaning that stocks in this habitat type were not estimated for the estate. For example, Kortelainen *et al*. (2004) estimated carbon stored in sediments in a study of Finnish boreal lakes (19 kg C/m^2 = 190 tC/ha) - but this may not be appropriate for the Welsh temperate (non-boreal) climate or for other types of open water habitat.
Rock exposure and waste	Zero sequestration / emissions were assumed for this category of land use, which is primarily made up of rocks, cliffs, scree etc.	Zero vegetation and soil carbon stocks were assumed for this category of land use, which is primarily made up of rocks, cliffs, scree etc.
Swamp, marginal and inundation (mineral soils)	As with IPCC guidance for other habitats, guidelines for estimating emissions or removals from inland wetlands on mineral soils are based on management or land use changes. In the absence	Vegetation carbon stock estimates associated with fen vegetation were adopted by CEH for swamp habitats as part of the stock estimates for deep-peat habitats. For consistency we also adopted these values to estimate the

	of central, comprehensive record of past management, we assumed that across the whole estate, management of this habitat type is likely to be unchanged in the long term. Leading to an assumption of no change in carbon stocks between the start and end of the base year i.e. no net sequestration.	vegetation carbon stocks in all swamp, marginal and inundation habitats on mineral soils. The mean soil carbon density for British fens, marshes and swamps from Emmett *et al*., (2010) was used to estimate stocks in this habitat category. Dead organic matter stocks were not estimated due to lack of data.

* The term mineral soils is used to cover all non-organic soils i.e. it also includes organ-mineral soils as is consistent with the IPCC reporting approach.

5.2.4. Summing the net sequestration and totals stocks of all habitat types

Having addressed habitat area discrepancies between data sets, the only outstanding issue in producing a net sequestration estimate for the NRW owned and managed estate was the duplication of afforested deep peat soil estimates between the FR and CEH work. We opted to utilise CO_2 exchange and carbon stock estimates from the FR work which were modelled spatially based on woodland characteristics and management, rather than a generic habitat EF per hectare. The CO_2 emission estimates for afforested deep peat in the CEH report (Williamson *et al*., 2016) should be considered superseded by the results in the FR report (Matthews *et al*., 2017). Because the FR CARBINE model does not currently estimate CH_4 and N_2O emissions we applied the CEH flux estimates for these gases to afforested deep-peats on the estate.

5.3. Lessons learned, caveats and suggested future improvements:

- Lack of digitised maps for some parcels of land meant that the boundary applied for sequestration (and carbon stock) accounting deviates somewhat form the organisational boundary applied in the GHG inventory. Improving digitised map records for these parcels of land would enable the organisational boundary for the GHG inventory and sequestration / stock accounts to be more closely aligned in any future net carbon status calculation.
- Estimating whole estate sequestration early in the project using average values for from the literature helped us to identify key habitats, for which we went on to work with industry experts to refine estimates.
- The availability of current and past management data for a habitat type will determine the level of detail and accuracy possible in sequestration calculations. In the absence of a centralised record of habitat management data e.g. for all NRW grassland, we defaulted to the simplest calculation method for sequestration (carbon stock change) estimates.
- There are significant sources of uncertainty underlying the NRW sequestration estimates e.g. the assumption that the majority of habitats have been under stable management for conservation purposes, with no change in land use in the last 20 years, resulting in an estimate of no net sequestration. NRW could improve the accuracy of whole estate estimates in future by centrally collating past and present habitat management data for habitats such as grasslands. However, this is unlikely to be a priority given the resources needed to collate such a database for the whole estate and the relatively small estimated contribution of these habitats to the overall stock and sequestration totals.
- Our boundaries for habitat sequestration calculations i.e. the gases and carbon pools accounted for are not consistent between habitats. We have adopted a range of methodologies as appropriate to the habitat category and data availability. Providing more detailed, accurate estimates for key habitats was prioritised over consistency of methods.
- The deep peat emissions mapping exercise carried out by CEH can be considered a high level, relatively coarse assessment of sequestration and stocks. Sources of uncertainty within the deep peat sequestration / emissions estimates, and opportunities for future improvement, are:
  - That the habitat condition categories to which sequestration / EFs were applied were broad mappable vegetation units, which do not reflect condition in the formal

monitoring sense. A ground-based assessment of peatland condition on the NRW estate would improve the accuracy of whole estate emissions estimates.

- The drainage ditch map layer used by CEH covered 70% of the deep peat area on the NRW estate meaning that the extent of near-natural fen and bog affected by drainage, and associated emissions, on the estate may be underestimated. Completing drainage ditch mapping using aerial photography for the 30% of NRW's peatland resource not mapped by Evans *et al*., (2015) would enable a more accurate re-run of the deep peat emissions mapping assessment. Comparison of mapped drains against drain alignments which have actually been blocked suggests an overall accuracy rate of c. 75% for the CEH peatland drainage map.
- Underlying assumptions on the area of peat surrounding a drain affected are subject to significant uncertainty and could be improved by further investigations and the use of site-specific estimates.
- The mapped area of restored deep peats was based on currently available NRW digitised data and is known to be an underestimate of the true extent of rewetting. A number of NRW restoration projects have not had the spatial extent of ditch blocking centrally digitised and made available to wider projects. Improved records and digitisation of restored peatlands across the estate would enable refinement of emissions estimates.

6. NRW's net carbon status results

In this section, results are presented separately for NRW's GHG inventory, carbon sequestration and carbon stocks for the base year 2015/16. These are followed by the organisation's net carbon status i.e. the balance of emissions and sequestration.

6.1. NRW's GHG emissions inventory results

NRW's total GHG emissions in the base reporting year 2015/16 were 41,304 tonnes CO_2e (tCO_2e). These include both direct GHG emissions to the atmosphere from NRW owned or controlled sources, and indirect GHG emissions to the atmosphere arising as a consequence of NRW activities. Table 6.1 presents a breakdown of NRW's GHG inventory by emissions scope, by category for scope 3 emissions, and by emissions source (refer to Section 4.2 for definitions).

Most notable within this breakdown is the relative contribution of each of the emissions scopes to the organisational total. Total scope 1 and 2 emissions were 2,997 and 1,869 tCO_2e respectively in the base calculation year, whilst scope 3 emissions were estimated to be 36,437 tCO_2e. Figure 6.1 shows the percentage contribution of emissions in each scope, and again highlights the dominance of indirect scope 3 emissions, which account for 88% of the organisation's GHG inventory.

Table 6.1. Breakdown of NRW's GHG inventory in 2015/16 by emissions scope and source.

NRW Base Year Greenhouse Gas Emissions (2015/16)	tonnes CO_2e/year
Scope 1 (direct emissions)	2,997
Natural gas heating	219
Kerosene heating	33
LPG heating	68
Biomass heating	10
Refrigerant loss from air-con & fridge units	36
Diesel and petrol use in owned cars and goods vehicles	1,808
Red diesel use in owned plant	668
Un-categorised fuel use	15
Grazing pony methane and nitrous oxide	141
Scope 2 (electricity indirect emissions)	1,869
Electricity use	1,869
Scope 3 (other indirect emissions)	36,437
Category 1 - purchased goods & services	22,667
Category 2 - capital goods	-
Category 3 - extraction, production & transportation of fuel & energy used	1,063
Category 4 - upstream transportation & distribution	1,803
Category 5 - waste generated in operations	129
Category 6 - business travel	443
Category 7 - employee commuting & homeworking	2,847
Category 8 - upstream leased assets	596
Category 9 - downstream transportation & distribution	5,167
Category 10 - processing of sold products	1,721
Category 11 - use of sold products	-
Category 12 - end of life treatment of sold products	-
Category 13 - downstream leased assets	-
Category 14 - franchises	-
Category 15 - investments	-
Total Scope 1, 2 & 3 emissions	**41,304**

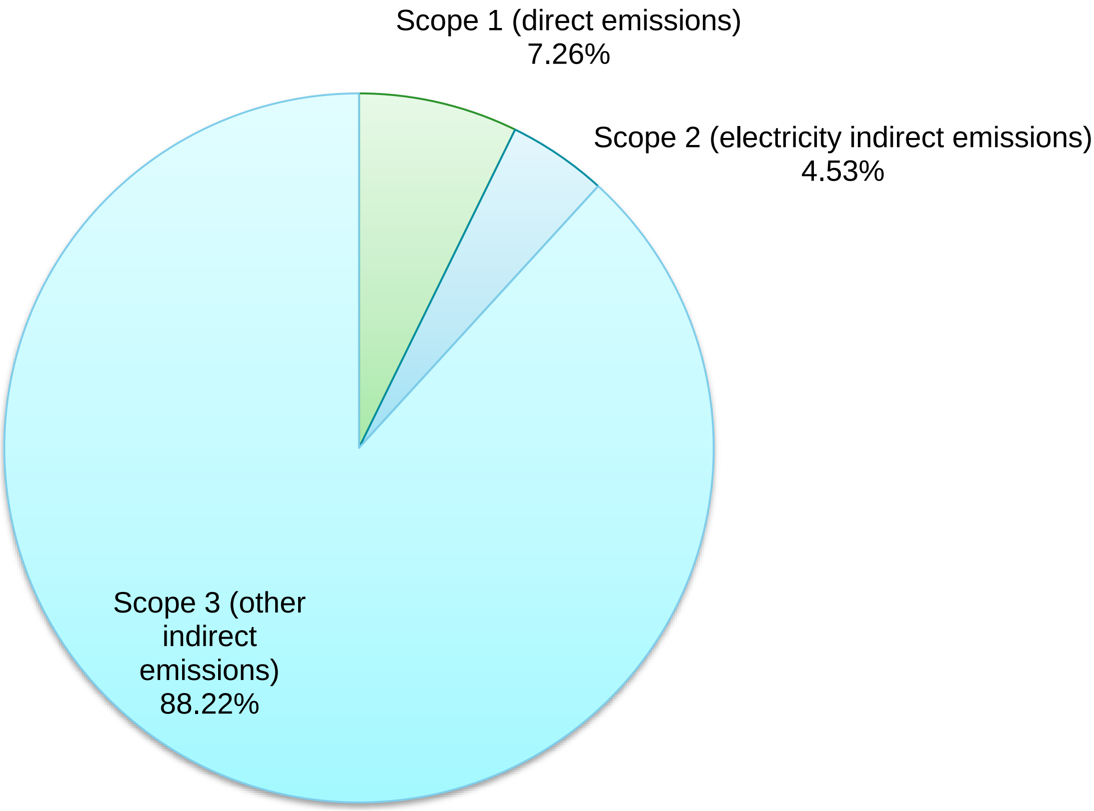

Figure 6.1. Breakdown of NRW GHG emissions by scope contribution.

The contribution of emission sources within each scope are explored in Sections 6.1.1 and 6.1.2.

6.1.1. Scope 1 and 2 emissions

NRW's total scope 1 and 2 GHG emissions were estimated to be 4,867 tCO_2e. Figure 6.2 shows the percentage contributions of emissions sources to the scopes 1 and 2 total.

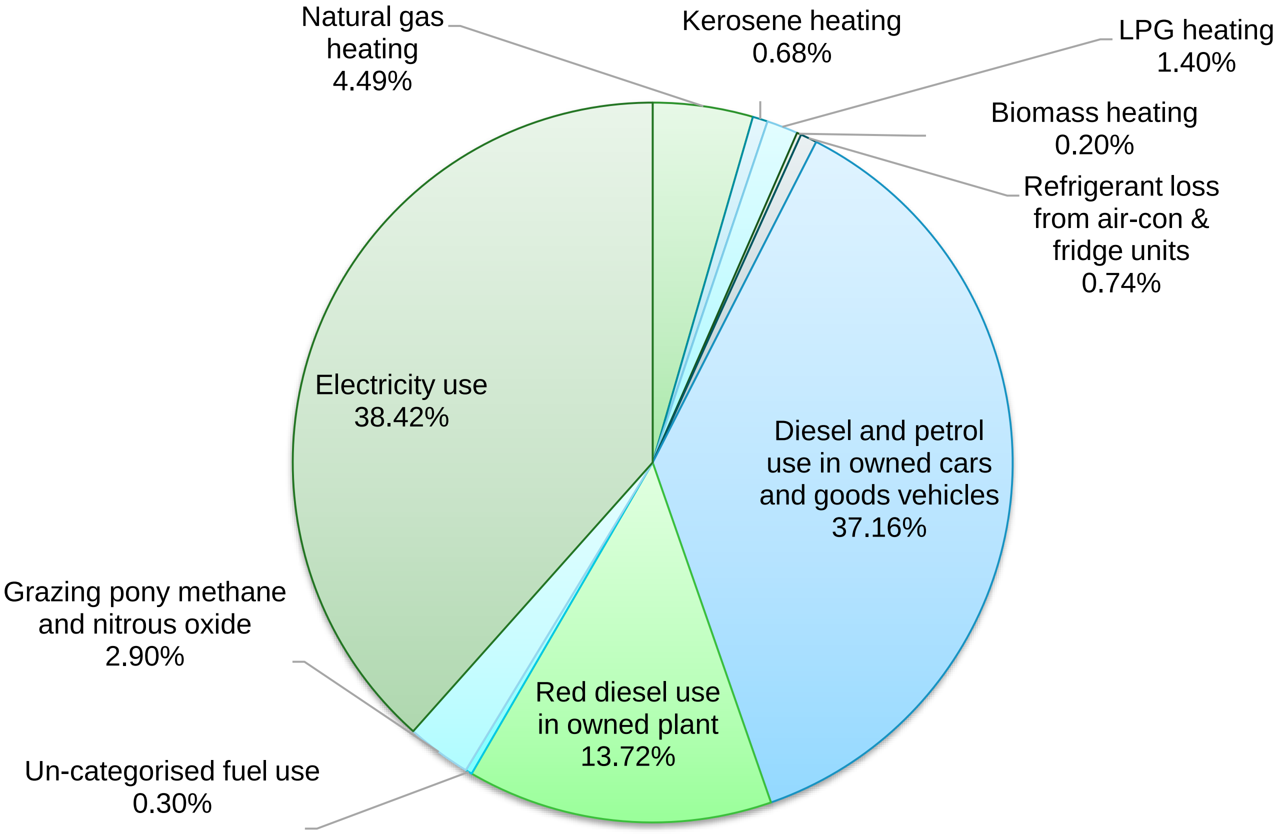

Figure 6.2. Breakdown of NRW scope 1 and 2 GHG emissions by source.

Headline results illustrated by Figure 6.2 (and Table 6.1) are that:

- Road and plant vehicle fuel use together account for the largest element of NRW's scope 1 and 2 emissions at 50.9% of the total, with 1,808 tCO_2e emitted from the combustion of fuel in NRW owned cars and good vehicles and 668 tCO_2e emitted through red diesel combustion in NRW owned plant. Of these direct vehicle fuel combustion emissions, 72.6% arise from diesel fuelled cars and good vehicles.
- Emissions arising from the generation of electricity used by NRW also make a significant contribution to the scope 1 and 2 total at 38.4% (1,869 tCO_2e). Electricity use in manned sites such as offices and depots accounts for 63% of the electricity total, and unmanned sites such as pumping stations and telemetry assets for the remaining 37%. Electricity produced through solar panels on manned sites avoided the generation of a further 38 tCO_2e (had this been generated using the grid average scope 2 EF). No equivalent figure can currently be produced for renewable electricity generated on assets.
- The combustion of heating fuels (Natural gas, kerosene LPG and biomass) emits 6.8% of the scope 1 and 2 total, with natural gas being the primary contributor (219 tCO_2e).
- NRW owned ponies are the source of 2.9% of scope 1 and 2 emissions, with 141 tCO_2e emitted as CH_4 or N_2O.
- Refrigerant losses from air conditioning and refrigeration units equate to 0.74% of total NRW scope 1 and 2 emissions.

6.1.2. Scope 3 emissions

NRW's total scope 3 GHG emissions were estimated to be 36,437 tCO_2e. Figure 6.3 shows the percentage contributions of emissions sources to the scope 3 total.

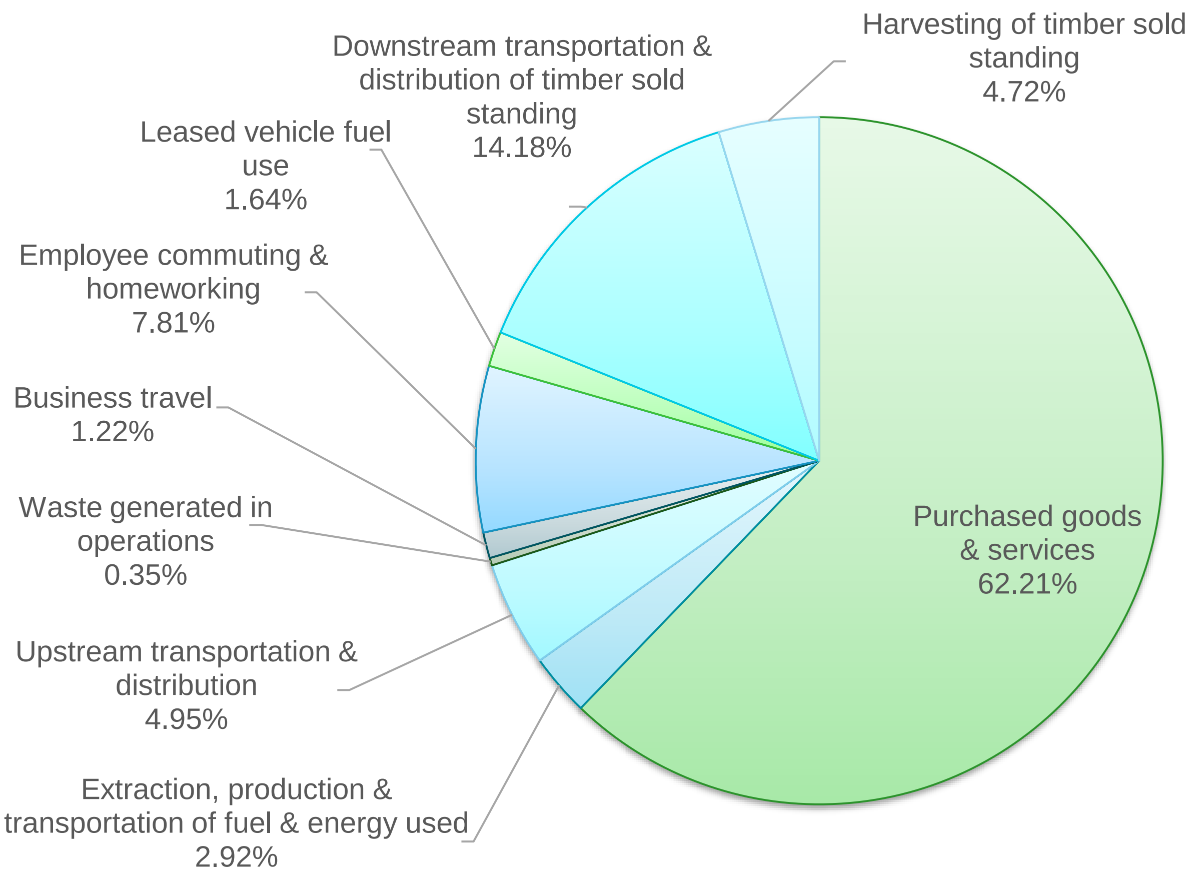

Figure 6.3. Breakdown of NRW scope 3 GHG emissions by source.

Headline results illustrated by Figure 6.3 (and Table 6.1) are that:

- Supply chain emissions associated with good and services purchased by NRW in the base year dominate the organisation's scope 3 emissions (category 1), accounting for 62.2% of the total. These are emissions arising from the extraction, production and transportation of goods and services used by NRW. Details of the primary contributors are given in Section 6.1.2.1.
- The second largest contributor to NRW's indirect scope 3 emissions is the downstream transportation to mill of timber sold standing by NRW (category 9) at 14.2% (in vehicles not owned or paid for by the organisation). These are fuel only emissions, after the point of sale by NRW, as estimated in the forestry emissions case study reported in Appendix B.
- Emissions arising from employee commuting and homeworking (category 7) account for 7.8% of the organisation's indirect scope 3 emissions. Employee commuting is responsible for the majority of these emissions (2,646 tCO_2e), with just 201 tCO_2e arising from the energy use of employees working from home.
- Emissions arising from the transport of products and from transport services (logistics) purchased by the organisation account for 5% of the overall scope 3 total (category 4).

These 1,803 tCO_2e comprise 1,699 tCO_2 from haulage (including upstream timber haulage) and 105 tCO_2e from spend on courier services.

- Emissions arising from the harvest of timber sold standing (category 10) totalled 1,721 tCO_2e in the base year i.e. 4.7% of total scope 3 indirect emission. These are fuel only emissions, after the point of sale by NRW, as estimated in the forestry emissions case study reported in Appendix B.
- Upstream emissions arising from the extraction, production and transport of fuels and electricity used by NRW (category 3) account for 2.9% of the scope 3 total.
- Fuel combustion in leased vehicles not under the operational control of NRW (category 8) contributed 596 tCO_2e, i.e. 1.6% of scope 3 emissions.
- Emissions associated with business travel in vehicles not owned, operated or leased by NRW (category 6) totalled 443 tCO_2e in the base year, i.e. 1.2% of scope 3 emissions. The breakdown of business travel emissions by mode was: 45.1% employee owned vehicles, 33.9% public transport and 21% hire cars.
- Emissions arising from the disposal and treatment of waste generated in operations under NRW's control (category 5) accounted for just 0.4% of the scope 3 total.

6.1.2.1. Emissions from purchased goods and services

Supply chain emissions associated with goods and services purchased by NRW (category 1) were estimated to be 22,667 tCO_2e in the base year. For reporting purposes, we grouped organisational spend into eight broad categories of goods and services. The percentage of the goods and services emissions total contributed by each broad category is given in Figure 6.4. The largest contributing broad procurement categories are: work carried out by contractors (35% (7,942 tCO_2e)); facilities management and ICT related (21.5% (4,883 tCO_2e)), SLAs and ROAs (13.8% (3,118 tCO_2e)). Within Figure 6.4, the largest procurement emissions category – work carried out by contractors (35%) is subdivided by contractor job type. This indicates that work on forest harvesting, engineering, flood asset delivery and forest restocking constitute the largest elements of supply chain emissions associated with work contracted out.

These areas of spend already highlighted can be considered emissions hotspots in the supply chain for further work, to improve the accuracy of emissions calculations and to focus emission reduction efforts. Table 6.2 provides a detailed breakdown of all scope 3, category 1 emissions and highlights that emissions hotpots should also be assessed at the disaggregated level – for example construction materials have greater associated emissions than many of the contractor groupings. Hotspots can also be identified at the account and product code level helping to target emissions reduction efforts to frameworks and possibly suppliers.

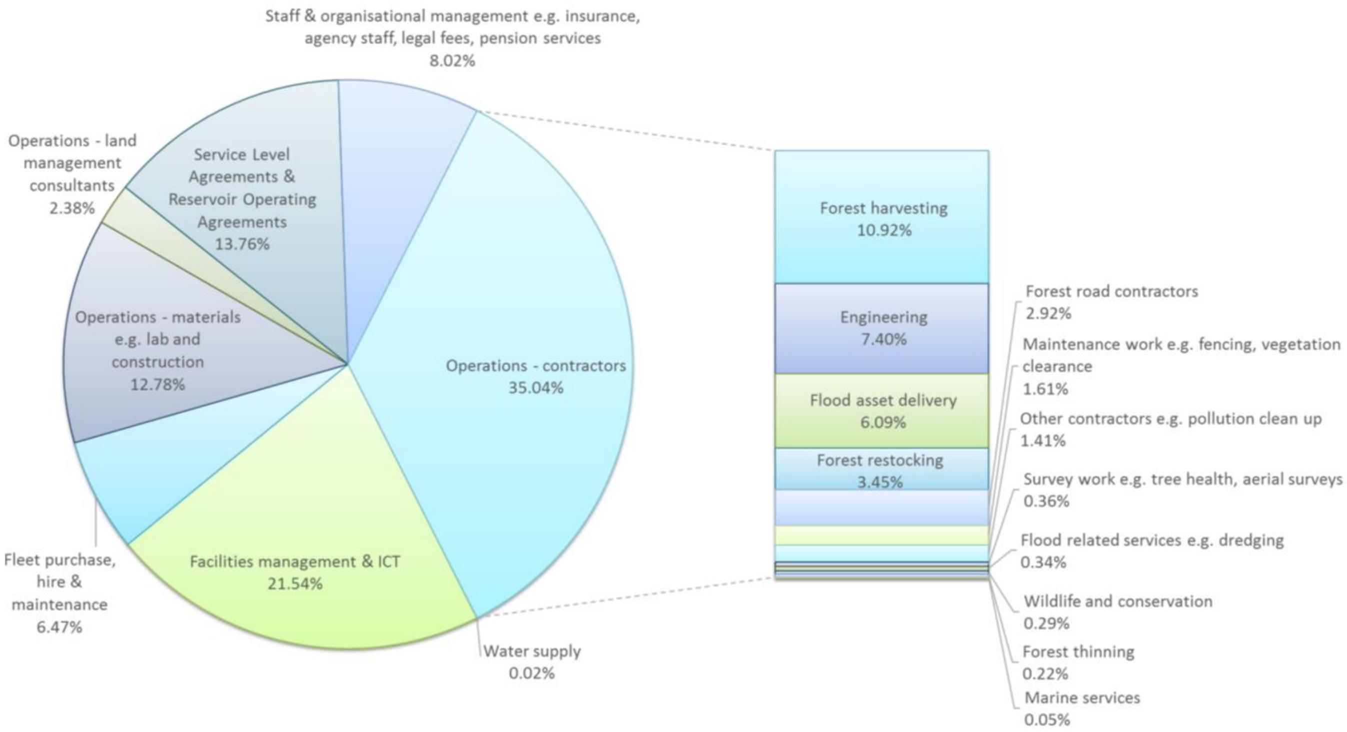

Figure 6.4. Breakdown of purchased goods and services emissions by percentage contribution, with detailed breakdown of emissions associated with work done by contractors.

Table 6.2. Detailed breakdown of emissions associated with goods and services purchased by NRW (scope 3, category 1).

Category of goods or services	Associated GHG emissions (tCO_2e)
Contractors and services	7,941.60
Contractors and services - Forest harvesting	2,474.45
Contractors and services - Engineering	1,676.25
Contractors and services - Flood asset delivery	1,379.39
Contractors and services - Forest restocking	781.43
Contractors and services - Forest road contractors	662.20
Contractors and services - Maintenance work e.g. fencing, vegetation clearance	365.65
Contractors and services - Other contractors e.g. pollution clean up	318.50
Contractors and services - Survey work e.g. tree health, aerial surveys	81.52
Contractors and services - Flood related services e.g. dredging	76.12
Contractors and services - Wildlife and conservation	65.17
Contractors and services - Forest thinning	50.63
Contractors and services - Marine services	10.30
ICT	4,042.07
ICT - Contractor and consultant services	2,365.05
ICT - Hardware, software and peripherals	1,044.58
ICT - Telecommunications	531.22
ICT - Data services and licences	101.22

Service level agreements and reservoir operating agreements	3,118.06
Materials	2,895.79
Materials - Construction	968.50
Materials - Chemicals, gases, paints & lab supplies	765.45
Materials - Livestock, fish & vegetation related	426.46
Materials - Visitor related	368.25
Materials - Equipment maintenance and components	235.75
Materials - Monitoring equipment	95.45
Materials - Promotion, exhibition materials & signage	35.92
Fleet purchase, hire and maintenance	1,466.54
Facilities management, office equipment and land agent fees	840.41
Land management and related consultants	539.31
Land management and related consultants -Surveying, design, engineering & construction	257.29
Land management and related consultants - Environmental services	154.31
Land management and related consultants - Other land management consultants	80.95
Land management and related consultants - Landscape, species and fisheries	46.76
Other consultants	450.41
Other consultants - Other e.g. engagement and accreditation	435.11
Other consultants - Economic and management consultants	14.58
Other consultants - Facilities management	0.49
Other consultants - People services e.g. health and pensions	0.24
Temp Agency staff	334.89
Accommodation, subsistence and events	301.61
Advertising, marketing and translation services	180.56
Bank, audit and legal fees	174.73
Training, conference and professional body fees	141.74
Protective and corporate clothing	94.58
Other payments including licences	47.18
Health services (eye tests, DSE etc.)	42.53
Insurance and repairs	41.13
Pension services	9.85
Water supply	4.26
Total	22,667.26

6.2. Carbon sequestration in habitats on the NRW estate

The total net quantity of carbon sequestered in habitats on the NRW estate in the base year 2015/16 was -390,924 tCO_2e. This is a GHG balance figure, where habitat emissions are subtracted from gross sequestration to give a net carbon sequestration figure for the estate. Emissions to the atmosphere are reported here as positive numbers and removals as negative.

Figure 6.5 shows the breakdown of carbon sequestration on the estate by broad habitat category. Habitat emissions (above the x axis) are subtracted from the gross sequestration (below the axis) to give the total net sequestration figure for the organisation. The estate's sequestration is dominated by removals in woodland habitats (-418,156 tCO_2e in the base year). Coastal habitats are also making a small contribution to removals on the estate (-6,661 tCO_2e). All other habitats are net emitters, apart from open water, rock exposure and waste for which no emissions or removals were assumed.

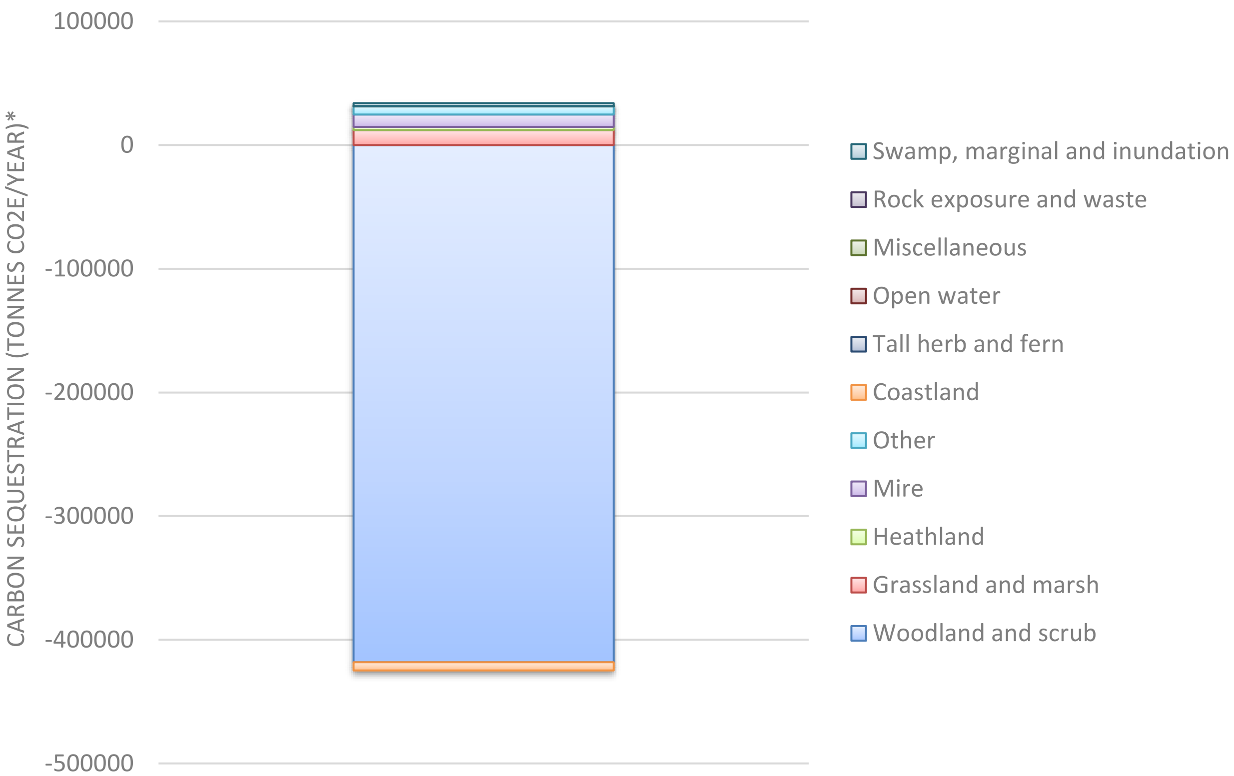

Figure 6.5. Carbon sequestration on the NRW estate by habitat type. (*Positive values indicate that the habitat type is a net source of emissions).

Grassland, marsh and mire habitats are the largest sources of emissions. Table 6.3 explains why many habitats on the estate were estimated to be net emitters. Results from the deep peat emissions mapping work carried out for the CPP by CEH indicate that while near natural blanket bog and raised bog habitats are net sequesters, current scientific evidence suggests that all other deep peat habitats are net emitters (Williamson *et al*., 2016). The majority of habitats on mineral soils were assumed to be in equilibrium with no net emissions or sequestration, therefore there were no removals to counterbalance or outweigh emissions from the areas on deep peat.

Table 6.3. Carbon sequestration i.e. GHG balance of habitats on the NRW estate by underlying soil type.

Carbon sequestration breakdown	tonnes CO_2e/year by underlying soil type		
Habitat category	**Deep peat soils**	**Mineral soils (including organo-mineral)**	**All soils total**
Woodland and scrub	-23,580	-394,576	-418,156
Grassland and marsh	12,124	0	12,124
Heathland	2,581	0	2,581
Mire[α]	9,781	203	9,984
Other	6,614	0	6,614
Coastland	0	-6,661	-6,661
Tall herb and fern	194	0	194
Open water	0	0	0
Miscellaneous	50	0	50
Rock exposure and waste	0	0	0
Swamp, marginal and inundation	2,346	0	2,346
Totals	**10,109**	**-401,034**	**-390,924**

[α] Mire is a Phase 1 survey habitat grouping that includes bog, fen, flush, spring and mire habitat codes.

Given the significant contribution of woodland removals to the estate's total net carbon sequestration, Figure 6.6 looks in more detail at the contribution of this habitat type. In the base year, clearfell conifer woodlands sequestered nearly -300,000 tCO_2e with almost equal contributions from soil, litter and HWP pools. Sequestration in the clearfell conifer tree pool was small compared to the other pools for this species-management category. Low impact sylvicultural conifer systems also made a significant net contribution to the woodland sequestration total. In the base year low impact sylvicultural broadleaf systems were a net source of emissions with emissions from litter, soil and HWP pools outweighing removals in trees. Non-commercial broadleaf woodlands were a small net source of removals.

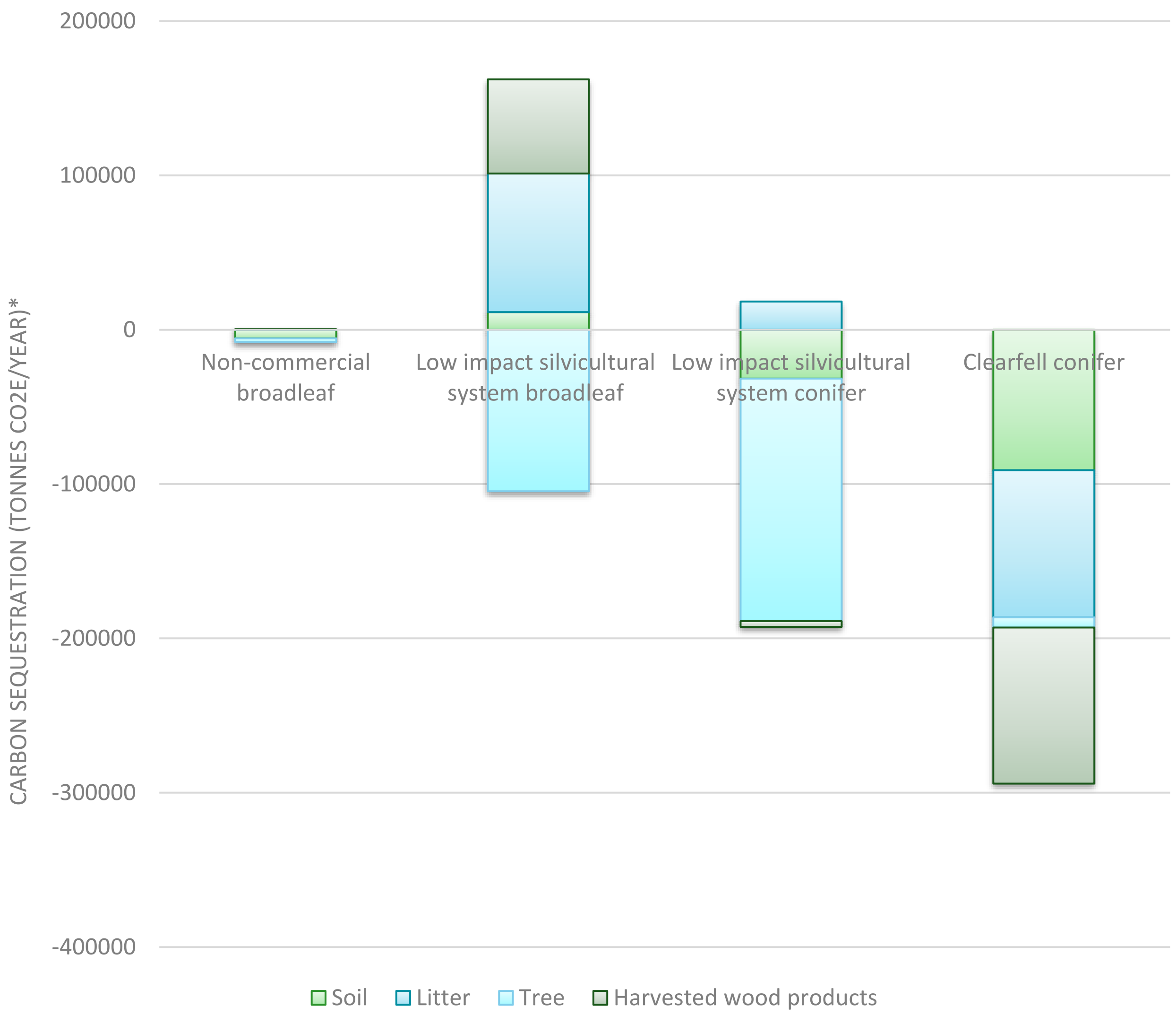

Figure 6.6. Woodland carbon sequestration by species, management type and carbon pool. (*Positive values indicate emissions, negative values indicate removals).

6.3. Carbon stocks in habitats on the NRW estate

Total carbon stocks in habitats on the NRW estate were estimated to be 32,862,217 tC in the base year 2015/16. If released these stocks would give rise to 120,494,794 tCO_2e. This is equivalent to 2,917.3 years' worth of organisational emissions at the rate of release in 2015/16 according to the estimated GHG inventory.

Figure 6.7 shows the breakdown of stocks by habitat type. Woodland and scrub habitats hold 80.9% of total stocks and mires (primarily bog and fen) a further 9.1% of the total.

Figure 6.8 gives a further breakdown of woodland stocks by carbon pool, species and management. Of the four broad management regimes represented, clearfell conifer systems hold the greatest carbon stocks and this is consistent across carbon pools. The soil pool holds the greatest carbon stock on the woodland estate, followed by trees and HWPs.

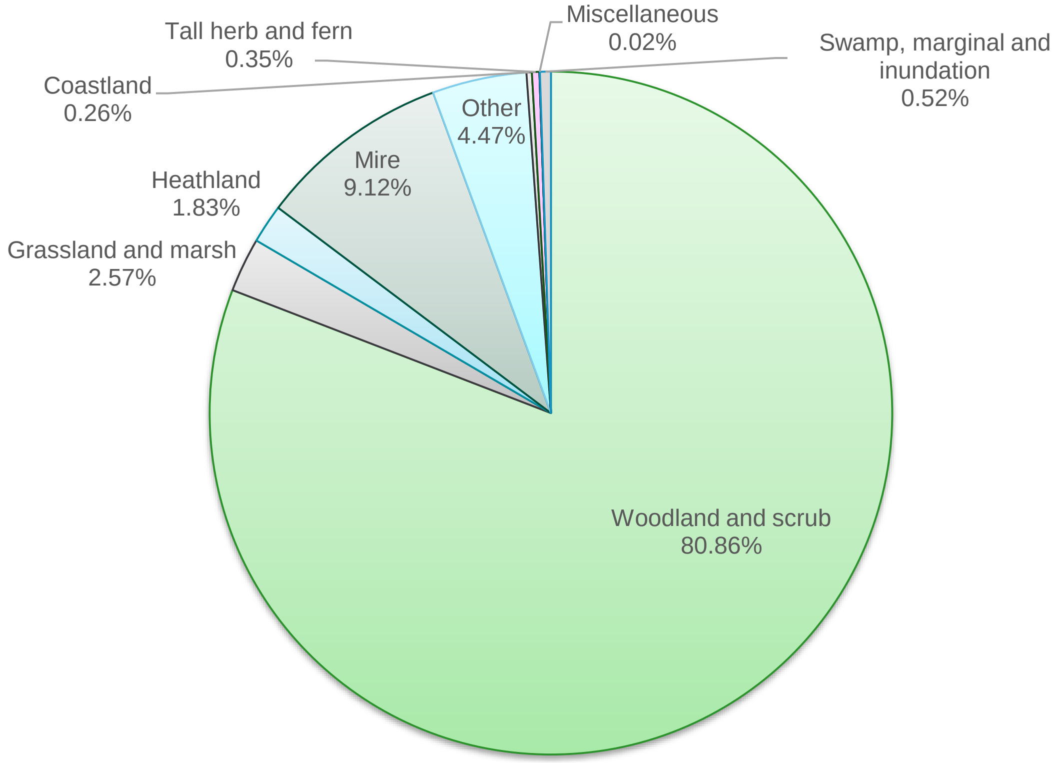

Figure 6.7. Carbon stocks in vegetation and soils on the NRW estate by habitat type.

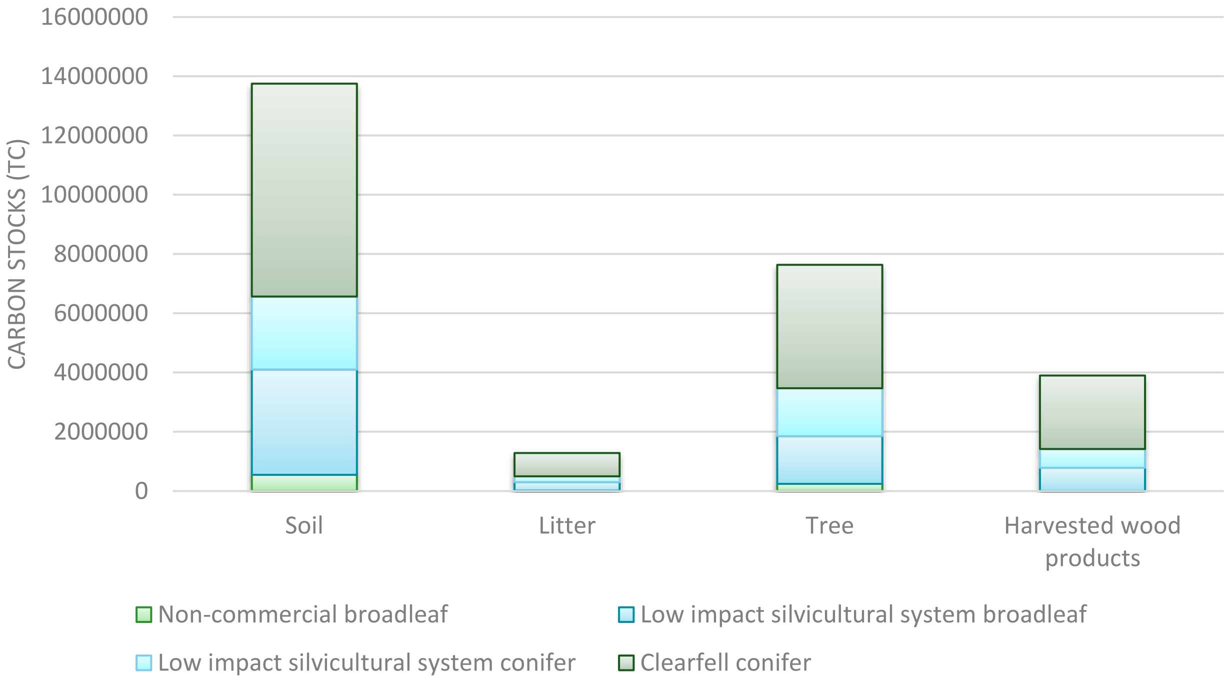

Figure 6.8. Woodland carbon stocks by carbon pool and management system.

6.4. NRW's net carbon status

In 2015/16 NRW sequestered 349,621 tCO_2e more in habitats on the estate than it emitted through its operations (see Table 6.4). The organisation could therefore be considered net carbon positive.

Table 6.4. NRW's net carbon status (all figures are rounded to the nearest whole number)

NRW's Net Carbon Status in 2015/16	tonnes CO_2e/year
Total scope 1, 2 & 3 GHG emissions	41,304
Total (net) carbon sequestration	-390,924
Net carbon status	**-349,621**

The organisation's net sequestration in the base year equated to 9.5 years' worth of emissions from its operations.

7. Discussion

This report records the approach taken, and the results attained, by the Carbon Positive Project (CPP) in calculating Natural Resources Wales' (NRW's) net carbon status and estimating the existing carbon stocks stored in habitats on the estate. It provides both: part of the evidence base needed for NRW to develop an Enabling Plan to reduce organisational emissions, enhance carbon sequestration and protect existing carbon stocks; and a reference, based in practical experience, for other organisations seeking to account for their own carbon impact.

7.1. Net carbon status

This piece of work was undertaken with the objective of developing an approach to comprehensively estimate NRW's greenhouse gas (GHG) impact, accounting for both GHG emissions from the organisation's operations and carbon sequestration in habitats on the managed estate.

In line with the suggested approach of the GHG Protocol (Ranganathan *et al*., 2004), the organisation's GHG inventory and sequestration results are presented separately. The results are also presented as a net carbon status, defined for the purpose of the CPP, as the balance between the quantity of GHGs emitted by the organisation's operations and the quantity of carbon sequestered in habitats on the NRW estate. This net carbon status approach recognises the positive contribution NRW's land management activities can make to carbon management. Although the results show that the organisation can be considered net carbon positive, sequestering 9.5 times more carbon than it emitted as GHGs through its operations, this sequestered carbon is not considered an emission offset. A carbon offset can only be provided by a new project that delivers sequestration which is additional to the baseline scenario. The organisations' net carbon positive status is not considered akin to carbon neutrality whereby emissions have been reduced or offset so that they are effectively zero.

Reducing GHG emissions from operations remains a key element of managing the organisations' carbon impact, alongside enhancing sequestration and protecting existing carbon stocks. Ultimately, this maintained focus on emissions reductions recognises that NRW can do more than rely on the role of sequestered carbon to manage its carbon impact, delivering actions to reduce emissions in an attempt to avoid the worst impacts of climate change on a global level. Other key reasons for NRW to maintain a focus on reducing GHG emissions from operations alongside managing carbon sequestration and stocks include:

- Showing leadership in managing its carbon impact, as Wales' environmental body, recognising that much of the public sector does not have landholdings to balance emissions with sequestration;
- Recognising that the rate of sequestration in NRW woodlands may decline and possibly reverse (i.e. become a source of emissions) in future as the overall age profile of the woodlands increases (Matthews *et al*., 2017);
- Recognising the scientific uncertainty inherent in sequestration estimates and potential for estimates to change as scientific understanding progresses; and
- The possibility that climate change may increase soil GHG emissions, possibly decreasing net sequestration.

7.2. GHG emissions from NRW operations

The GHG Protocol requires scope 1 and 2 emissions to be accounted for and reported as a minimum within a corporate GHG inventory, with scope 3 being an optional reporting category. To provide as complete an account of NRW's GHG emissions as possible, we included a broad range of scope 3 emissions within our inventory, focussing on those expected to make the biggest contributions, and those which the organisation can influence.

Scope 1 emissions account for 7.3% of the organisation's GHG inventory total, scope 2 emissions for 4.5% and scope 3 for 88.2%. These results confirm the importance of taking a comprehensive approach to carbon accounting and management within an organisation. A typical corporate GHG inventory based on scope 1 and 2 emissions alone would have reported a fraction of the organisation's full GHG impacts, missing the wider upstream and downstream emissions that arise as a consequence of the organisation's activities. Accounting for and reporting the organisation's scope 3 emissions provides a valuable opportunity to exert further positive influence for decarbonisation through working with our suppliers and customers.

7.2.1. Scope 1 and 2 emissions

Although scope 1 and 2 emissions represent a relatively small proportion of the organisation's overall GHG inventory total, these sources are likely to be easiest for NRW to influence and may therefore offer the most immediate opportunities for emissions mitigation. The most significant contributions to scope 1 and 2 emissions are fuel combustion in NRW owned road vehicles and plant machinery, and electricity use.

In 2015/16, the NRW vehicle fleet comprised 899 road vehicles and 204 pool vehicles. By 2016/17, the fleet had been reduced to 432 road vehicles and 193 pool vehicles following a review of the fleet and the termination of lease cars allocated to specific members of staff. Most lease vehicles have been relinquished with a small number absorbed into the pool fleet. The composition and size of the NRW fleet has altered considerably following the base year, and reported emissions are expected to be atypical, with a shift expected from scope 3 lease car emissions to scope 1 owned car emissions in future years. A further review of the remaining NRW vehicle fleet from an emissions perspective would therefore be beneficial, with the aims of better understanding the types of journeys being made, and the potential for low emission vehicles and fuels to be incorporated into the fleet to reduce scope 1 emissions. A review of this kind will provide the robust evidence base needed for the expansion of existing measures to reduce fleet emissions, such as the electric vehicles incorporated into the fleet as part of the CPP demonstration projects, and the use of biofuel in high concentrations in road vehicles at an NRW depot.

Electricity emissions are another significant component of NRW scope 1 and 2 emissions. As explained in Section 4.5, the review of electricity consumption and supply conducted for scope 2 calculations, helped to catalyse a move to 100% renewable electricity supply for all assets (including buildings, depots and operational assets, e.g. pumping stations and gauging stations). As per GHG Protocol guidelines (Sotos, 2015), providing Renewable Energy Guarantees Origin certification is supplied, this could mean that an Emission Factor (EF) of zero could be applied to all NRW electricity purchased in future scope 2 emission calculations. However, tariffs may change and this does not guarantee that the organisation will continue to purchase 100% renewable in future. Using a zero EF may also have a detrimental effect on the case for delivering mitigation measures to reduce electricity use. It must be recognised that opportunities for reducing electricity use, e.g. through behavioural change, equipment efficiencies and opportunities for generation of renewable energy on site, should still be explored as means of reducing scope 2 emissions and contributing to reducing energy demand. These avenues will also provide long term cost saving and energy security benefits, which may not be achieved by purchasing renewable energy through the national grid.

7.2.2. Scope 3 emissions

As is often the case in corporate GHG inventories (GHG Protocol, 2012a), scope 3 emissions account for the most significant element of NRW's GHG inventory at 88%. The magnitude of scope 3 emissions reflects both the comprehensive approach taken by the CPP to estimating scope 3 emissions (i.e. the more sources included in the calculation the more emissions will be recorded), and that a significant proportion of NRW work previously carried out in house is now outsourced to contractors, effectively shifting emissions from scope 1 to scope 3.

The largest contributing category to scope 3 emissions is purchased goods and services (22,667 tonnes of carbon dioxide equivalents (tCO_2e)). This result is based on the use of broad EFs (DEFRA, 2013) for groups of goods and services applied to NRW spend data, and therefore has a higher level of attached uncertainty than calculations based on primary activity data and EFs specific to the emissions source. As a result, the emissions hotspots identified through this approach may warrant further detailed work to improve the accuracy of emission calculations, e.g. contractor work and ICT services. To demonstrate the potential for further detailed work on hotspots, having identified forest harvesting, forest restocking and forest road construction activities as significant areas of contractor emissions, we conducted the forestry case study outlined in Appendix B to refine these emissions estimates.

Even without any further refinement of calculations, the magnitude of emissions associated with purchased goods and services highlights the need for NRW to influence its upstream emissions. Levers available to do this may include incorporating emissions considerations into internal procurement policy and procedures, inserting specific criteria into frameworks, and contract specifications. This mitigation activity is also a valuable contribution to stimulating a low carbon economy and working with our suppliers to build resilient supply chains for the future.

To demonstrate the potential for working within procurement to reduce emissions, having identified NRW's flood scheme construction activities as significant areas of contractor emissions, we delivered a demonstration project (NRW, 2018) to reintroduce the use of the Environment Agency's carbon planning tool 'ERIC' into NRW flood asset construction projects. This type of approach could be replicated for other types of work contracted out by NRW e.g. engineering work and forestry operations. The GHG Protocol (Bhatia *et al*., 2011) recommends working with suppliers to account for and manage supply chain emissions. Drilling down into or improving on the results of the spend based analysis for goods and services could enable the identification of frameworks, account codes, product codes and subsequently suppliers to focus engagement efforts to reduce NRW's upstream emissions.

Several other scope 3 categories are also significant emission sources for NRW relative to scope 1 and 2 totals, for example:

- category 4 emissions arising from upstream transportation and distribution (1,803 tCO_2e) are a similar size to the scope 2 total (1,869 tCO_2e),
- category 7 employee commuting and homeworking emissions (2,847 tCO_2e) are almost equal to the scope 1 total (2,997 tCO_2e),
- category 9 downstream emissions from transportation and distribution (5,167 tCO_2e) are greater than scope 1 and 2 emissions combined (4,866 tCO_2e).

Although the input data used for scope 3 emission calculations is less certain, with a greater number of assumptions necessary than for scope 1 and 2 calculations, these results highlight scope 3 areas where further work should be focussed. Further work could mean revisiting and refining calculations to improve the accuracy of hotspot estimates, or taking the decision to begin to tackle these emissions, accepting inherent uncertainty arising from input and emission data. For example, although staff commute emissions estimates are based on a number of significant assumptions, developing a sustainable travel plan to begin to tackle these and other travel emissions could be considered an important element of a comprehensive approach to organisational emissions management, irrespective of the uncertainty surrounding the estimates. Prioritising further work on scope 3 emissions will be a balance between requirements for more accurate data for some emissions categories, and the need to deliver emission reductions without further delay.

A limited number of downstream impacts have been accounted for in this GHG inventory and NRW may wish to revisit this in future to provide further insight into the organisations' wider carbon impact. Three key areas of interest are: visitor travel, provision of advice to other land managers and our provision of grant funding.

Although scope 3 emissions lie outside of the immediate control of the organisation and are therefore likely to be most challenging to influence, many of the principles outlined for reducing emissions through procurement may also be applicable for use in other scope 3 emission categories. For example, one suggested next step in the forestry emissions case study conducted (Appendix B), is to explore the potential to include conditions of sale into the contracts for standing timber sales, in an effort to reduce downstream emissions.

7.3. Net carbon sequestration in habitats on the NRW estate

Given NRW's significant role as a land owner and manager, estimating the carbon sequestered in the vegetation and soils of habitats on the NRW owned and managed estate was considered a crucial element of the organisation's overall carbon status. As part of our net carbon status methodology, we did not seek to present land-based emissions from habitats on the NRW-managed estate within our GHG inventory. Instead, we presented a 'net carbon sequestration' figure, which takes into account both emissions and sequestration in habitats on the estate.

In the absence of guidelines on accounting for corporate sequestration, we adopted and developed habitat specific calculation methodologies, where possible following the broad principles of the GHG Protocol Corporate Standard for emissions accounting. These methods are not necessarily consistent and compatible within or across habitat categories but reflect the best data currently available for use for each. Because of limitations in available land management data and scientific uncertainty surrounding the emissions associated with different habitat types under different management regimes, there are significant sources of uncertainty underlying the NRW sequestration estimates.

Accounting for land-based emissions and removals across all habitats types, the estate was found to be a net sequesterer in the base year. Woodland habitats make the most significant contribution to carbon sequestration on the NRW estate, with coastal habitats also making a small contribution to removals. All other habitats were estimated to be net emitters, apart from open water, rock exposure and waste for which no emissions or removals were assumed. The results confirm that for organisations like NRW with a land ownership and / or management remit, accounting for sequestered carbon can be a crucial element of understanding the organisation's full carbon impact.

The net carbon sequestration result for the NRW estate is dominated by the contribution from woodland habitats. Figure 6.6 illustrates the contribution of different woodland types and carbon pools to total woodland sequestration in 2015/16. These figures are taken from a study undertaken by Forest Research (FR) for the CPP to model woodland carbon sequestration and stocks over the period 2015 to 2040, which shows the changing contributions from woodland types over time. The full report (Matthews *et al*., 2017) explores possible drivers behind trends in net sequestration over the whole period, accounting for the impact of variables such as the area of young woodland and the area of conifer clearfell. A range of potential woodland management strategies for carbon management are suggested. The report also flags up a modelled decline in the rate of carbon sequestration in trees in NRW woodlands after 2030, and that net sequestration by NRW woodlands cannot be maintained indefinitely, as the proportion of older woodlands increases. Therefore, although significant, NRW cannot therefore rely on current rates of sequestration to maintain the organisation's net carbon positive status in the long term.

The majority of other habitat categories on the NRW estate were estimated to be net emitters, as a result of emissions from underlying drainage modified deep peat soils. Peat soil EFs used in calculations were from a study undertaken by the Centre for Ecology and Hydrology (CEH) for the CPP to map the emissions of deep peat habitats on the estate, taking into account drainage condition (Williamson *et al*., 2016). The EFs used in the study were the product of a recent review conducted to provide new Tier 2 EFs for peat soil in the UK GHG inventory (Artz *et al*., 2016 in Williamson *et al*., 2016). Therefore, this work is at the forefront of literature on the subject. The study conducted for the CPP by CEH suggests that all deep peat habitats other than bogs in a near natural condition are net emitters. The greatest emissions per hectare arise from drainage modified deep peats now under arable or intensive grassland. Even fen habitats in a near natural condition were estimated to be a net source of emissions due to natural methane (CH_4) emissions from these wetland ecosystems. However, as CEH completed the report for the CPP they flagged up new evidence that semi-natural fens in good condition may be sequestering overall and suggested that EFs be revisited in future.

Whole estate emissions from deep peat habitats could therefore be overestimated in this base year net carbon sequestration calculation. This may however be counteracted by the fact that only 70% of the deep peat area on the NRW estate was mapped for drainage ditches in the CEH work; meaning the extent of near-natural fen and bog affected by drainage on the estate may have been underestimated, leading to a slight underestimation of GHG emissions. As NRW habitat mapping is improved and as the evidence base on deep peat soil emissions grows, the accuracy of sequestration estimates can be improved. Scientific understanding of emissions associated with deep peat soils is continually improving and so it is recommended that estimates are revisited in future to inform effective land management for carbon benefit.

Despite some uncertainty in the magnitude of emissions in light of improving evidence, it is acknowledged that deep peat soils on the NRW-managed estate are net emitters overall due to significant emissions from those that are drainage modified. This highlights a clear steer to restore modified deep peat soils to reduce emissions. For NRW, mitigation action to restore degraded peat soils should be prioritised alongside other emissions reduction activities aimed at operational emissions, e.g. LED lighting and solar PV.

Similar to peat soils, the sequestration and emissions estimates for non-woodland habitats on mineral soils are based on significant assumptions. In the absence of detailed spatial information on past and present land management for the whole estate, we assumed that the majority of habitats have been under stable management for conservation purposes, with no change in land use in the last 20 years. This resulted in an assumption of no net sequestration in these habitats, with carbon stocks having reached a state of equilibrium. It may be possible to improve on this methodology in future using past and present land management data for habitat types e.g. all NRW grasslands. However, we consider the resources needed to collate such a data set are likely to be disproportionate to the gain in accuracy in the overall net sequestration estimate for the estate.

Despite the necessary underlying assumptions and inherent uncertainties, the net sequestration results highlight woodland and peatland management as crucial factors in the overall net carbon status of the estate. Both the CPP commissioned reports, carried out by FR and CEH, provide insights on managing for carbon benefit, forming a crucial part of the evidence base needed to enhance or maintain sequestration, and support reducing land related emissions on the NRW estate.

7.4. Carbon stocks

Although existing carbon stocks do not form part of the net carbon status calculation for NRW, they were calculated and reported concurrently to provide a full understanding of the carbon impact of the estate. As with sequestration estimates, we developed habitat specific calculation methodologies to estimate carbon stocks, differing in accuracy between habitats depending on data and resource availability.

Woodland and mire habitats combined hold 90% of existing carbon stocks on the estate. Figure 6.8 highlights that soils currently hold the largest carbon stock in woodland habitats on the estate, followed by trees. This pattern is expected to be maintained over the modelled period 2015 to 2040 based on NRW's current planned management. All woodland stocks are predicted to increase over this period. In their full report (Matthews *et al*., 2017), FR highlight a trade off in woodland carbon management strategies between managing to increase carbon stocks in woodland biomass in situ and managing to produce harvested wood products as a reservoir of sequestered carbon and means of displacing higher carbon materials (e.g. steel). FR suggest that NRW could undertake a strategic exercise to assign areas of NRW woodland to broad GHG management objectives based on whether the sites are most suited to management for carbon reserves (with or without intervention) or for timber production. Within these categorised areas, specific measures to reduce net GHG emissions or enhance stocks could then be applied, e.g. enhancing timber production through adjusting rotations or increasing the harvest of offcuts and branchwood.

The estimated magnitude of the carbon stock held in the biomass, soils and associated wood products of the NRW estate suggests that protecting stocks should be prioritised as part of the organisation's future carbon management activities. Protecting carbon stocks on the NRW-managed estate will be crucial to avoid an increase in land based GHG emissions (which would decrease NRW's net sequestration). Oxidation of existing stocks could release up to 3,000 times the organisation's base year operational emissions. The significant emissions reported from drainage modified deep peat habitats in the base year highlight the importance of preventing deterioration in these habitat types. Minimising disturbance to soils or habitats and avoiding negative land use changes to protect stocks should be aligned with current NRW management practices, given the organisation's purpose to pursue the sustainable management of natural resources.

7.5. Overall lessons learned

In addition to the category specific lessons learned in the process of estimating emissions, there were also some consistent and overarching lessons to support others looking to understand their own carbon impact:

- We relied heavily on our existing Environmental Management System (EMS) activity data to estimate most scope 1 and 2 emissions, and consequently we feel that having an existing EMS system or equivalent data collection procedure in place to collect good quality data for scope 1 and 2 calculations is crucial before considering progressing to scope 3. A staged process to estimating an organisation's GHG inventory for the first time is helpful – starting with scope 1 and 2 emissions and progressing to estimate scope 3 emissions.
- Given the magnitude of our scope 3 emissions, estimating these indirect emissions has been shown to be a crucial element of the organisation's GHG inventory and in understanding the organisations wider carbon impact. From our experience, within scope 3 emissions, producing an estimate of emissions associated with purchased goods and services is central to this.
- The significance of contractor emissions within the scope 3 element of our GHG inventory partially reflects work previously carried out in house and now outsourced to contractors, shifting emissions from scope 1 to scope 3. There is a risk that organisations not accounting for scope 3 emissions may not fully understand their carbon impact and the opportunities available to them to effect carbon emissions reductions through the work being carried out on their behalf.
- Producing accurate estimates of scope 3 emissions is likely to require significant resources. We have frequently defaulted to the least supplier specific calculation method, e.g. the spend-based method for purchased goods and services or relied on

significant assumptions in activity data. Our experience in NRW showed that having estimates of scope 3 emissions, even with the uncertainty, was crucial to steer further work on decarbonisation.

- Sequestration is a significant element of NRW's net carbon status, and other organisations with land may also benefit from estimating and reporting sequestration to understand their full carbon impact alongside operational emissions. The available guidance for estimating sequestration is limited, and, as part of delivering the CPP work, we have largely developed our own mixed methods approach to suit the organisation's needs, working with industry experts where possible to ensure our approach was robust and uses best available evidence. This report summarises our approach and experiences in developing a method for NRW, from which others can draw in understanding their own carbon impact.
- The time needed to gather organisational activity data for emissions and sequestration calculations should not be underestimated, for example, we spent many months ensuring that our electricity use estimates did not have any omissions. Where information wasn't already collected consistently or was partial for the organisation, it was challenging to source quickly and efficiently as it was often held by different individuals across the organisation.
- The calculation of an organisation's net carbon status must be built upon best available information at the time of calculation, accepting that some assumptions and uncertainties will be unavoidable when time is limited. These can be refined over time through improved data collection procedures, if the calculation is revisited. For NRW, the calculation of the organisation's net carbon status was principally to enable priorities for mitigation to be identified, therefore once an implementation plan is in place, a review of the net carbon status may only be necessary periodically to evaluate progress.
- The requirements for activity data to produce a comprehensive organisational GHG inventory are considerable, and we couldn't have developed and accessed the requisite datasets without the co-operation of colleagues from across the organisation. Keeping others informed of the aims and progress of the project was crucial to ensure their input. We delivered introductory sessions on the CPP and periodic updates open to all staff, including presentations over Skype and in person, written updates and using internal intranet pages. We also delivered tailored presentations to existing relevant internal groups and fora such as EMS regional groups and the Estate Management Forum. Having this general awareness of the project across the organisation helped when identifying and contacting individuals with access to specific data.
- Communicating with and learning from other organisations already managing their carbon impact helped to inform our approach and reduce time spent on developing methods to deliver our own GHG inventory e.g. the National Trust shared some of their travel emissions calculation work with us.
- NRW will need to consider periodically reviewing the organisation's net carbon status and carbon stock calculations to monitor decarbonisation progress. However, the calculation methods adopted for some emissions sources will not reflect the impact of any management changes if recalculated e.g. the spend based analysis method for purchased goods and services will not reflect any work done to reduce supply chain emissions because of the use of non-specific EFs for broad product and services groups. Alternative indicators may need to be developed to show progress for these emissions sources.

8. Conclusion

NRW developed the net carbon status approach to comprehensively calculate and report the organisation's carbon impact. The results highlight the organisation's most significant sources of operational emissions, in addition to its most significant land-based emissions and sequestration. The extent of the organisation's scope 3 emissions confirms the importance of tackling the organisation's upstream and downstream emissions to maximise its decarbonisation impact. The magnitude of the organisation's net sequestration and carbon stocks confirms the worth of the net carbon status approach. Measures aimed at maintaining and enhancing sequestration and protecting carbon stocks must be a priority for the organisation alongside more conventional mitigation measures to reduce GHG emissions from operations.

Although there is some uncertainty surrounding emissions and sequestration estimates for some sources and habitats (either stemming from organisational or emissions data), the results provide the evidence base needed to inform the identification, evaluation and prioritisation of mitigation options for the organisation. This report provides a complete and transparent record of our calculation approach and will serve as a basis to revisit or refine any calculations as needed in future. The level of detail provided along with lessons learned should make this a useful practical reference for other organisations accounting for their own carbon impact, extending decarbonisation benefits beyond NRW to the wider Welsh public sector.

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Appendix A

Table A.1. Account codes excluded from the spend analysis because they relate to costs other than goods and services procured by the organisation.

Account Group	Account Code	Account Description
Pay	10000	Basic Pay
Pay	10001	Overtime
Pay	10002	Other Allowances
Pay	10003	Superannuation
Pay	10004	NIC
Pay	10006	Holiday Pay Accrual Charge
Other Pay Costs	11000	Occ Sick Pay & SMP
Other Pay Costs	11001	Premature Retirement Costs
Other Pay Costs	11002	Unfunded Pension Costs
Other Pay Costs	11003	VES Costs
Other Pay Costs	11004	Other Termination Costs
Travel & Subsistence	12014	Relocation Expenses
People support costs - Office/Ops	14004	Other Staff Related Costs
Manpower Recharges	20000	Manpower Recharges - Cost
Manpower Recharges	20001	Manpower Recharges - Charged out
Manpower Recharges	20002	Manpower Recharges - Charged out (Capital)
Other Operational Costs	26000	Grants and Contributions
Other Operational Costs	26005	Collaborative Agreements
Other Operational Costs	26008	EU Grants and contributions - Capital
Other Operational Costs	26009	EU Grants and contributions - Revenue
Other Operational Costs	26010	Compensation
Other Operational Costs	26103	Sponsorship
Other Operational Costs	26104	Donations

Table A.2. Account codes excluded from the spend analysis because they relate to good and services for which more detailed emission calculation approaches were possible.

Account Group	Account Code	Account Description
Travel & Subsistence	12000	Casual Mileage
Travel & Subsistence	12001	Lease Mileage
Travel & Subsistence	12005	Train Travel
Travel & Subsistence	12006	Air Travel
Travel & Subsistence	12007	Lease Car Cost
Travel & Subsistence	12008	Personal Cont to Lease Car
Services & Fees	21003	Operational Waste
Services & Fees	21028	Operational Waste - Recycled
Services & Fees	21029	Hazardous Waste
Fleet Costs	23002	Fleet Hire / Lease
Fleet Costs	23006	Fleet Fuel & Oil & Lubricants
Facilities Costs	24017	Electricity
Facilities Costs	24021-0001	Other Building Costs - Gas Fuel
Facilities Costs	24021-0002	Other Building Costs - Gas Fuel-Meter Reading

Table A.3. Examples of how NRW product and account codes were mapped to the 75 DEFRA product group categories. This is not an exhaustive list but aims to show the range of procured goods and services and the process of mapping to the DEFRA codes.

Account code description	Product code description	Code	DEFRA product category code	Notes
Travel & Subsistence - UK accommodation		12002	UK-54 Hotels, catering, pubs etc.	
Travel & Subsistence - Other domestic travel		12009	UK-56 Road transport	Buses & Taxis included
Training - Health & safety		13000	UK-70 Education	UK-70 includes private training (National Statistics, 2003)
People support costs - Office/Ops - Protective clothing	Protective clothing & footware	14001-0002	UK-11 Wearing apparel	
	First Aid Supplies	14001-0003	UK-24 Pharmaceuticals	Assuming first aid supplies are covered by the pharmaceuticals category
People support costs - Office/Ops - Eye tests & glasses		14005	UK-71 Health & social work	
Services & Fees - Translation fees		21000	UK-68 Legal, consultancy and other business activities	Welsh translation & interpretation, UK-68 includes translation services
Services & Fees - Audit fees		21004	UK-68 Legal, consultancy and other business activities	Product code is for auditors' services
Services & Fees - DP harvesting felling contractors		21009	UK-2 Forestry	Product code is for felling, harvesting and mensuration, SIC description of UK-2 (SIC 02) includes forestry, logging & related service activities
Services & Fees - Restocking planting contractors		21013	UK-2 Forestry	SIC description of UK-2 (SIC 02) includes forestry, logging & related service activities
Services & Fees - Contractors (other)	IT Contractors	21017-0001	UK-66 Computer services	
	Framework - WEM: Asset Delivery	21017-0003	UK-50 Construction	UK-50 includes civil engineering construction and water projects construction
	Pollution clean up service	21017-0009	UK-72 Sewage and refuse services	UK-72 includes decontamination and clean up following pollution
	Scrub clearance & bush cutting	21017-0013	UK-1 Agriculture products	UK-1 includes arboriculture and tree surgery, including tree pruning and hedge trimming, replanting of large trees.
	Framework - Marine & Coastal Casework - Ornithology	21017-0037	UK-67 Research and development	UK-67 includes R&D relating to natural sciences
Services & Fees - Consultants	Accreditation Services (not training)	21018-0001	UK-68 Legal, consultancy and other business activities	UK-68 includes auditing services, business management services etc
	Environmental Consultancy	21018-0005	UK-68 Legal, consultancy and other business activities	UK-68 includes technical consultancy
	Fisheries Services & Consultancy	21018-0014	UK-3 Fish products	UK-3 includes service activities incidental to the operation of fish hatcheries and fish farms
	IT Consultants	21018-0018	UK-66 Computer services	UK-66 includes hardware & software consultancy
	Architect and Design Fees	21018-0020	UK-68 Legal, consultancy and other business activities	UK-68 includes architectural services
Services & Fees - Agents Fees / In Land Agents		21020	UK-64 Real estate activities	These are land agent fees
Services & Fees - Other bought in services	Data & Information Services	21023-0001	UK-66 Computer services	UK-66 includes data services
	BACS and Direct Debit Solution	21023-0019	UK-61 Banking and finance	

Services & Fees - Printing & design services		21027	UK-15 Printing & publishing	UK-15 includes printing and publishing of materials including brochures, leaflets, and pre-press activities such as desktop publishing & design
Services & Fees - Pension services		21030	UK-62 Insurance & pension funds	
Services & Fees - Laboratory services		21031	UK-68 Legal, consultancy and other business activities	UK-68 includes technical testing e.g. water samples
Services & Fees - Helicopter support		21037	UK-58 Air transport	This is helicopter & pilot hire. UK-58 includes non-scheduled air transport.
ICT Costs	Computer Hardware & Accessories- IT Equipment & Associated Services	22000-0002	UK-40 Office machinery and computers	UK-40 includes computer equipment and peripherals
	IT Support & Maintenance: CISCO Switches Onsite	22000-0006	UK-66 Computer services	UK-66 includes hardware consultancy, maintenance and repair
Fleet Costs - Fleet service & repairs		23001	UK-51 Motor vehicle distribution and repair, automotive fuel retail	
Fleet Costs - Fleet spares & parts		23003	UK-51 Motor vehicle distribution and repair, automotive fuel retail	
Fleet Costs - Fleet purchase	Vehicles Purchase - 4x4	23005-0003	UK-44 Motor vehicles manufacturing	
	Plant & Vehicles Livery & Racking	23005-0008	UK-44 Motor vehicles manufacturing	
Fleet Costs - Plant hire	Fixed Plant - Hire	23008-0001	UK-65 Renting of machinery	UK-65 inclues rental of machinery
	Low Loader & Lorry Hire & Sourcing of Aggregates	23008-0002	UK-56 Road transport	UK-56 includes heavy haulage
Facilities costs - Office cleaning		24000	UK-75 Other service activities	
Facilities costs - Catering Services		24001	UK-54 Hotels, catering, pubs etc.	
Facilities costs - Furniture and fittings		24002	UK-46 Furniture, other manufactured goods, recycling services	
Facilities costs - Postage & courier services		24013	UK-60 Post and telecommunications	UK-60 includes post and courier activities
Materials - Metal	Steel piles	25001-0001	UK-35 Iron and steel	
Materials - Stone	Stone & Aggregates - Primary	25002-0001	UK-7 Stone, sand and clay, other minerals	
Materials - Plants/ Shrubs/ Trees		25007	UK-1 Agriculture products	
Materials - Timber - known source		25015	UK-13 Wood and wood products	UK-13 includes lumber
Materials - Visitor centre café stock		25020	UK-8 Food and drink products	

Appendix B

Estimating emissions associated with forestry operations on the Welsh Government Woodland Estate – A case study

B.1. Background

Natural Resources Wales' (NRW's) supply chain emissions were estimated following a spend based analysis outlined in Annex E of the DEFRA Environmental Reporting Guidelines (2013). This approach enables an organisation to identify the most significant environmental impacts in their supply chain to focus efforts to reduce emissions. Analysis of NRW's upstream scope 3 emissions highlighted that a number of forestry operations feature amongst the top emissions sources. These include forest harvesting contractors and services, timber haulage, forest restocking contractors and services, forest road contractors. The above assessment involved applying the same generic forestry spend emission factor (EF) to a range of forestry operations including thinning, harvesting and restocking activities, which did not therefore provide an accurate indication of the relative emissions contribution of each activity. It was felt that a more detailed assessment of forest operations emissions was needed to provide this more accurate breakdown to enable NRW to target its efforts for reduction.

B.2. Method

To initiate work on this forestry operations emissions case study, the Carbon Positive Project (CPP) approached the organisation's Estate Management Forum, who nominated one of the organisation's five Operational Resource Managers to work with the project. An initial conversation was held to determine data availability for work done by contractors and the scope of the case study. It was felt that using data held or collated by the Operational Resource Manager for the South West (SW) region to develop activity specific EFs for NRW forestry operations was the best approach to estimating whole Welsh Government Woodland Estate (WGWE) emissions. Based on operations in the SW, the aim was to produce EFs such as litres of fuel used per m^3 of timber harvested to enable scale up to the rest of the WGWE, using readily available metrics. Figure B.1 shows the steps of the process followed to estimate emissions associated with forestry activities on the WGWE. Further detail on key steps is given in the sections that follow the figure.

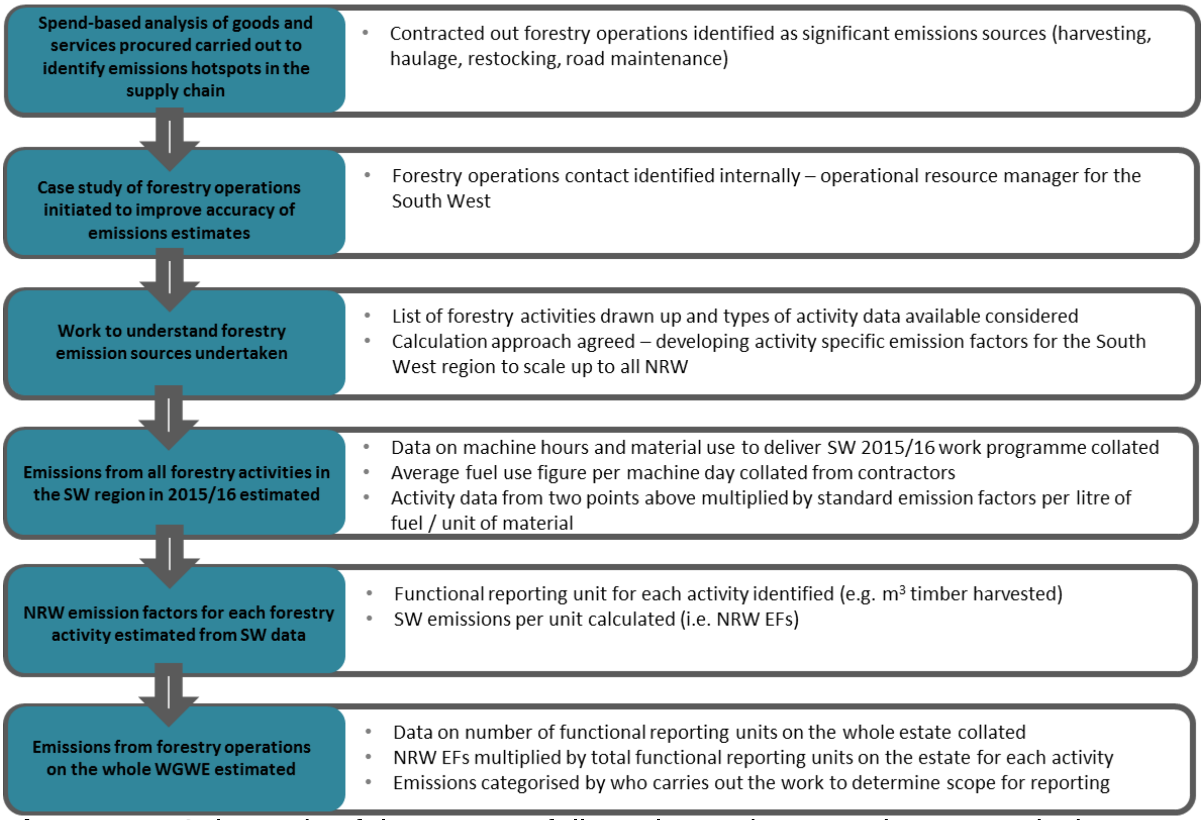

Figure B.1. Schematic of the process followed to estimate and report emissions associated with forestry activities on the WGWE.

B.2.1. Estimating emissions from all forestry activities in the SW region in 2015/16

Having decided on an overall methodology, the next step was to estimate total emissions for each activity in the SW, before dividing by a suitable unit to derive a useable EF for each forestry activity.

This involved estimating the material and machinery requirement to carry out the financial year 2015/16 work programme based on machine efficiency and capacity e.g. full time equivalent harvester / forwarder units needed to remove the full 250,000 m^3 harvested in the SW region in 2015/16; quantity of timber and wire needed to construct the 20,000 metres of fences replaced in the SW in 2015/16. Machine use was estimated on a full time equivalent basis i.e. 80% utilisation of 220 days per year. Estimates of machine use for each activity/job over the year were matched with average fuel use figures per day. All data on machine and material requirements, and average fuel use were collated by the Operational Resource Manager based on records held for the SW, interviews with NRW managers and NRW contractors, across all teams and Directorates working in the SW Region. The data used to estimate total emissions in the SW for the 2015/16 work programme for each activity are summarised in Table B.1.

Data were collated / estimated for activities undertaken on the WGWE whether carried out in house by NRW machines and operatives, by contractors on behalf of NRW, or by another party after sale of timber. It was felt that each activity/ job would have the same emissions associated with it, irrespective of who carried it out therefore only one estimation was made for each. Emissions could then be apportioned between emissions scopes for accounting purposes depending on who carried out the work. Only fuel and materials for operational activities were considered. Supporting activities such as staff or contractor travel to site and maintenance of machinery were not included in the analysis, as these activities were considered to represent a small proportion of overall WGWE emissions, and figures required were not readily available.

Emission factors for work carried out internally are therefore limited to fuel and material use scope 1 and 3 emissions. Similarly, the EFs for work carried out by contractors is limited to machine fuel use and material use for the activity. The carbon footprint boundary for this case study is therefore cradle to mill, or end producer/customer excluding the aforementioned elements.

Table B.1. Methodology for estimating emissions associated fuel and material use for South West region forestry activities in 2015/16.

Activity / job type	Activity data used*	Emission factor and reference	
Forest stewardship activities			
Fencing	Volume of timber and weight of wire used estimated based on length of fencing installed	0.2 kg CO_2e/kg CCA treated softwood timber, 3.02 kg CO_2e/kg virgin steel wire	Hammond and Jones (2011)
Tree works	Estimated full time equivalent (FTE) chainsaws operators used to carry out the SW work programme based on contractor spend / average day rate, and average fuel use per day	2.75 kg CO_2e/litre petrol (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Tractor work and recreational site grass cutting	Estimated FTE tractors and motor manual required to carry out the SW work programme and average fuel use per machine day	2.75 kg CO_2e/litre petrol, 3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Civil engineering related for conservation & recreation	Estimated FTE machines required to fulfil contracts awarded and average fuel use per machine day	3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
National services activities			
Timber harvest	Estimated FTE machines required to produce the SW timber harvest in 2015/16 including harvester/forwarder units, skyline units (skyline, ancillary forwarded, roadside processor and motor manual operations), skidder units (tractor and manual chainsaw operators) and contractor provided estimates of average fuel use per machine day	2.75 kg CO_2e/litre petrol, 3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Timber haulage	Estimated FTE lorries required to haul the SW timber harvest, based on average timber load and contractor estimates of average fuel use per day to mill or end producer/customer	3.165 kg CO_2e/litre white / standard forecourt diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Tree planting and maintenance	Estimated FTE machinery required to prepare the area planted in the SW including excavator, walking excavator, scarifier unit, and average fuel use per day for each machine	3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
	Trees	Not estimated due to lack of EF	
	Estimated tree delivery haulage based on number of journeys required to deliver all trees planted in the SW, average distance from nursery and average fuel use per mile	3.165 kg CO_2e/litre white / standard forecourt diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)

	Planting and maintenance by hand (weeding, spraying, respacing) – contractor labour only.	No fuel or materials	
	Pesticide use from Wales Silvicultural Operations chemical register of quantity and active ingredient (AI) of chemicals used; AIs proportions from material safety datasheets; energy use per kg AI by chemical from Audsley *et al*. (2009)	0.069 kg CO_2e / MJ pesticide energy	Audsley *et al*. (2009)
Forest civil engineering activities			
Forest road network maintenance	Estimated FTE machinery required to deliver the SW work programme, including graders, tractor and roller, and average fuel use per day for each machine - this is a combined figure of both NRW machinery and resource and contractor resource.	3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Provision of harvesting facilities	Estimated FTE machinery required to provide facilities for the 2015/16 harvest, and average fuel use per day for each machine	3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Quarry work – extraction and processing	Estimated FTE machines required to provide the quantity of stone quarried in 2015/16 including drilling and crushing, and average fuel use per day	3.49 kg CO_2e/litre red diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)
Quarry work - haulage	Estimated based on average load; number of journeys required to move all stone quarried; and average fuel use per day.	3.165 kg CO_2e/litre white / standard forecourt diesel (combustion and upstream emissions)	Ricardo-AEA and Carbon Smart (2015)

* All figures for FTE machinery estimates and average fuel use per day from records held for the SW, interviews with NRW managers or contractors. FTE assumes full time working for 80% utilisation over a 220 available working days.

B.2.2. Estimating emission factors for each forestry activity

Once total emissions for each activity had been estimated for the SW for the year, a suitable functional unit was selected for each activity. This functional unit is the unit against which emissions are reported e.g. per hectare or per m^3 of timber harvested and needed to be appropriate for scaling up emissions from the SW region to the whole WGWE. The functional unit therefore needed to have a strong positive relationship with the size of emissions from the activity to ensure that it would produce an accurate estimate of emissions in the other regions of the forest estate. The functional unit also needed to be a readily accessible metric, for any given annual programme, to enable simple scale up to the whole WGWE. Total emissions per activity in the SW in the base year are given in Table B.2 alongside, the selected functional unit for each and subsequent estimated EF.

Table B.2. Total emissions from SW forestry operations in 2015/16 by activity and the emission factors derived from this data set.

Activity / job category	Total SW emissions (tCO_2e/year)	Functional unit (FU) and number in SW		Emission factor (kg CO_2e/FU)
Forest stewardship activities	782.47	30,000	hectares	26.08
Tree harvesting	869.67	250,000	m^3 timber harvested	3.48
Timber haulage	2,611.13	250,000	m^3 timber harvested	10.44
Tree planting - trees	0	1,125,000	trees planted	
Tree planting - delivery	8.23	1,125,000	trees planted	0.01
Tree planting – ground prep	138.34	1,125,000	trees planted	0.12
Tree planting – planting, weeding, respacing	0	1,125,000	trees planted	
Tree planting – spraying	8.70	1,125,000	trees planted	0.01
Forest civil engineering – road maintenance	382.89	391	Kms of road	978.48
Forest civil engineering – road construction	0	0		
Forest civil engineering – harvesting facilities	553.38	250,000	m^3 timber harvested	2.21
Forest civil engineering – quarrying	41.92	25,000	tonnes quarried	1.68
Forest civil engineering – aggregate haulage	197.81	25,000	tonnes quarried	7.91
	5,709.83			

B.2.3. Estimating emissions from forestry activities for the whole WGWE

Using the estimated SW forestry activity EFs and internal data on a number of functional units, total emissions from all forestry operations on the WGWE were estimated (see Table B.3 for number of FUs for each activity on the whole WGWE). For accounting purposes it was necessary to accurately apportion emissions between NRW and others carrying out forestry activities on the estate. Depending on who completed the work the scope of the emissions would differ - following the guidelines in the WBCSD and WRI GHG Protocol (Ranganathan *et al.*, 2004) the organisation's scope 1 emissions include fuel combusted directly by the organisation. Scope 3 upstream emissions include those associated with work carried out by contractors on NRW's behalf i.e. paid for by NRW. Scope 3 upstream emissions also include extraction, processing and transport related emissions associated with the fuel combusted directly by NRW. Scope 3 downstream emissions include those associated with products sold by NRW i.e. timber sold as standing sales. For all scopes the footprint boundary remains the same – cradle to mill or end producer/customer excluding the elements mentioned previously. NRW's harvesting and sale model includes a small amount of harvesting in house (in North Wales region only) with the remainder split between contractors and standing sales. The proportion of each activity carried out in house, by contractors and by others through standing sales is given in Table B.4 for the year 2015/16. Figures were provided by forestry operations staff.

Table B.3. Number of functional units on the whole WGWE for emissions scale up of all forestry activities

Number of FUs on the WGWE	
127,637	hectares
899,534	m^3 timber harvested
4,195,500	trees planted
1,408	Kms of road maintained
0	Kms of road constructed
138,000	tonnes aggregate quarried
40,000	tonnes aggregate purchased*

* Data on aggregate purchased for road maintenance were only available at the whole WGWE estate level and this activity has therefore been added to the list at this stage.

Table B.4. Percentage of work programme undertaken in-house, by contractors and through standing sales for the range of forest activities undertaken on the WGWE.

Activity / job category	In-house	Contractor	Standing sales
Forest stewardship activities	0	100	n/a
Tree harvesting*	2	43	55
Timber haulage*	0	45	55
Tree planting - trees	0	100	n/a
Tree planting - delivery	0	100	n/a
Tree planting – ground prep	44.17	55.83	n/a
Tree planting – planting, weeding, respacing	0	100	n/a
Tree planting – spraying$^{\alpha}$	0	100	n/a
Forest civil engineering – road maintenance graders$^{\beta}$	100	0	n/a
Forest civil engineering – road maintenance tractors and rollers	0	100	n/a
Forest civil engineering – road construction	0	100	n/a
Forest civil engineering – harvesting facilities	0	100	n/a
Forest civil engineering – quarrying	0	100	n/a
Forest civil engineering – aggregate haulage	0	100	n/a

* The split of harvesting and haulage is likely to change as NRW moves away from a direct production programme of roadside sales towards a standing sales dominated model. These figures are 2015/16 specific.

$^{\alpha}$ All chemicals are purchased by NRW but applied by contractors.

$^{\beta}$ NRW currently has 4 in-house graders this is likely to change as NRW moves away from ownership of plant towards a model of contracting out works. These figures are 2015/16 specific.

B.3. Results and interpretation

By applying these proportions to the number of functional units for each activity on the estate it was possible to estimate whole estate emissions by scope. Table B.5 breaks down the emissions estimate for all forestry operations on the WGWE by scope (and emissions source). Figure B.2 provides an overview of all emissions by broad activity type.

Table B.5. Greenhouse gas emissions from WGWE forestry operations by scope and source for each activity. All figures have been independently rounded to the nearest whole number.

Activity / job category	WGWE forestry operation emissions (tCO_2e/year)			
	Scope 1	Scope 3 (NRW fuel)	Scope 3 (upstream contractors)	Scope 3 (downstream standing sales)
Forest stewardship activities			3,329	
Tree harvesting	52	10	1,346	1,721
Timber haulage			4,228	5,167
Tree planting - trees			0	
Tree planting - delivery			31	
Tree planting – ground prep	190	38	288	
Tree planting – planting, weeding, respacing			0	
Tree planting – spraying*		32		
Forest civil engineering – road maintenance graders	921	185		
Forest civil engineering – road maintenance tractors and rollers			272	
Forest civil engineering – road construction			0	
Forest civil engineering – harvesting facilities			1,991	
Forest civil engineering – quarrying			231	
Forest civil engineering – aggregate haulage			1,092	
Forest civil engineering – aggregate purchase		440		
Scope totals	1,163	706	12,807	6,888
WGWE grand total	**21,565**			

*All chemicals are purchased by NRW and applied manually by contractors. The only emissions accounted for are therefore from the manufacture and transport of the chemicals.

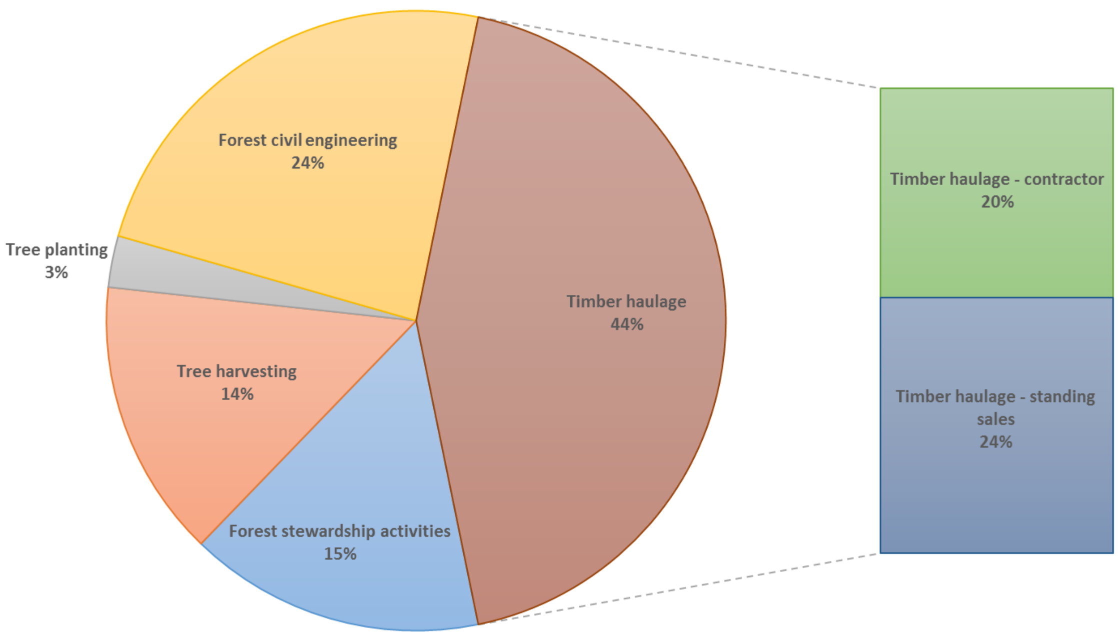

Figure B.2. Contribution of broad forestry activities to WGWE forestry operation emissions, and the split of timber haulage emissions attributed to contractors and standing sales.

The results show that timber haulage is the main source of operational emissions on the WGWE, with approximately half arising from haulage by contractors and half from haulage of timber sold standing. Forest civil engineering activities are the second largest source of emissions on the WGWE, primarily from the provision of harvesting facilities, grading roads and aggregate haulage. Emissions associated with tree harvesting activities are perhaps a smaller proportion of the total than anticipated based on the initial spend based analysis. Tree planting activities have a comparatively low emissions impact.

Over half of forestry operational emissions arise from work completed by contractors on NRW's behalf, demonstrating the importance of utilising procurement frameworks and contracts as a means of influencing the organisation's indirect, supply chain emissions. Downstream haulage and harvesting emissions currently represent over 30% of NRW forestry operations emissions, and the overall significance of this emissions category is likely to increase as the organisation moves towards a model of increased standing sales.

B.4. Next steps

- Share results with forestry staff who helped with the analysis to ask for their thoughts on opportunities to reduce emissions from top sources, both in house and through contracts.
- Explore opportunities for reducing emissions from top sources. Current avenues of interest include:
    - Biofuel (recycled cooking oil) use in plant to reduce red diesel use. The Environment Agency currently use a biofuel blend in plant and we may be able to learn from their experiences. Some off-road national nature reserve management vehicles within NRW currently run on 100% biofuel in the summer months, with proven carbon savings even when taking into account delivery of fuel.
    - Strategic logistics using GPS trackers in lorries to minimise haulage journeys and maximise fuel efficiency.
    - Other opportunities such as managing tyre pressures to maximise fuel efficiency.
- Explore the potential to influence forestry contracts and frameworks with procurement and forestry operations staff e.g. the inclusion of carbon criteria such as managing tyre pressures in contracts or frameworks, working with haulage providers to trial a GPS system to increase the efficiency of logistics.
- Explore the potential to include conditions of sale into standing sale timber contracts.

B.5. References

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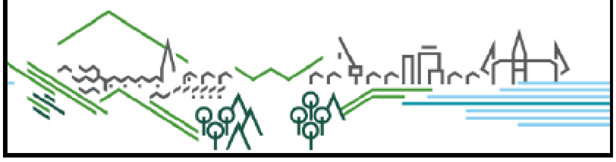
Appendix C

Woodland habitats



Background and aim

- Forest Research's CARBINE model – a leading forest carbon accounting model
- Tier 3 carbon stock change estimates for the UK GHG inventory
- For woodland habitats on the NRW owned and managed estate, we asked Forest Research to model:
  - Annual sequestration or emissions?
  - Total carbon stocks of all woodlands?
  - How stocks and sequestration are predicted to change out to 2040?
  - GHG emissions arising from forestry operations?

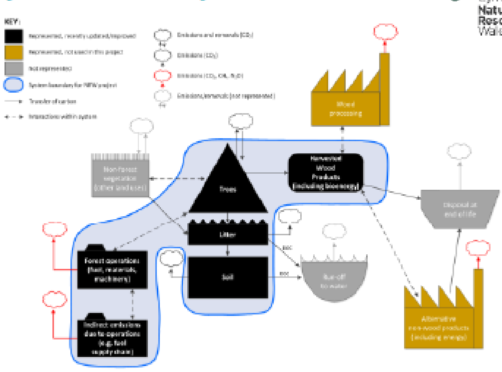
The NRW woodland estate

- >108,000 hectares of commercial forest (Welsh Government woodland estate leased and managed by NRW)
- 1600 hectares of non-commercial woodland on nature reserves

Method: The CARBINE model

- Models carbon exchanges between the atmosphere, forest ecosystem and harvested wood products at a stand or forest level (CO_2 only)
- Whole forest level output and operational regions
- 3 CARBINE sub-models used:
  - Tree carbon dynamics
  - Soils
  - Harvested wood products

System boundary for calculations



CARBINE: Tree carbon dynamics

- Algorithms determining tree stem growth based on Forestry Commission yield models:
  - Tree species specific
  - Linked to yield class (tree growth rate)
  - Influenced by management regime
    - Clearfell on a specified rotation
    - Continuous cover (selective harvesting)
    - Coppice
    - Minimum intervention (no felling)
    - Changes in management over time

CARBINE: Tree carbon dynamics

Cyfoeth Naturiol Cymru Natural Resources Wales

- Biomass in tree roots, branches and foliage estimated based on allometric relationships with stem biomass
- Wood carbon content conversion 0.5 tC/odt

NRW input data for tree carbon sub-model:

- Forestry sub-compartment database – species, planting year, spacing, areas and yield classes
- Forest design plans – planned thinning and felling
- Timber marketing plan - volumes to market
- Non-commercial woodland management data

CARBINE: Soil sub-model

Cyfoeth Naturiol Cymru Natural Resources Wales

- 3 carbon components: inert, slow turnover, fast turnover
- Organic matter inputs primarily from litter and fine root turnover
- Organic matter inputs to soil vary with soil type, tree species and growth rate (based on tree growth model)
- Standard decay rate constants for temperate conditions used for litter decay
- Fluxes of CH_4 and N_2O from soils not represented in the current version of CARBINE
- Peatland extent from Wales unified peat map

CARBINE: Harvested wood products (HWP)

Cyfoeth Naturiol Cymru Natural Resources Wales

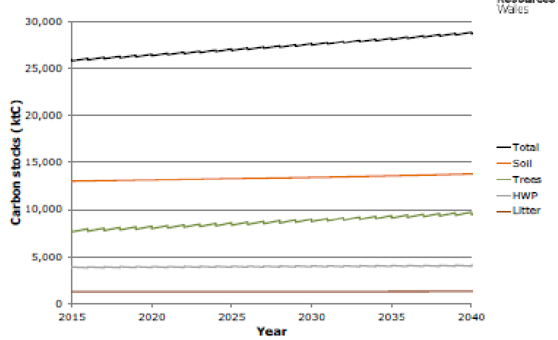
- Annual sequestration in HWP (net carbon stock change) = additions of HWP carbon – losses of HWP carbon

Input data:

- NRW timber use statistics:
  - % of stemwood to the board industry
  - % to fuelwood
  - % to fencing
  - % structural
  - Remainder: horticulture, pallets, joinery, round wood

Results: Carbon stocks

Cyfoeth Naturiol Cymru Natural Resources Wales



Results: Net GHG emissions and removals from NRW woodland

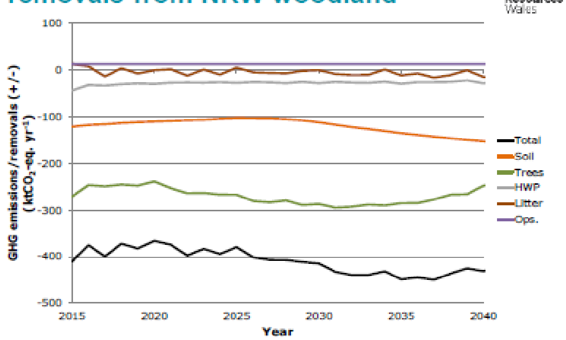
Cyfoeth Naturiol Cymru Natural Resources Wales

Contribution	GHG emissions (+)/ removals (-) (kt CO_2e/year)
Soil	-119.7
Litter	-4.4
Trees	-270.1
HWP	-28.0
Total*	-422.2
Forest operations GHG emissions[a]	+12.7
Net total	-409.5

*CO_2 exchanges only; [a]CO_2, CH_4 and N_2O (expressed as CO_2e)

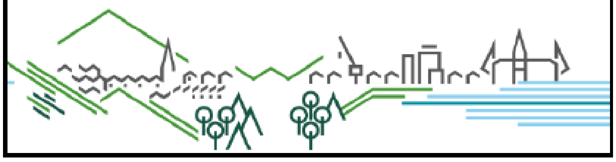
Results: Net GHG emissions and removals from NRW woodland

Cyfoeth Naturiol Cymru Natural Resources Wales



Appendix D

Habitats on deep-peat soils

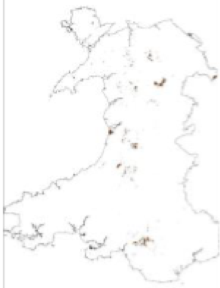


Background and aim

- CEH working collaboratively on the latest Tier 2 peat emission factors for the UK GHG inventory
- CEH led on an all Wales peatland condition and emissions mapping project in 2015
- For all deep peat habitats on the NRW owned and managed estate, we sought to determine:
  - Annual sequestration or emissions for each habitat and condition?
  - Potential to reduce emissions / increase sequestration through ditch blocking and restoration?
  - Total carbon stocks?

Method: Emissions / sequestration

1. Mapping the NRW deep peat resource



- Wales unified peat map developed by CEH for Welsh Government (deep peat >40cm)
- Total area: 11,345 hectares on the NRW owned and managed estate
- Deep peat by habitat type:
  - 50.6% conifer plantation
  - 9.1% blanket bog
  - 6.7% mosaic habitat
  - 5.8% wet modified bog
  - 5.2% raised bog

Method: Emissions / sequestration

2. Initial categorisation of habitat type - Phase 1 habitat classification maps

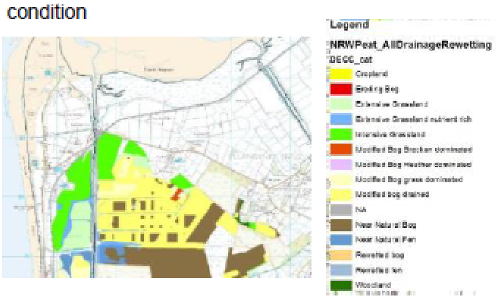
3. "Condition" mapping:
   - Overlaying with all-Wales digitised ditch layer
   - NRW mapped blocked ditches, restored and bare peatland
   - Buffer zones mapped to represent area drained by ditches

     10 meter drainage radius assumed for upland peat

     50 meter for lowland raised bog and fen peats

Method: Emissions / sequestration

4. All habitats re-categorised by type and peat condition



Method: Emissions / sequestration

5. Most appropriate emission or sequestration factor for each habitat & condition category applied
   - Latest evidence from review of UK relevant data
   - Soil fluxes
   - GHG balance rather than carbon only:

     CO_2,

     CH_4,

     N_2O,

     Fluvial carbon fluxes.

Results: Emissions / sequestration

- NRW peats emit 99,653 t CO_2e/year*
  - Near natural blanket and raised bogs are net sequesters
  - Current science suggest all other peat habitats are net emitters
- Top 5 emitting habitats (82% of total):

Habitat category	Emission factor (t CO_2e/ha/yr)	Area on NRW estate (ha)	Total emissions (t CO_2e/yr)
Planted coniferous woodland*			65,466
Marshy grassland			4,458
Mosaic (heather dominated)			4,227
Improved grassland			4,128
Wet modified bog			3,676

* Afforested deep peat emissions estimates were superseded in our final net carbon status calculation by the results modelled by Forest Research for the NRW estate using their CARBINE model.

Results: Emissions mitigation potential

- 4 restoration scenarios modelled
- Even if all peat habitats were rewetted and reverted to near-natural condition the estate would still be a net emitter

Scenario	Whole estate peatland emissions (t CO_2e/yr)
Current baseline	**99,653**
1) All drained fen and bog rewetted (rewetted condition)	97,533
2) All peat except woodland, cropland and intensive grassland rewetted (rewetted condition)	81,585
3) All peatland rewetted to fen or bog (rewetted condition)	21,060
4) All peatland rewetted to fen or bog (near-natural condition)	1,579

Method: Soil carbon stocks

- Peat depth modelled using equations developed for a similar altitude and topography range in Ireland
- Based on the relationship between slope and peat depth
- Slope mapped using digital elevation model
- Parametrised using Wales field data on peat depth, including all NRW peat depth measurement records
- Maximum peat depth constrained to 3 meters
- Converted to carbon stocks using assumptions including
  - Fraction of organic matter in peat =0.94
  - Proportion of organic matter that is carbon =0.5

Results: Soil carbon stocks

- NRW peatland carbon stocks: 7,078,293 t C*
- Top 5 carbon stocks by habitat (76% of total):

Habitat category	Area on NRW estate (ha)	Total C stock (t C)
Planted coniferous woodland		2,655,446
Raised bog		1,016,667
Wet modified bog		710,103
Blanket bog		604,047
Mosaic (heather dominated)		361,959

* Afforested deep peat carbon stock estimates were superseded in our final carbon stock calculation by the results modelled by Forest Research for the NRW estate using their CARBINE model.

Please note:

Some figures have been redacted.

The above afforested deep peat emissions and carbon stock estimates were superseded in our final calculations by the result modelled by Forest Research for the NRW estate using their CARBINE model. See section 5.2.4 of the main report for details.

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