Forest Reference Level 2021-2025: Iceland

National forestry accounting plan

skógræktin
ICELANDIC FOREST SERVICE

Submitted in accordance with Decision of the EEA Joint Committee No 269/2019 of 25 October 2019

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Acronyms and abbreviations

50YCP	50 years conversion period
C	Carbon
CAD	Cutting Activity Database
CF	Cultivated Forest
CP	Compliance Period
CRF	Common Reporting Format
CsC	Carbon stock Change
DW	Deadwood
FAO	Food and Agriculture Organization of the United Nations
FAWS	Forest Available for Wood Supply
FMP	Forest Management Practices
FNAWS	Forest Not Available for Wood Supply
FrF	Forest remaining Forest
FRL	Forest Reference Level
G-FRL	Guidance on developing and reporting Forest Reference Levels
GHG	Greenhouse Gas
GHGR	Greenhouse Gas Reporting
HWP	Harvested Wood Products
IC-GHGR	Icelandic Greenhouse Gas Reporting
IC-GHGR-2016	Icelandic Greenhouse Gas Report submitted 2018 with 2016 as latest reporting year
IFR	Icelandic Forest Research
IFS	Icelandic Forest Service
IPCC	Intergovernmental Panel on Climate Change
LcF	Land converted to Forest land
MANR	Mean Annual Net Removal
NBF	Natural Birch Forest
NBW	Natural Birch Woodland
NFI	National Forest Inventory

NFS	National Forest Strategy
NFAP	National Forest Accounting Plan
NIR	National Inventory Report
RP	Reference Period (for Iceland 2002-2009)
UNFCCC	United Nations Framework Convention of Climate Change

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1 General Introduction

In this report, Icelandic Forest Research has by appointment of the Ministry for the Environment and Natural Resources, made a national forest accounting plan (NFAP) and proposed a forest reference level (FRL) for managed forest land for the period 2021-2025 as requested in the EU-Regulation 2018/841 and in accordance to the decision of the EEA Joint Committee No 269/2019 of 25 October 2019.

A FRL for 50 years conversion period (50YCP) is described as the default FRL suited to fit to the Icelandic Greenhouse Gas Report where a 50 years conversion period has been used for land converted to forest (LcF) from the start of LULUCF-reporting instead of a default 20 years conversion period. The argument for using 50YCP is that in-country research showed a significant increase in the C stock of mineral soil and litter pool up to 50 years after afforestation (Bjarnadóttir 2009, Hellsing et al. 2018). In addition, the development of forest in Iceland on afforested land is a slow process, mainly taking place in exposed environments under a harsh climate near the polar/mountain forest limit. Use of the 50YCP has been noted by the Expert Review Team of the UNFCCC without any comment or criticism.

The use of 50YCP in this report is done in line with Article 1 in the Decision of the EEA Joint Committee No 269/2019 of 25 October 2019.

The proposed Forest Reference Level for the period 2021-2025 is in this report estimated to -30.345 kt CO_2 eq., considering instant oxidation of all harvest and -30.405 kt CO_2 eq. including Harvested Wood Products carbon stock change.

1.1 Description of Forest Reference Level

1.1.1 Forest definition

All woodland defined as forest in the initial report from Iceland (Ministry for the Environment 2006) and reported in the annual greenhouse gas reporting (IC-GHGR) in the National Inventory Report (NIR) and the Common Reporting Format (CRF) to the United Nations Framework Convention of Climate Change (UNFCCC) as Forest remaining Forest (FrF) are subject to the Forest Reference Level (FRL).

In the initial report all woodlands that fulfil these requirements at maturity are defined as forest; minimum tree crown cover: 10 %, minimum land area: 0.5 ha, minimum tree height: 2 m and minimum area width: 20 m. Tree covered areas are excluded if the ground vegetation is modified by crop cultivation (cropland) or cultivation of ornamental plants or grass (parks in settlements etc.). Treeless areas inside forest are defined as forest if they are less than 0.5 ha in area or 20 m in width. This definition is also used in the National Forest Inventory (NFI) with three subclasses of mature height:

1. High forest: 5 m or more height at maturity
2. Regular woodland: 2 – 4.99 m height at maturity
3. Shrubland: under 2 m height at maturity

All forests, both naturally regenerated and planted, are defined as managed as they are all affected by human activity.

The natural birch woodland (NBW) is the native woodland of Iceland. It has been under continuous usage for many centuries. Until the middle of the last century, it was the main source for fuel wood for house heating and cooking in Iceland (Umhverfisráðuneytið 2007). Most of the NBW has been used for grazing and still is, although some areas have been protected from grazing. Cultivated forest (CF) consists of tree plantations and areas cultivated using direct seeding or from natural regeneration of cultivated forest.

1.1.2 Icelandic National Forest Inventory

Icelandic Forest Research (IFR), the research division of the Icelandic Forest Service (IFS) is responsible for the Icelandic NFI. In the NFI the NBW is defined as one of the two predefined strata to be sampled. The other stratum is the CF. The sampling fraction in the NBW is lower than in the CF. Each 200 m^2 inventory plot in NBW is placed on the intersection of a 1.5 x 3.0 km grid, but in the CF the grid is 0.5 x 1.0 km (Snorrason 2010). All plots in the NFI are permanent. CF-NFI plots are visited on a 5-year interval and every year one fifth of the plots are visited. NBW-NFI plots are visited on a 10-year interval. The NBW-NFI round takes 5 years as for the CF with one fifth of the plots visited every year when the inventory is ongoing. The sample population for NBW is the area of NBW mapped in the field in 2010-2014 (Snorrason et al. 2016). The sample population of CF is an aggregation of maps of forest management reports from actors in forestry in Iceland. In some cases, the NFI staff does mapping in the field of private CF. To ensure that forest areas are not outside the population area, the populations for both strata are increased with a buffer of mapped border. The current buffer is 16 m. The third inventory cycle of CF was finished in 2019. The second one of the NBW (2015-2020) was finished in 2020. The part of NBW defined as forest (reaching 2 m or greater in height at maturity in situ) is estimated based on the NBW 2010 – 2014 map and is defined as Natural Birch Forest (NBF).

1.1.3 Forest area

The category of FrF in the IC-GHGR has three subcategories:

1. NBF older than 50 years (87.633 kha in 2016): By analysing the age structure in the NBW that does not merge geographically with the old map from a survey in 1987-1991, it was possible to re-estimate the area of NBW in 1987-1991 and in 2010-2014. Results of these estimates where that the area was 137.69 kha at the time of the initial survey in 1987-1991 (Snorrason, et al. 2016). Earlier analyses of the 1987-1991 survey resulted in 115.40 kha (Traustason and Snorrason 2008). The difference is the area that was missed in the earlier survey. The estimated area of NBW was 150.65 kha in the 2010-2014 survey. The difference of 12.95 kha is an estimate of a natural expansion over the period of 1989 to 2012 (23 years) where the midyears of the two surveys are chosen as reference years. In the new map of 2010-2014, the ratio of NBW that can reach 2 m height at maturity and is defined as forest (NBF) was 64% of the total area. NBF is accordingly estimated to have been 87.72 kha in 1989 and 95.97 kha in 2012, the former figure categorizing NBF classified as FrF in GHGR and the differences between the two figures (8.25 kha) as NBF classified as Land converted to Forest land (LcF) with mean annual increase of 0.36 kha.

   Even though this subcategory is named NBF older than 50 years it consists of woods in different dominant age classes. It can be difficult to assess the age of the NBW as they are often without clear age structure and with more than one tree layer in the same area. Despite that, the age of the dominant tree layer was assessed in the mapping survey of 2010-2014 (Snorrason, et al. 2016). To test the accuracy of this assessment, core and disk samples were taken from subsamples of mapped woodland units. Estimated age classes of NBF older than 50 years is shown in Figure 1.

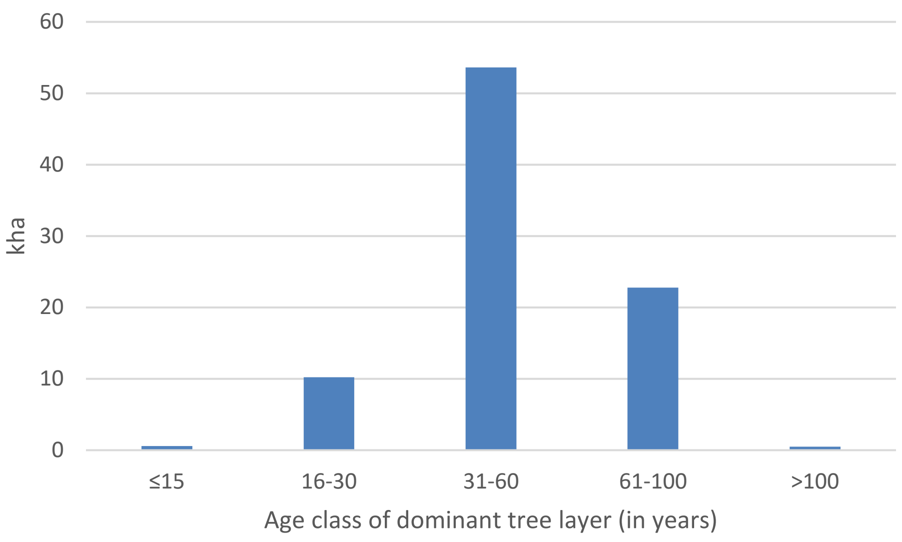

Figure 1. Age classification of the NBF by age classes of dominant tree layer.

2. Plantations in NBF (1.18 kha in 2016): These are forests that have been converted from NBF to CF by plantation, mostly of introduced conifer species. They are covered by the CF-NFI and the area is estimated based on the sample plot inventory of the CF. Plantation in NBF was practised in the early years of forestry but NBFs are now generally protected under both the Nature Conservation and Forestry Acts. The youngest new plantation reported in sample plots is from 2004. Conversion timing is the year of plantation that was often done after light thinning of the NBF but leaving the birch canopy largely intact. Later if the plantation was successful the natural birch was removed. CF takes precedence over NBF which means that if canopy cover of the plantation will reach 10% at maturity the forest will be defined as CF despite higher current natural birch cover.
3. Afforestation older than 50 years (0.97 kha in 2016): These are forests that where cultivated on other land than forest more than 50 years ago. They are covered by the CF-NFI and the area is estimated based on the sample plot inventory of the CF. Forests under LcF are moved into this category when they reach the age of 51 years. Age is defined as year since plantation plus one year as the majority of planting is done in spring before the growing season.

Table 1. shows the development of the forest area (in kha) in Iceland divided into Forest remaining forest and Land converted to forest and its subclasses from 2000 to 2016. A>50: Afforestation older than 50 years; P NBF: Plantations in Natural Birch Forest; NBF>50: Natural Birch Forest older than 50 years; A≤50: Afforestation 50 years or younger; NBF≤50: Natural Birch Forest 50 years or younger.

	Forest remaining forest				Land converted to forest			Total
	A>50	P NBF	NBF>50	Sum	A≤50	NBF≤50	Sum	Forest
2000	0.18	1.16	87.72	89.06	18.92	3.95	22.87	111.93
2001	0.18	1.16	87.72	89.06	20.01	4.31	24.32	113.38
2002	0.18	1.16	87.72	89.06	22.23	4.66	26.89	115.95
2003	0.18	1.16	87.72	89.06	24.69	5.02	29.71	118.77
2004	0.18	1.18	87.72	89.08	25.95	5.38	31.33	120.41
2005	0.26	1.18	87.72	89.16	28.24	5.74	33.98	123.15
2006	0.26	1.18	87.72	89.16	29.63	6.10	35.73	124.89
2007	0.26	1.18	87.72	89.16	30.93	6.45	37.38	126.54
2008	0.37	1.18	87.72	89.27	32.38	6.81	39.19	128.46
2009	0.37	1.18	87.72	89.27	34.19	7.18	41.37	130.64
2010	0.66	1.18	87.72	89.56	35.11	7.54	42.65	132.21
2011	0.69	1.18	87.72	89.59	36.09	7.90	43.99	133.58
2012	0.74	1.18	87.72	89.64	36.81	8.25	45.06	134.70
2013	0.80	1.18	87.72	89.70	37.62	8.61	46.23	135.93
2014	0.80	1.18	87.72	89.70	38.41	8.97	47.38	137.08
2015	0.97	1.18	87.71	89.81	39.13	9.33	48.46	138.32
2016	0.97	1.18	87.71	89.86	39.58	9.69	49.27	139.13

1.1.4 Deforestation

In accordance with article 19 of the Icelandic Forestry Act (Alþingi 2019), the IFS and the National Planning Agency hold a register on planned activity that can lead to deforestation (Skógræktin and Skipulagsstofnun 2017). Planned activities that lead to deforestation must be reported by the municipalities to the IFS before giving formal permission to conduct deforestation. IFR samples activity data of the affected areas and data about the forest that has been removed. This data is used to estimate emissions from lost biomass and C- stock in litter and soils. Deforested area from FrF is then excluded from the FRL.

1.2 Adherence to the criteria set in Annex IV of the LULUCF Regulation

The criteria and guidance for establishment of FRL are set out in section A of Annex IV of the EU-Regulation 2018/841. Table 2 below cross-references sections in this document which address adherence to the criteria as set out in Annex IV with specific reference to paragraphs under section A.

Table 2: Summary and cross-reference to text addressing specific criteria as set out in section A of Annex IV of the EU-Regulation 2018/841.

Paragraph in section A	Description	Reference in the report	Comment
a	Balance between emissions and removals and enhancement of forest sinks in the second half of this century	Ch. 2.3.2. Fig. 2	Projected afforestation up to 2130 shows substantial increase in net CsC in the period 2050 - 2100
b	Mere presence of C excluded from accounting	Table 12	By following the methodology given in the Guidance on developing and reporting Forest Reference Levels, this criterion is met for FrF
c	Robust accounting system		See comment for paragraph b
d	Inclusion/exclusion of Harvested Wood Products	Table 12	Final FRL is presented both with and without applying first-order decay function and half-life values
e	Assumed constant ratio between solid and energy use of forest biomass	Ch. 4.1.6	Mean ratio of 3.1% of C-stock in HWP of the C-stock total wood production in RP used constantly in estimating CsC in HWP C-pool in the modelling period
f	Conservation of biodiversity and sustainability	Ch. 2.3.1 Ch. 2.3.2 Fig. 2 Fig. 3	Clear sustainability with planned substantial increase in forest area and C-seq. 99% of NBF under conservation and erosion protection management. Afforestation plans take into account nature protection etc.
g	Consistency with national projection reporting under EU Regulation 523/2013	Ch. 2.3.2.	
h	Consistency with national inventory	Ch. 4.2	This is met by passing tests of validation.

2 Preamble for the forest reference level

2.1 Carbon pools and greenhouse gases included or excluded in the forest reference level

When predicting greenhouse gas fluxes and constructing the FRL, the main rule followed was to use the same Carbon pools and greenhouse gases as reported in the submission of GHGR from Iceland to the UNFCCC, published in 2018 with 2016 as the last reporting year (Hellsing, et al. 2018). In this paper it will be referred to as IC-GHGR-2016. This was done to make comparison of projected GHG emission/removals to reported figures possible.

Table 3 gives an overview of Carbon pools and gasses included and excluded in the IC-CGCR-2016 for FrF and in the FRL estimation. Further information and explanations are given in subchapters below.

Table 3: Carbon pools and greenhouse gasses included and excluded in the IC-GHGR-2016 for FrF and in the FRL estimation. I = included, E= excluded, IE: Included elsewhere.

	Natural birch forest		Cultivated forest	
	GHGR	FRL	GHGR	FRL
Biomass				
Trees	I	I	I	I
Gain	I	I	I	I
Loss	IE*	IE*	I	I
Other veg.	E	E	E	E
Litter	E	E	E	E
Dead wood	I	I	I	I
Soil				
Mineral	E	E	E	E
Organic	I	I	I	I
CO_2	I	I	I	I
N_2O	I	I	I	I
CH_4	I	I	I	I
HWP	I	I	I	I

*See explanation in Chapter 2.1.2.1 below.

In general, the methods used to estimate Carbon stock changes (CsC) in different sources are more simple than those used in many other more forested countries in Europe where the FrF category plays a much bigger role in the LULUCF bookkeeping than in Iceland. In IC-GHGR-2016 the FrF was not defined as a Key source category, neither in size nor trend.

2.1.1 Common reporting in subcategories of FrF

2.1.1.1 Litter and mineral soil

In the IC-GHGR-2016, CsC of the litter and mineral soil pools was reported as not estimated (NE). For LcF country specific removal factors were used, built on in-country research. No evidence from research literature exists for FrF in Iceland, but models and model modifications used in other Nordic countries show increase in litter and mineral soil pools in the long run (Dalsgaard et al. 2016). In the newest GHGR, CsC for litter and mineral soil pools in FrF was reported as not occurring (NO), at least until in-country research shows otherwise.

Accordingly, C-pools of litter and mineral soil were excluded from the FRL. Emissions of other gases than CO_2 were also reported as not occurring (NO) for litter and mineral soil and excluded from the FRL.

2.1.1.2 Organic Soil

Emissions from organic soil were calculated by default factors for drained organic soil from the IPCC 2013 Wetlands supplement (for CO_2 and CH_4) (IPCC 2013) and by a country specific factor for N_2O (Guðmundsson 2009). It was reported in IC-GRGR-2016 and was accordingly included in the FRL.

2.1.2 Difference in reporting in subcategories of FrF

Reporting of gains and losses of biomass is different between subcategory NBF and the two other CF subcategories.

2.1.2.1 NBF older than 50 years

CsC of biomass are estimated by the stock difference method of the 2006 IPCC guidelines (IPCC 2006). Total biomass in two different periods is compared and the difference between the two periods is an estimate of the net CsC including both gains and losses. That is the reason why biomass losses are registered as IE (Included elsewhere) in Table 3 above. The two years compared are 1987 and 2007. Estimated mean annual removal of the C-stock pool of biomass was -13.13 kt CO_2 eq. (IC-GRGR-2016). Direct extrapolation of the mean annual removal is used for years beyond 2007.

2.1.2.2 Plantations in NBF and Afforestation older than 50 years

These two subcategories were handled together and the CsC accounted with the more commonly used method of separate estimate of gain and loss. Biomass stock in other vegetation than trees is supposed to be not changing in the long run. Research results show that fluctuation in the stock of other vegetation with changing forest age evens out over the rotation (Sigurdsson et al. 2005). CsC in other vegetation than trees is therefore excluded.

2.1.2.2.1 Estimation of biomass gain

Aboveground biomass of living trees measured in a sample plot in the NFI is compared to the aboveground biomass of the same trees measured 5 years ago. Change in the size of single trees between NFI measurements is defined as the CsC gain. Country specific single tree/stem equations are used, most of them species specific (Snorrason and Einarsson 2006, Bjarnadottir et al. 2007, Jónsson 2007, Hunziker 2011). Different equations for different size of trees are used, but when changes are calculated the same equation has to be used. Biomass below ground is either estimated by root/shoot ratio described in country specific literature (20/80) (Snorrason et al. 2002) or by country and species specific equations (Hunziker 2011).

2.1.3 Common reporting of FrF with category LcF

Both biomass loss and the deadwood pool of the two CF subcategories in FrF are, in IC-GHGR-2016, reported as included elsewhere (IE) and only reported under subcategory Grassland converted to Forest – Afforestation 1-50 years old on LcF, together with reporting of dead wood and biomass losses. In a similar manner the estimation of harvested wood products was not divided between FrF and LcF in IC-GHGR-2016.

2.1.3.1 Deadwood

CsC to the deadwood (DW) pool is reported when DW meeting the definition of lying DW (diameter ≥ 10 cm and length ≥ 1.3 m) is found on sample plots in the NFI. Its initiation year is also assessed up to 5 years back. At the initiation year (year of dying) the C-stock of DW is reported as loss of C from the biomass pool. Loss of C from the DW pool is calculated only if the DW is totally decomposed and not registered again. DW occurrence in plots is very rare and CsC to the DW pool is not reported for every year in the IC-GHGR-2016. Deadwood was first registered for the year 2002 in the CF-NFI. Deadwood has never been reported in NBF plots. Future improvement is needed to include deadwood in stumps, root stock and standing dead trees and to include continuous decomposition of all deadwood. Hence, technical correction of FRL is to be expected regarding DW.

2.1.3.2 Biomass loss from harvest

In the IC-GHGR-2016, loss of biomass from harvest is estimated from annual reporting of production of wood sold on the commercial wood market in Iceland as reported in the Journal of the Icelandic Forest Association (Gunnarsson and Brynleifsdóttir 2017). Only the C-stock of annual roundwood production and DW is reported as loss. Improvement of the biomass loss calculation that will include other parts of cut trees and natural mortality figures is planned. These improvements will lead to future technical correction of the FRL.

2.1.4 Reporting of Harvested Wood Products (HWP)

The only HWP category reported in IC-GHGR-2016 is sawnwood. Production of the two other product classes from domestic wood does not exist. FAO statistics from the Icelandic statistics agency (Statistics Iceland) are incomplete and not usable as data feedstock into the domestic HWP pool. Instead the annual report of production of wood, sold on the commercial wood market in Iceland as reported in the Journal of the Icelandic Forest Association is used as a source. There, sold sawnwood classified by tree species or species groups is reported. No records are found on export of domestic sawnwood and the statistic of the Icelandic Forest Association does only cover production of domestic sawnwood excluding totally imported sawnwood or sawnwood originating from imported roundwood. Table 4 shows annual amount of sawnwood compared to total amount of wood produced. Table 4 is identical to Table 6.8 in the IC-GHGR-2016 National inventory report (Hellsing et. al 2018).

Table 4: Amount of sawnwood compared to total amount of wood produced for the period 1996 - 2016.

Year	Wood total o.b. m3	Sawnwood m3	% of total
1996	403	9	2.1%
1997	314	18	5.7%
1998	308	5	1.7%
1999	309	9	2.8%
2000	326	6	1.7%
2001	286	7	2.3%
2002	458	11	2.3%
2003	620	9	1.4%
2004	537	10	1.8%
2005	961	6	0.6%
2006	884	6	0.7%
2007	642	27	4.2%
2008	1.444	21	1.5%
2009	1.528	46	3.0%
2010	4.185	50	1.2%
2011	3.845	112	2.9%
2012	3.459	93	2.7%
2013	5.511	93	1.7%
2014	5.923	165	2.8%
2015	4.744	64	1.3%
2016	4.182	133	3.2%

It should be noted that part of the total harvest is from thinnings in forest younger than 50 years which do not belong to FrF category. On the other hand, all sawnwood originates from FrF category. The first order decay model as described by IPCC was used to estimate CsC in the HWP pool (IPCC 2014). The same methods were used in the FRL prediction of HWP. All other domestic harvest was defined as for energy use, using instant oxidation in calculations.

2.1.5 Reporting of deforestation

As already mentioned, every deforestation event is reported. In general deforestation is rare and, in the IC-GHGR-2016, a new deforestation event is not reported every year. Deforestation events can easily be classified into forest land categories as used in IC-GHGR. Emissions from biomass loss are estimated on the basis of information sampled in or near the forest removed. Emissions from litter and soil follow the default Tier 1 method described in the IPCC GPG 2006. An in-depth description of methodology and calculations of country wise litter and SOC-stock estimations is found in Chapter 6.5.2.2 and 6.8.2.2 in IC-GHGR-2016. The mean annual area moved from FrF to Deforested area was assumed to be the same as was reported in the IC-GHGR-2016 for the period 2002-2016 as described in Alternative 2 in Box 19 in the Guidance on developing and reporting Forest Reference Levels (G-FRL) (Forsell et al. 2018).

2.2 Demonstration of consistency between C pools in the FRL

Transfer of C-stock between C-pools is described in detail in Chapter 3. The IC-GHGR-2016 was not totally consistent and all gaps and incompleteness are described in Chapter 3. To maintain as much consistency and comparability as possible between IC-GHGR-2016 and estimation of FRL, the same data sources and estimation methods were used wherever possible. New sources of data, such as cutting activity data and C-stock growth curves, were carefully examined to understand how their relationship and fit was to already used data sources in IC-GHGR-2016.

2.3 Description of the long-term forest strategy

2.3.1 Overall description of the forests and forest management and the adopted national policies

New forest legislation passed the Icelandic Parliament in 2019, replacing the old legislation from 1955 and the specific legislation on the regional afforestation programs from 2006. Among the lead policy instruments the new forest act creates and sets legal basis for a comprehensive National Forest Strategy (NFS). A working group nominated by the Minister for the Environment and Natural Resources is working on the first NFS which is planned to be published in the year 2021. The new NFS will further pave the way forward and sharpen the vision for the future of forestry in Iceland.

The new Icelandic forest law prohibits clearcutting without formal permission from IFS. Deforestation without permission is also prohibited. Unavoidable deforestation shall be compensated by afforestation. As already mentioned in Chapter 1.1.4 all planned deforestation is notifiable and must be approved by the IFS. The new forestry act implements an official cutting licence system to regulate cutting activity in accordance with the main goal of sustainable use of wood resources in the forest. Requirements for reforestation after felling are strengthened as well.

One of the main goals of the new forestry act is to protect and restore biodiversity. To prevent negative effect of afforestation on biodiversity, all planned forest plantations must consider nature protection, antiquities preservation and landscape influences, to be in accordance with NFS as described in article 4 of the forestry act.

The afforested area in Iceland is increasing every year as can be seen in the IC-GHGR-2016. The government of Iceland has launched an action plan and put more resources into measures to mitigate climate change (Verkefnisstjórn aðgerðaáætlunar í loftslagsmálum 2018). One of these measures is accelerated afforestation. In July 2019 the Ministry for the Environment and Natural Resources issued a more detailed plan which includes the highlights for LULUCF operations 2019-2022 (Umhverfis- og auðlindaráðuneytið 2019). This includes increasing annual afforestation from 1.100 ha in 2018 to 2.300 ha in 2022. The main emphasis is on increasing support for the farm afforestation grants scheme.

2.3.2 Description of future harvesting rates under different policy Scenarios

Future rates of harvest are derived using a silvicultural forecast as used for the FRL. A new prediction of the net CO_2 sequestration of two scenarios of afforestation since 1990 was published early 2018 (Snorrason and Brynleifsdóttir 2018). The scenarios where business as usual and quadrupled afforestation from the year 2023 (Figure 2). Same projections were used in the first voluntary report from Iceland on national projections of anthropogenic greenhouse gas emissions provided to the European Environmental Agency submitted in 15th of March 2019 (Helgadóttir et al. 2019). In the report, the business as usual projection was defined as "Projection with existing measures" (WEM) and the quadrupled projection as "Projection with additional measures" (WAM). These two scenarios were interpreted as results of two different forestry policies although a final decision on long-term afforestation had not been taken by the government in Iceland when these projections were done. Later the government decided to a double annual afforestation rate from BAU until 2023 as already described in chapter 2.3.1 above. That strategy was restated in a new Climate Action Plan published in June 2020 (Verkefnisstjórn aðgerðaáætlunar í loftslagsmálum 2020).

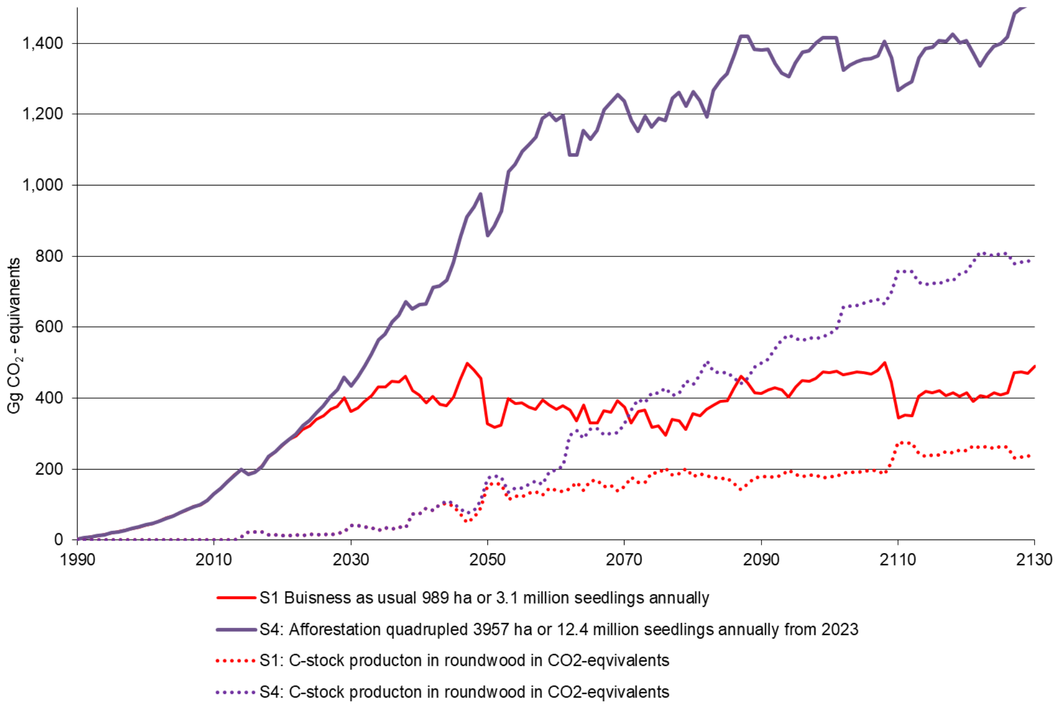

Figure 2. Net annual CO_2-eq. sequestration of two scenarios of afforestation since 1990. Removals are shown as positive figures as in the referred article (Snorrason and Brynleifsdóttir 2018). Stippled lines show projected annual harvesting rates of roundwood as CO_2-eqvivalents.

Figure 2 shows that steady afforestation will result in significant and stable net annual CO_2 sequestration.

The projected development of annual increment of the growing stock and the harvest for the two scenarios are shown in figure 3.

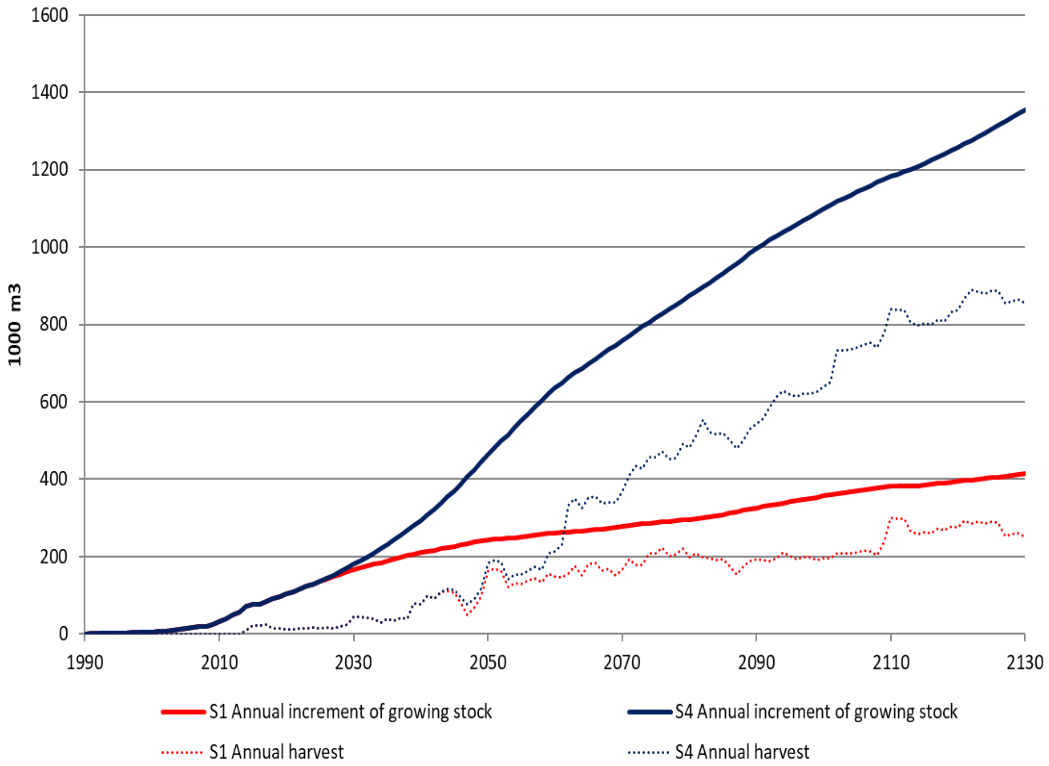

Figure 3. Projected annual increment of growing stock of the two scenarios of afforestation since 1990. Stippled lines show projected annual harvesting rates.

Even though the ratio between growing stock and possible harvest vary from one year to another, a rather good balance will be achieved after 2050. The prediction follows the sustainable goal of the new forestry act, that the annual harvest in Icelandic forests shall not exceed their annual increment.

3 Description of the modelling approach

3.1 Description of the general approach as applied for estimating the forest reference level

Iceland followed these main guidelines when making the FRL:

1. Use the same calculation methods as in the Framework estimates (IC-GHGR-2016)
2. For the NBF:
    a. Use extrapolation of NFI based stock change results
    b. Use data from the IFS Forest rangers to estimate cuttings in RP from NBF
3. For CF:
    a. Use NFI plot data directly and neglect statistical sampling error
    b. Predict the change in biomass C-stock of each plot or plot segment separately
    c. Use data from annual report of production of wood, sold on the commercial wood marked in Iceland as reported in the Journal of the Icelandic Forest Association to estimate total harvest in the RP
    d. Use data from the IFS Forest rangers to estimate stratified share of cuttings between FrF and LcF, cutting type and the cutting system of CF in RP

IFR started its systematic sample plot inventory in 2005. Because of the continuous 5 years inventory rounds of the CF inventory a midyear approach is used to estimate annual C-stock gain of biomass in the GHGR. As 5 previous year's growth was estimated in the first inventory of 2005-2009 it is possible to estimate the C-stock five years back from the first 5 inventory years and calculate a midyear estimate down to 2002. Estimates beyond that in the GHGR (for 2001 and earlier) were made by rather weak modelling and not suited to build FRL estimates on. For that reason, **the RP for Iceland was shortened to cover the period of 2002-2009 (8 years instead of 10 years).**

3.2 Documentation of data sources applied for estimating the forest reference level

3.2.1 Forest area

3.2.1.1 Natural birch forest older than 50 years

The area of NBF defined older than 50 years was previously documented in Chapter 1.1. As its expansion was assumed to start at year 1989 the area will not increase before 2039. On the other hand, the area is predicted to decrease because of deforestation, as deforestation has been reported in 2002-2016.

3.2.1.2 Subcategories of Cultivated forest (CF)

Subcategories of cultivated forest under FrF are handled together. Area estimation is built on the representation of systematic sampling plots of the NFI where each whole plot represents 50 ha. If the plot is partly inside forest its representation of area is assumed to be the ratio between plot area and the area of the plot inside forest. Hence, a plot 50% inside forest represent 0.5 x 50 ha = 25 ha. Plots can contain not just area with trees but also area inside forest that are temporarily or permanently without trees. Different land-type classes are given in Table 5. Land-type classes prescribed by the letters S and O are defined as forest. Land-types with the letter U are outside forest. Plots that are split between land-type classes or different forest cohorts are mapped into segments in the field. Area representation of land-type segments is calculated as area representation of plots partly inside forest as described above. The first five classes (100-400) are currently stocked forest area and the first eight classes are supposed to be stocked most of the time (100-700). Other classes are supposed to be unstocked at least in the nearest future. The area of land-type classes 100-700 is defined here as the net area of forest and the area of classes 100-2500 as the gross area of forest. The ratio between gross and net forest area of CF-NFI data used in IC-GHG-2016 was 1.26 where treeless area was 21% and tree-covered area was 79%.

Table 5: Land-types used to describe plots or plot-segments in the NFI of CF.

ID	Land-type class	ID	Land-type class
0	Undefined	1700	O-Garden 500-5000m2
100	S-Tree cover < 1.3 m in height	1800	O-Buildings 500-5000m2
200	S-Tree cover 1.3 -2 m	1900	O-Lake <5000m2
250	S-Tree cover 2-3 m	2000	O-Path 4-20m wide
300	S-Tree cover 3-5 m	2100	O-Track 4-20m
400	S-Tree cover > 5 m	2200	O-Road 4-20m
500	S-Clearcut area	2300	O-E.line <20m
600	S-Dead forest	2400	O-River 4-20m
700	S-Wind blown forest	2500	O-Other
800	S-Clearing < 500 m2	2600	U-Range land
900	S-Garden < 500 m2	2700	U-Cultivated land
1000	S-Woodpile <500m2	2800	U-Garden
1100	S-Buildings <500m2	2900	U-Settlement
1200	S-Path <4m wide	3000	U-Lake
1250	S-Path <4m wide no vegetation	3100	U-Road
1300	S-Track <4m wide	3200	U-E.line
1350	S-Track <4m wide no veg.	3300	U-River
1400	S-Stream <4m wide	3400	U-Treegrove <500m2
1500	S-Other <500m2	3500	U-Shelterbelt <20m wide
1600	O-Treeless area 500-5000m2	3600	U-Other

3.2.2 C-stock in biomass of trees in CF

C-stock is estimated at the same time as C-stock change in biomass as described above in chapter 2.1. C-stock as estimated from the NFI data in the inventory 2005-2009 was used as an initial C-stock in the process of predicting the historical (from initiation year down to 2002) and future (from initiation year up to 2025) C-stock for all plot segments with tree cover.

Predictions were made by using curves that show changes in biomass C-stock, above and below ground, of trees by age. These curves were derived from data sampled by forest mensuration on sites evenly spread around the country in the years 1999-2001 (Snorrason and Einarsson 2001, Snorrason et al. 2001, Snorrason et al. 2001, Snorrason and Einarsson 2002, Snorrason et al. 2002). Figure 4 shows the dispersion of measuring sites around Iceland.

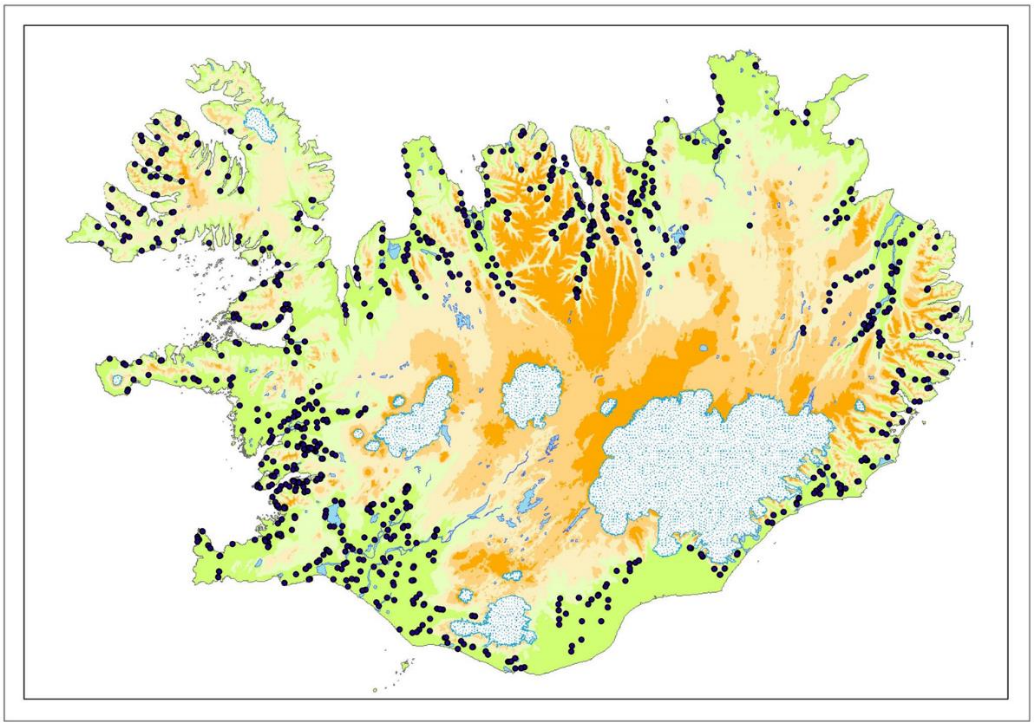

Figure 4. Black spots show dispersion of measuring sites in the tree growth survey of 1999-2001. A total of 1940 plots were measured.

Sites of eleven tree species where measured:

1. Downy birch (*Betula pubescens* Ehrh.)
2. Black cottonwood (*Populus trichocarpa* Torr. & Gray)
3. Rowan (*Sorbus aucuparia* L.)
4. Feltleaf willow (*Salix alaxensis* Cov.);
5. Darkleaved willow (*Salix myrsinifolia* Salisb.).
6. Sitka spruce /Lutz spruce (*Picea sitchensis* (Bong.) Carr.) / (*Picea × lutzii* Little)
7. Engelmann spruce (*P. engelmanni* Parry)
8. White spruce (*P. glauca* (Moench) Voss.)
9. Norway spruce (*P. abies* (L.) Karst.)
10. Lodgepole pine (*Pinus contorta* Dougl.)
11. Siberian larch (*Larix sibirica* Ledeb.)

Of the 1940 measurements, 1340 were useable to study the relationship between age and C-stock and make growth curves for different species. Country specific yield studies for birch, lodgepole pine and larch together with yield curves from the United Kingdom were used as a proxy for making growth curves for five species/species groups (Ragnarsson and Steindórsson 1963, Hamilton and Christie 1971, Heiðarsson 1998, Juntunen 2010).

Figure 5 shows how measurement sites where classified into yield classes by the relationship between top height and year from planting (age). The example shown is for Sitka spruce. After classification, age of sites was plotted against C-stock in trees (above and belowground) and sigmoidal curves made by iteration, as shown in Figure 6. In that way it was possible to make three different growth curves for Sitka spruce. One for yield classes 6, 8 and 10; one for classes 2 and 4 and one for sites with yield less than class 2. Below, species/species classes and numbers of growth curves made for each class are shown:

1. Downy birch: 2 curves
2. Black cottonwood: 3 curves
3. Sitka spruce: 3 curves
4. Slow growing spruces (P. abies, P, engelmanni, P. glauca): One curve
5. Lodgepole pine: 2 curves
6. Siberian larch: 2 curves
7. Fast growing willows: 1 curve

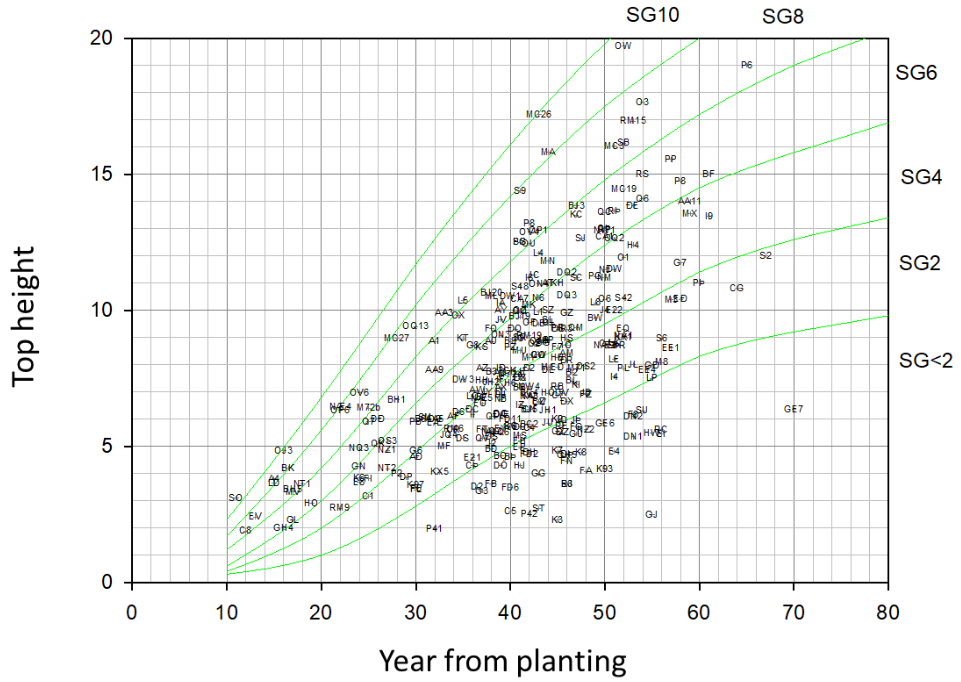

Figure 5. Measurement sites of Sitka spruce from the 1999-2001 survey classified into yield classes by the relationship between top height and year from planting (planting age).

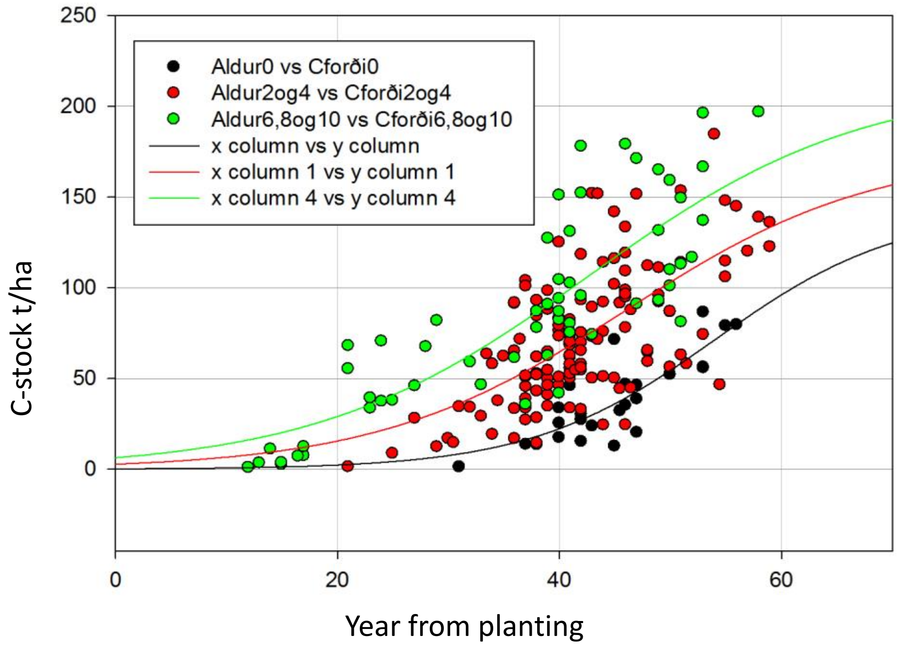

Figure 6: Measurement sites of Sitka spruce from the 1999-2001 survey classified into 3 yield classes where age of sites is plotted against C-stock in trees (above- and belowground) and sigmoidal curves fitted by iteration.

3.2.3 Forest management practices

Modern silviculture is at a starting phase in Iceland. Literature about forest management practices is very limited. General information in English about forestry in Iceland is available at the website of IFS (https://www.skogur.is/en/forestry/forestry-in-a-treeless-land).

It was a challenge to gather information about forest management practice (FMP) activities in the RP. Wood cutting activities in the National Forests of the IFS was used as a proxy of FMP in Iceland. The IFS operate four Forest Ranger regions, in West, North, East and South Iceland. Two of the Forest Rangers of IFS, in the North and East, hold rather good registers over cutting activities published in their annual reports (https://www.skogur.is/is/um-skograektina/utgefid-efni/arsskyrslur-skogarvarda). Data for the South and West regions are not as good, but the forest rangers have sampled information of cutting activities in these regions as well.

There is a long tradition of wood usage from the NBW but in modern times only the IFS practice small-scale wood extraction from the NBF with a selective cutting system where there is removal of larger trees on a cycle of ca. 60-100 years. This is only practised in North and East Iceland where high stature birch forest grows. From 1990 to 2016 around 170 ha were cut yielding 3465 m^3 of birch logs. The average annual cut was 120 m^3. In the RP the wood removal was 957 m^3 with an average annual cut of 122 m^3. As shown in Figure 7 there is an interannual variation that can be explained by the other source of birch wood originating from plantations in NBF where the birch is felled in shelterwood felling (canopy felling) to give way for planted conifers. When looking at total annual birch wood removals from the North and East region the interannual variation is small (Figure 8).

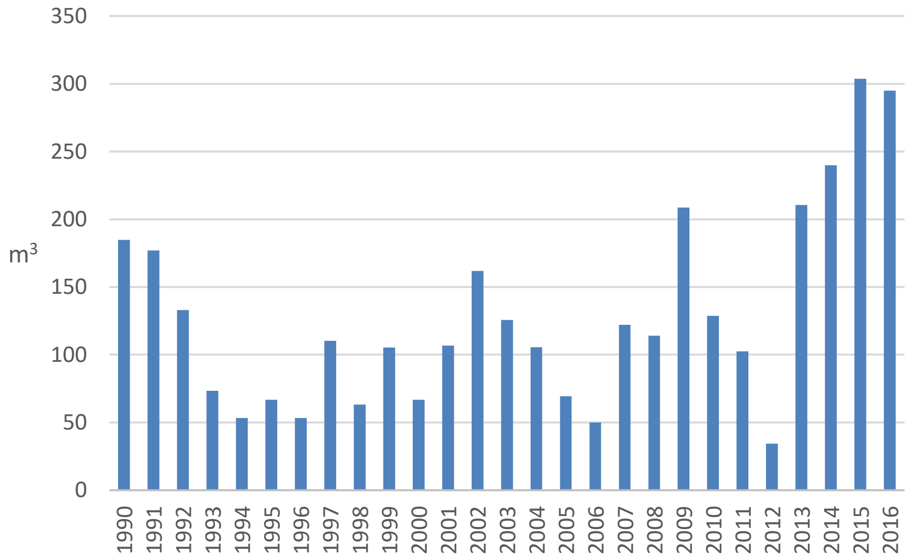

Figure 7. Birch wood harvested from NBF.

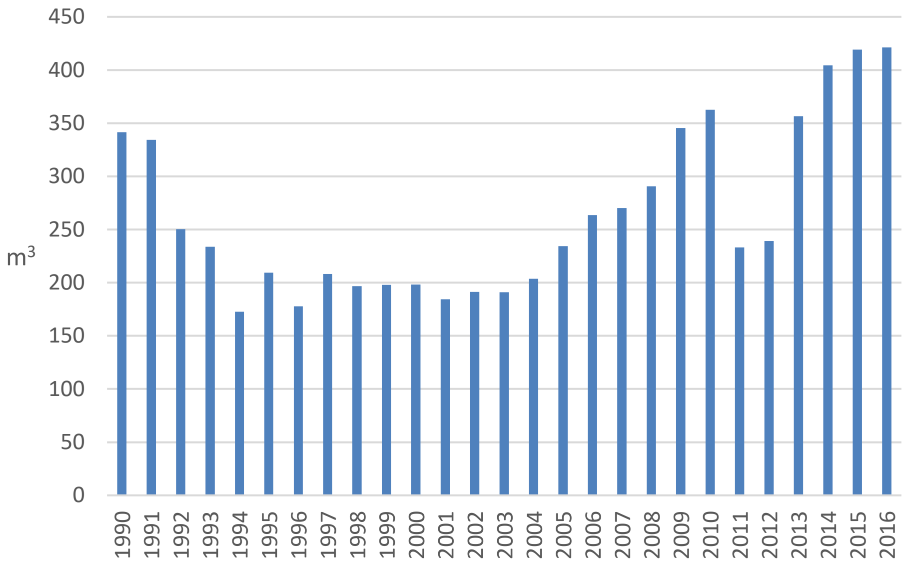

Figure 8. Birch wood harvested from NBF and CF plantations in NBF.

To explore cuttings in CF a list of thinnings and clear cuttings in the RP (2002-2009) was constructed from data from all four regions of IFS (See Annex 1 in this report). Thinned stands were 263 and only two were clearcut. The total area of thinned stands was 213.6 ha, thereof were 148.9 ha thinned in FrF. Most of thinned stands were in plantations in NBF and in some cases the native birch was felled in shelterwood felling. The clearcut was 4.5 ha, all in FrF category and only in the years 2008 and 2009 (See Figure 9).

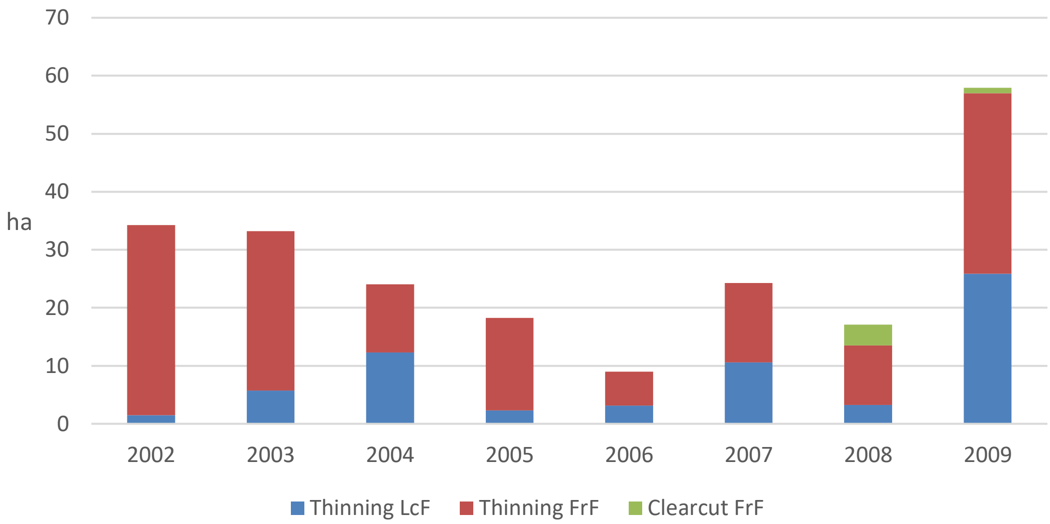

Figure 9. Cutting activity at IFS in the RP.

Larch was the most commonly thinned species group, with 31% of thinned area in category FrF in the RP. Next came slow growing spruces with 30%, Sitka spruce with 19%, Pine with 17%, Birch with 1.8 % and Black Cottonwood with only 0.4%. The only clearcut species was larch.

Although information on thinned volume and thinning strength is not complete for all thinned stands in the table of Annex 1 the data was analysed as shown in Table 6.

Table 6: To the left the table shows hectares thinned in each age class defined. Favourable thinning periods for species groups are marked with colours where green is first thinning, and light brown is second thinning. Thinning strength (%) weighted by area is shown to the right. Figures marked with yellow consist of only one measurement, but figures marked with brown consist of many measurements. Figures not marked with colour consist of few measurements. For three species groups extended age classes (41-60 years) fit better and are shown in the bottom line. Abbreviations for species groups: BC = Black Cottonwood, L = Larch, P = Pine, SS = Sitka spruce, S = other spruces.

	Ha thinned						Thinning strength				
Age class	Birch	BC	L	P	SS	S	BC	L	P	SS	S
1-10				0.47	0.00	0.29					
11-20			2.16	0.00	0.00	7.42		11%			
21-30		0.19	47.16	3.33	6.76	5.30	36%	**29%**			
31-40	0.13	0.57	11.77	7.06	3.36	5.03		38%	66%	55%	
41-50	0.71		14.38	16.11	30.13	24.13		**52%**	**20%**	**51%**	**17%**
51-60	0.26		9.62	5.45	4.48	7.68		66%	60%	63%	42%
61-70	1.56		0.00		0.22	1.03					
71-80			1.19					25%			
41-60				21.56	34.61	31.81			**31%**	**54%**	**24%**

Based on the information in Table 6, a thinning system was constructed for the species groups described (Table 7). As clearcut (100% cut in Table 7) was rare in the RP an expert judgement was used to define the age of clearcut considering the growth rotation length, when current increment crosses the mean annual increment as appropriate clearcut age.

Table 7: Thinning time, strength, and rotation length at clearcut (100% cut).

Species	**Age**	**% cut**
Black cottonwood	25	35%
Black cottonwood	50	100%
Pine	50	30%
Pine	70	100%
Sitka spruce	50	55%
Sitka spruce	75	100%
Slow growing spruce	50	25%
Slow growing spruce	90	100%
Larch	25	30%
Larch	50	50%
Larch	65	100%
Birch	50	50%
Birch	70	100%

It should be noted that only part of the CF is available for wood supply. The first attempt to estimate the area of Forest Available for Wood Supply (FAWS) resulted in 65% of the stocked area (net forest area) of CF being classified as FAWS (Snorrason 2016). In a harmonized

European project 35.2% of the forest area was defined as Forest Not Available for Wood Supply (FNAWS) and 37.2% of the above ground biomass (Snorrason et al. 2017). Since 2014 plot segments in the NFI have been classified into FAWS and FNAWS. These variables were used in the harmonized European project described above. The same information was used in this paper to classify plot segments into FAWS or FNAWS forest management practices for defined species groups.

3.2.4 Harvest data

As already mentioned in Chapter 2.1 the harvest data are from annual reports of production of wood, sold on the commercial wood marked in Iceland as reported in the Journal of the Icelandic Forest Association. The last reference is from 2017 (Gunnarsson and Brynleifsdóttir 2017), but the reports have been published with information of wood production annually since 1996. Total wood production is shown in Figure 10 measured in roundwood volume on bark. It increased dramatically in 2010 as economic markets for domestic wood opened, caused by the economic crash in late 2008.

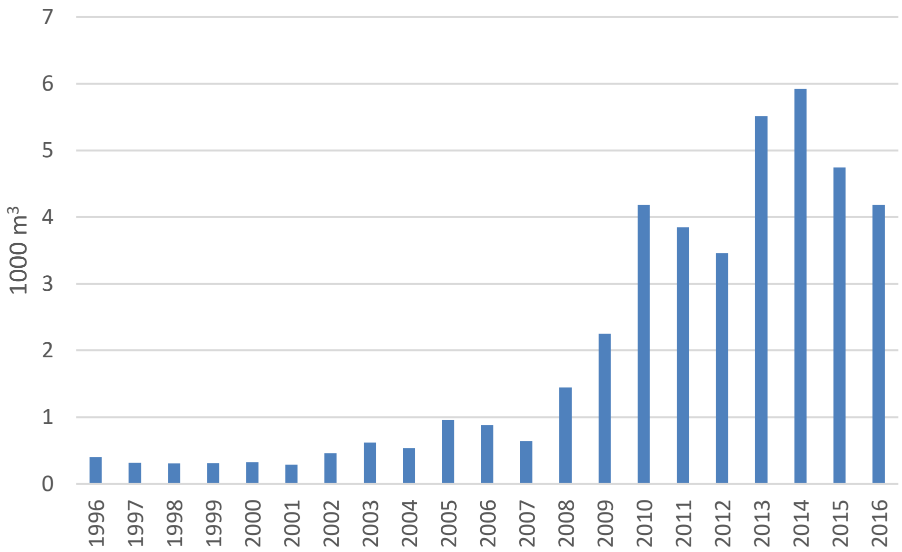

Figure 10. Total wood production sold on the marked in Iceland.

The wood production in the RP (2002-2009) mostly originates from the Forest Ranger regions at the Icelandic Forest Service (IFS) as shown in Figure 11. In some years the IFS was the only producer but more recently the share of other producers, such as forest farmers and forest societies, has increased. A slow increase in annual production from 2002 to 2008 with a sharp increase in 2009 is evident. The share of IFS was 85% during the RP. Total production in the RP was 7798 m^3 with mean annual production of 975 m^3. The total production of IFS during the RP was 6617 m^3 with mean annual production of 827 m^3.

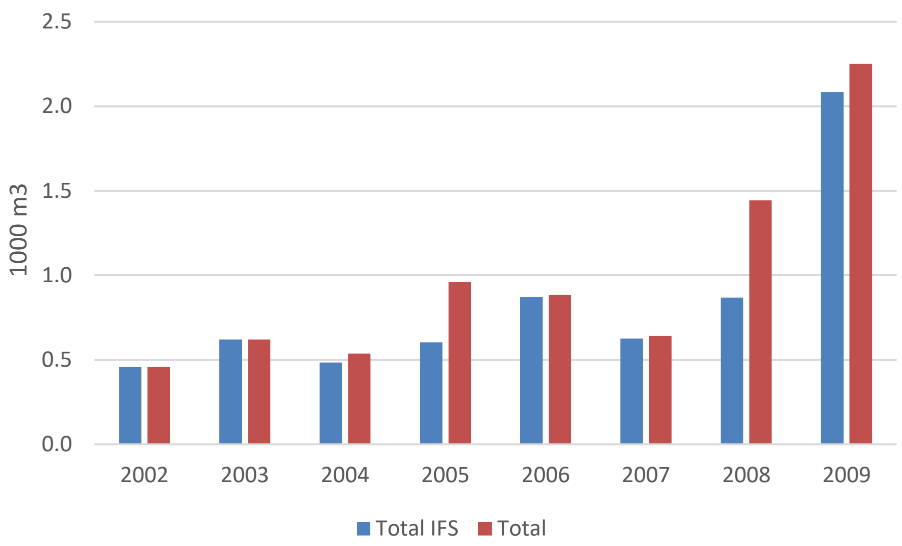

Figure 11. Comparison of wood production of the IFS and total production in the Reference Period.

It is possible to estimate the wood production from CF by subtracting the birch wood production from NBF. Of the birch wood removals in the RP 52% were from CF. Total production during the RP from CF was 6688 m^3 with mean annual production of 836 m^3. Total production of the IFS during the RP from CF was 5507 m^3 with mean annual production of 688 m^3.

It is not as easy to split the CF wood production between FrF and LcF categories. The area of each category can however be estimated based on the harvested area of the IFS were total area of thinned stands was 213,6 ha thereof were 148,9 ha thinned in FrF (69.7%). The stock fraction will be different as most of the cuttings before 50 years of age are with lower stock removals than cuttings after 50 years. Comparison of the first and second thinning in larch at age and strength given in Table 7 resulted in 18% lower stock removals in the first thinning compared to the second thinning. Larch stands represented 57% of the cutting area in the LcF category. Considering both area ratio and stock ratio of first thinning the partitioning of thinning in LcF is estimated to be around 21% of the total wood production.

To convert m^3 to dry biomass, default conversion factors given in table 3.A.1.9-1 in IPCC GPG (IPCC 2003) were used.

3.2.5 Documentation of stratification of managed forest land

The number of NFI sample plots used to characterise the FMP and for model projection is very small. Therefore, careful consideration of the stratification approach was required and, in the end, only two strata were defined:

1. **Natural birch forest (NBF).** The NBF is characterised by uneven aged forest and can be classified into non-wood utilisation and wood utilisation functions. The non-wood utilisation NBF class has more of a conservation and erosion management function representing most of the NBF area (86.997 kha in the RP). The remaining 0.64 kha of NBF are subject to selective cuttings where there is removal of larger trees on a cycle of ca. 60-100 years. There is no existing modelling framework for the NBF and the available data on the growth of the NBF wood utilisation strata would be too small to derive a robust estimation of biomass increment. Therefore, only one stratum will be

defined for the NBF, which will include both woody and non-woody utilisation functions. The IFS database on harvest was used to describe FMP for this stratum.

2. **Cultivated Forest (CF).** Because of a very limited number of sample-plots, an attempt to classify species groups into independent strata failed. Instead it was decided to define CF as one stratum despite its heterogeneity. This decision will not affect the quality of the process and the result as every plot-segment will be opted a suitable growth curve and forest management practices.
   Cultivated forests are for the most part even aged plantations with known planting year. Further description will be given in the next chapter.

The first stratum is identical to subclass NBF of the IC-GHGR. The second stratum originates from the two CF subclasses of FrF in the IC-GHGR.

3.2.6 Documentation of sustainable FMP as applied in the estimation of FRL

Classification into FMP classes was carried out using two dimensions:

a. The tree species measured with highest ratio of biomass at the initial state in the RP (measured in the first NFI 2005 -2009) in each plot segment.
b. Registration of plot segments into FAWS or FNAWS.

Description of FMP's:

1. **Black cottonwood (BC).** (*Populus trichocarpa*). Fast growing poplar with relative short rotation and high total yield on fertile soils. It was represented by 4 plot segments from the NFI and 2 stands in the IFS cutting activity database (CAD). Three of the plots were defined as FAWS.
2. **Pine (P).** Most of the pine forest was of lodgepole pine (*Pinus contorta*), rather fast growing with medium yield and rotation. Other pine species are slow growing: One stemmed Mountain pine (*Pinus mugo ssp. uncinata*), shrubby Mountain pine (*Pinus mugo ssp. mugo*) and Scots pine (*P. silvestris*). Pine was represented by 16 plot segments from the NFI and 44 stands in the IFS CAD. Nine of the NFI plots were defined as FAWS.
3. **Sitka spruce (SS).** Either Sitka spruce (*Picea sitchensins*) or Lutz spruce (*Picea x lutzii*). Slow growth in the beginning but high total yield on a rather long rotation. This species class was represented by 20 plot segments from the NFI and 67 stands in the IFS CAD. Eighteen of the plots were defined as FAWS.
4. **Slow growing spruces (S).** Norway spruce (*Picea abies*) is most prevalent. Other spruces are White spruce (*Picea glauca*) and Engelmann spruce (*Picea engelmannii*). Hemlocks are also included in this group. Slow growth with relative low yield on long rotations. This class was represented by 21 plot segments from the NFI and 77 stands in the IFS CAD. Seventeen of the plots were defined as FAWS.
5. **Larch (L).** Mostly Siberian or Russian larch (*Larix sibirica or Larix sukaczewii*). Fast juvenile growth with medium yield and rotation. It was represented by 8 plot segments from the NFI and 63 stands in the IFS CAD. All plots were defined as FAWS.
6. **Birch (B).** Native downy birch (*Betula pubescens*) predominates. Other slow growing deciduous tree species are included as well. Slow growth with relative low yield on medium rotation due to small stature. This class was represented by 13 plot segments from the NFI and 5 stands in the IFS CAD. Six of the plots were defined as FAWS.

The number of FMP's total 12 classes as in all cases both FMP with no cutting activity for forest defined as FNAWS and FMP with cutting activity defined as FAWS did occur. These assessments were done on the NFI plots as already described above. Table 8 shows estimated area of each FMP in CF during the RP.

Table 8: The area (in ha) of forest management practices for cultivated forest in the reference period. BC: Black cottonwood, P: Pine, S: Slow growing spruces, B: Birch, L: Larch, SS: Sitka spruce, FAWS: Forest available for wood supply, FNAWS: Forest not available for wood supply.

Species		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
BC	FAWS	0	0	0	0	0	0	54	54
BC	FNAWS	17	17	18	18	18	18	18	18
P	FAWS	119	119	121	124	124	124	124	124
P	FNAWS	68	68	69	70	70	70	70	70
S	FAWS	451	451	459	522	522	522	578	578
S	FNAWS	59	59	60	62	62	62	62	62
B	FAWS	139	139	142	145	145	145	145	145
B	FNAWS	221	221	224	229	229	229	230	230
L	FAWS	87	87	88	90	90	90	91	91
L	FNAWS	0	0	0	0	0	0	0	0
SS	FAWS	129	129	131	134	134	134	134	134
SS	FNAWS	0	0	0	0	0	0	0	0
Sum	FAWS	925	925	940	1014	1014	1014	1125	1125
Sum	FNAWS	365	365	371	379	379	379	380	380
Total	**Sum**	**1290**	**1290**	**1311**	**1393**	**1393**	**1393**	**1505**	**1505**

The NBF stratum had two FMP classes, similar to the CF. One with no cutting activity covering about 99.3% of the area and a small part with selective cutting practiced in the North and the East Forest Ranger regions of IFS. Both FMP's do not change in area in the RP.

3.3 Detailed description of the modelling framework as applied in the estimation of the forest reference level

3.3.1 Natural Birch Forest

As NBF are without defined age classes and estimated by the stock difference method they are processed separately from CF. Mean annual net removal (MANR) to the C-stock pool of biomass was in IC-GRGR-2016 was estimated to be -13.13 kt CO_2. Direct extrapolation of the mean annual removal was used for the years beyond 2007 until 2025 with proportional subtraction of forecasted annual loss of area caused by deforestation. The same modelling framework was used to predict net CsC of the biomass in the CP. A new inventory of NBF that will be finished in autumn 2020 will make comparison of the biomass between 2007 and 2017 possible, shortening the extrapolation period by ten years. This new information will without doubt lead to improvement of the IC-GHGR and consequently technical correction the FRL.

Harvest, like other biomass losses, is included in the MANR. Nevertheless, any change in relative harvest rate will affect the MANR, so unchanged relative harvest rate from the biomass stock comparing period was a precondition of using this approach. Although wood removal from NBF from 1990 to 2009 showed interannual fluctuation (Figure 7), no decreasing or increasing trend was present. Note that the period 1990–2009 almost overlaps the biomass stock comparing period of the NBF which is 1987-2007.

To predict the same harvest activity level in the Compliance Period (CP), Alternative 2 in Box 12 in the G-FRL was used. The C-stock in NBF was estimated to be 658 kt C in 2007 with mean annual increase of 3.58 kt C between 1987 and 2007 (Hellsing, et al. 2018). Mean C stock in NBF was thus 653 kt during the RP. Mean annual harvest from NBF during the RP was 157 m^3 or 48 t C. The harvest fraction was thus 0.0073%. Predicted average C-stock of NBF in 2021-2025 was 715 kt. Mean annual harvest from NBF in the CP was then predicted to be 52 t C. All harvest beyond the predicted amount during the CP will decrease the MANR and will be calculated as a debit in relation to FRL. In the same manner all harvest below predicted harvest will be calculated as credit in relation to FRL.

Emission from drained organic soil was calculated by the area of NBF on drained organic soil which was predicted to be unchanged at 0.084 kha. Emission factors used were the same as used in IC-GHGR-2016 with the same assumptions regarding ditch size and distance (Table 9).

Table 9: Factors used to estimate GHG emission from forest on drained organic soil.

	Source	Units/ha	CO_2 eq. t/ha
Direct CO_2 emission in C t/ha	IPCC	-0.37	1.36
Off-site CO_2 emission in C t/ha	IPCC	-0.12	0.44
N_2O emission in N_2O-N kg/ha	CS	-0.44	0.21
CH_4 emission in kg/ha	IPCC	-7.37	0.18
Sum emission effect			2.19

Annual emissions from drained organic soils were estimated to be the same during the CP as during the RP as the area of NBF on drained organic soils was assumed to be unchanged.

3.3.2 Cultivated forest

Prediction of CP values of CF were more in line with the method described in G-FRL. C-stock densities of trees (C t/ha) on plots or plot segments classified by species classes were compared to growth curves of C-stock in tree biomass at different ages (planting age) as shown in Figure 12 for Sitka spruce. The C-stock densities were measured in the first NFI round 2005-2009. When forwarding the C-stock change, the relative distance to nearest growth curve was calculated as the C-stock measured/C-stock in curve at same age. This factor was used to calculate biomass C-stock in trees in the CP for each plot segment separately. As the growth curves only predict current biomass C-stock at different ages and not the total yield of the forest, and stocks from thinning are not added to the curve, only clearcutting will affect the C-stock of the site. In cases were the plot segment is defined as FAWS and the age will reach defined clearcut age as given in Table 7 above, C-stock of trees was set to 0 at the time of reforestation. C-stock on these plots was then predicted by the same yield curve again assuming no change in tree species on each particular plot segment. In the case of plot segments defined as FNAWS, clearcut is omitted and CsC continues as the biomass curve shows until it reaches equilibrium.

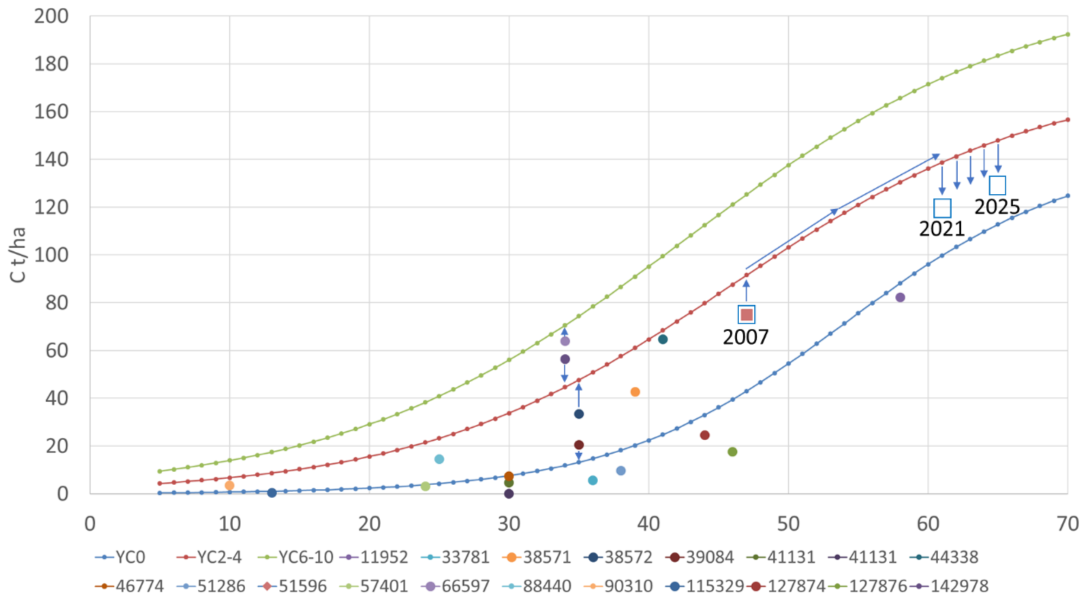

Figure 12. C-stock in plot segments dominated by Sitka spruce measured in the first NFI inventory 2005-2009 (illustrated with dots and number labels, the ID number of the plots) in relation to three growth curves for different growth classes (illustrated with whole line with dots and labels: YC0, YC2-4, YC6-10) showing C-stock of biomass at different age (planting age = year from planting + 1 year). Arrows show how the nearest growth curve is used to predict the development of the tree biomass on plot segments.

Harvest output was estimated for each plot segment by using age and cutting ratio given in Table 7. To make the harvest output more flexible and realistic, harvest from each plot segment was spread evenly over five years with the "trigger" age in Table 7 as the midyear. Plot segments classified as FNAWS had, by definition, no harvest output. C- stock of cut trees left in the field or lost on the way to the market were subtracted from the gross C-stock. Species wise factors between C-stock of the stem and the whole tree were calculated from single biomass functions (Snorrason and Einarsson 2006). These factors were from 0.29 to 0.34. Stem leftover on the cutting fields was estimated to be 25% by the forest rangers of the IFS. Crooked and damaged trees are just cut and not removed from the forest. The forest rangers assumed that transport and process losses are 5% until merchantable roundwood is fully prepared for sale. Total loss of harvested roundwood was accordingly estimated 30%.

Emissions from drained organic soil were calculated by the area of CF on drained organic soil. Development of the area of drained organic soil in CF is shown in Figure 13 below. Emissions factors used are the same as used in IC-GHGR-2016 with the same assumptions regarding ditch size and distance (Table 9).

As already described in Chapter 2.1.3.1 above, only new occurrences of lying deadwood (DW) with diameter ≥ 10 cm and length ≥ 1.3 m measured on NFI plots are reported in IC-GHGR-2016 as CsC of DW. DW was first measured in the first CF NFI 2005-2009 and reported in the years 2002, 2003 and 2009. All logs reported in the RP where measured again in CF in the second NFI 2010-2014.

The rationale for estimating deadwood in CP was:

1. Calculate mean annual CsC in DW stock in the RP
2. Assume same mean annual CsC in DW per area unit in CF in 2021-2025
3. Calculate mean annual CsC DW kg/ha in 2002-2009 ($CsCDW_{RP}$)
4. Annual CsC in DW in 2021-2025 is then estimated as $CsCDW_{RP}$ x CF-$area_{CP}$

As already mentioned in Chapter 2.1.3.1, the DW C-stock estimation in the IC-GHGR is incomplete and must go through total recalculation along with other pools, for instance the litter pool. Future technical correction is needed to include dead wood in stumps, root stock and standing dead trees and to include continuous decomposition of the DW stock. The solution will probably be to introduce and adapt a CsC simulation model such as the Canadian Forest Service Carbon Balance Model.

Currently no natural disturbance has been reported in the IC-GHGR. Natural disturbances were therefore excluded in the model work. Its provision will be considered after the 1st compliance period and a reanalysis of the historic fire/blow-down data set to define a background level for natural disturbance was postponed.

3.3.3 Harvested wood products

The inflow stock of sawnwood, the only long-lived harvested wood products pool produced from domestic wood, was calculated by the ratio between sawnwood C-stock and the C-stock of the total annual wood production in the period 2002-2009 (RP) in accordance to Chapter 2.5.6 in the G-FRL. The volume ratio was rather stable during the RP as shown in Table 4. It was assumed that the sawnwood stock originated only from fellings in FrF as the sawnwood portion of fellings in younger forests is negligible. The mean ratio between C-stock in sawnwood and C-stock in total wood production was for the RP 3.1%. The same conversion factor to convert m^3 into tons C was used as in the IC-GHGR-2016. This was done although the factor was found to be incorrect in the IC-GHGR-2016 as it only converts m^3 into tons dry biomass. So, the C input to the HWP pool was overestimated by a factor of 2. This led to correction of the HWP calculation in the IC-GHGR-2017 and will result in future technical correction of the HWP portion in the FRL.

4 Forest reference level

4.1 Forest reference level and detailed description of the development of the carbon pools

4.1.1 Area

As area affects the C-stock estimate heavily, its development is described in detail below. Estimation methods were described in Chapter 1.1.3 above.

4.1.1.1 Natural birch forest (NBF) older than 50 years

The area of NBF was estimated 87.7167 kha in the year 2000. In 2015 and 2016, 3.0 and 0.5 ha of NBF was deforested. NBF in the end of 2016 was then 87.7133 kha. Deforestation of 3.5 ha in 17 years translates to 0.206 ha/year and was assumed to be the average annual deforestation rate in the future period of 2017-2025. The area of NBF was then predicted to be 87.7122 kha in 2021 and 87.7113 kha in 2025. Drained organic soil was assumed to be unchanged at 0.08 kha.

4.1.1.2 Subcategories of Cultivated forest (CF)

Subcategories of cultivated forest under FrF were handled together as these classes were merged into one stratum. Plantation in NBF was assumed not to happen as it is now prohibited by the nature conservation law. Prediction of area increase every year was rather easy as the ages of the plantations on sample plots are known. CF afforestation was added annually to the area of FrF when reaching age over 50. Figure 13 shows how the area of CF in FrF will increase until 2025. Afforestation on drained organic soils was handled separately as it was reported with GHG emission from soils. No deforestation of CF FrF was reported for the period 2000 – 2016 so predicted deforestation was set to zero. Area of plantations in NBF will increase from 1.16 kha in the year 2000 to 1.18 kha in 2025. Afforestation older than 50 years on mineral soil will increase from 0.18 kha in 2000 to 2.08 kha in 2025 and afforestation older than 50 years on drained organic soil will increase from 0 kha in 2000 to 0.10 kha in 2025. It must be noted that the number of plots or plot segments representing each of the three classes were very few as shown in Table 10 and are not statistically significant in many instances.

Table 10: Number of sample plot segments representing the area of subclasses in CF under FrF.

	2000	2009	2016	2020	2025
Plantation in natural birch forest	32	33	33	33	33
Afforestation on mineral soil	4	9	24	41	55
Afforestation on drained organic soil	0	0	1	2	2
Sum	36	42	58	76	90

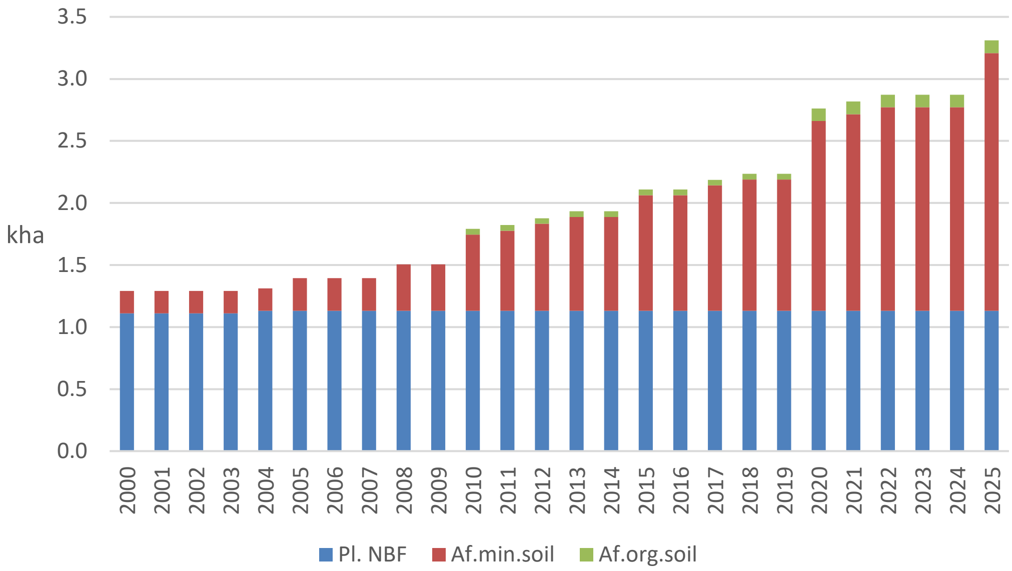

Figure 13. Area change with time of CF under FrF (> 50 years old). Pl. NBF: Plantations in Natural birch forest. Af.min.soil: Afforestation on mineral soil. Af.org.soil: Afforestation on drained organic soil.

4.1.2 GHG emission from drained organic soils

GHG emissions from drained organic soils is directly linked to the development of the area of drained organic soil described above in Chapter 4.1.1. Emissions factors used are given in Table 9. The area of FrF on drained organic soil increases from 80 ha in 2002-2009 to 126 ha in 2010-2019 and then rises again to 182 ha in 2020-2025.

Development of GHG emissions in C-equivalents for all four sources of Table 9 is shown in Figure 14.

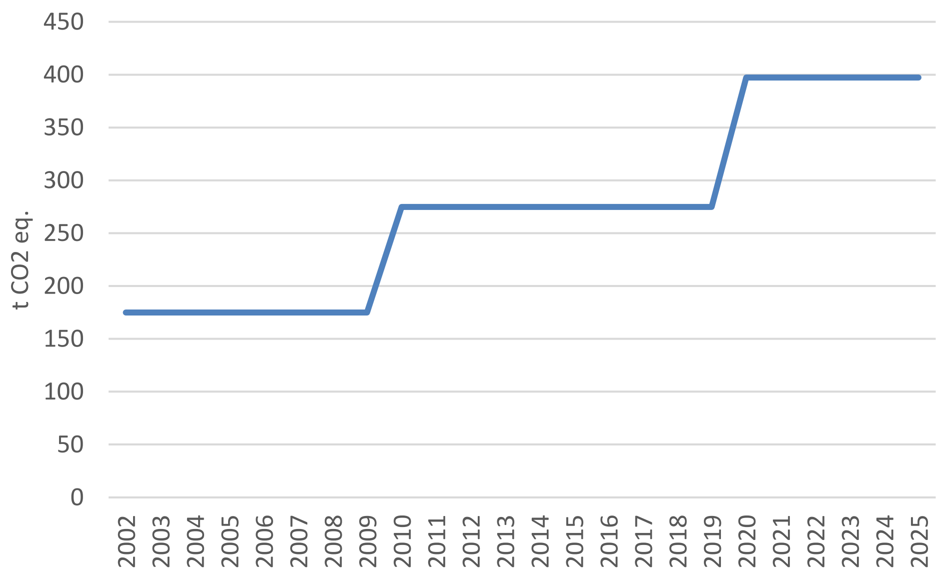

Figure 14. Development of GHG emissions from drained organic soils in tonnes CO_2 eq. for all four sources of Table 9.

4.1.3 C-stock in biomass

When predicting future growth, no attempts were made to incorporate the effect of climate change on growth rate. Growth estimates of both NBF and CF are historical. The growth curves of CF are built on measurements of forest growing in the period 1950-2000 and the biomass growth of the NBF were measured in the period 1987-2007. New measurements that can update these growth data can possibly lead to technical correction of the FRL.

4.1.3.1 Natural birch forest (NBF) older than 50 years

As future growth of NBF is assumed to be unchanged as long as the area is unchanged, the C-stock net change follows the development of the area as the GHG emission of drained organic soils. Net removal to the biomass stock is -13.13 kt CO_2 eq. on the initial area of NBF (87.7167kha), resulting in - 0.15 t CO_2 ha^{-1} yr^{-1} in annual C-stock removal to the biomass stock. Given the change in area caused by reported and predicted deforestation, the change in net CsC will be negligible or -13137.97 t CO_2 in 2021 and -13137.85 t CO_2 in 2025.

It should be highlighted that the constant net removal depends on constant harvest rate, as described in Chapter 4.1.4, of the prediction of wood production in NBF.

4.1.3.2 Subcategories of Cultivated forest (CF)

Figure 15 shows net CsC due to removal to biomass of trees. As pointed out in Chapter 4.1.1.2 the area of the stratum increases every year when afforestation areas reach more than 50 years in age and are moved from LcF to FrF. Notice that these figures are not gross CsC gain and will in Chapter 4.2.1 be calibrated and adjusted.

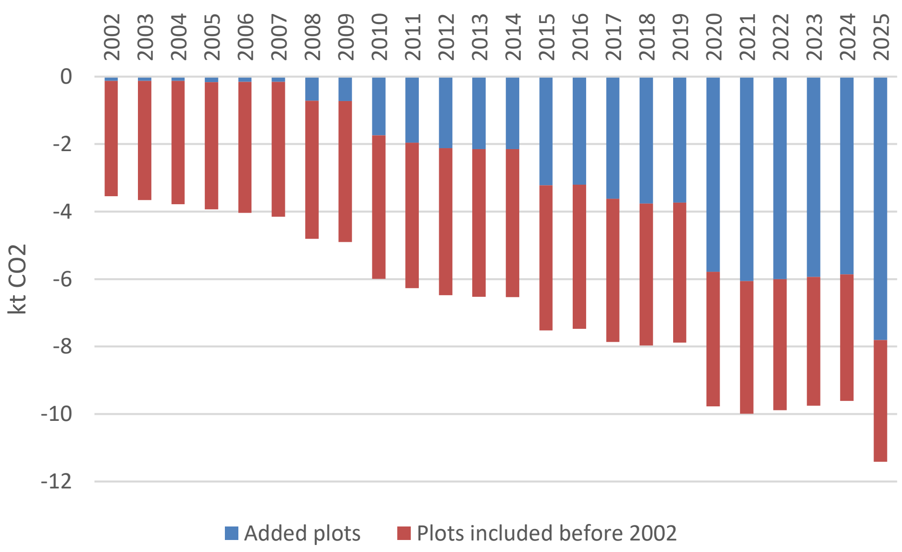

Figure 15. Net CsC due to removal of trees in the CF-stratum. CsC estimated on the basis of plots that where already included in the FrF category in the year 2002 are in red but CsC for plots added to the stratum after 2002 are in blue.

4.1.4 C-stock in wood production

Although harvest in NBF is included in the estimated mean annual net removal (MANR) from the C-stock pool of biomass as explained in Chapter 3.3.1. above, increased or decreased harvest rate will affect the MANR. With the same harvest ratio, mean annual harvest from NBF during the CP is predicted to be 0.192 kt CO_2. All harvest beyond/below the predicted amount in CP will decrease/increase the MANR and will be calculated as a debit/credit in relation to FRL.

Despite the 5 year spread in CF cuttings in an attempt to level out artificial variation, annual values of modelled C-stock in wood production have high interannual variation due to the low number of plots in the source data (See Figure 16). Practical constraints will even out such fluctuations.

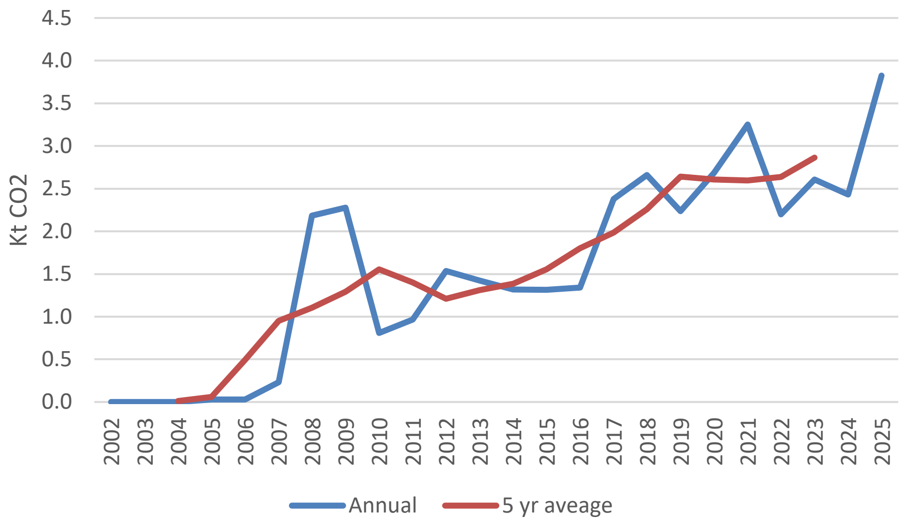

Figure 16. Annual values of modelled C-stock in wood production of CF (blue line) and 5 year running midyears averages (red line).

It is more informative to present this data as annual averages in periods as done in Figure 17. Actual reported figures are shown as well in Figure 17.

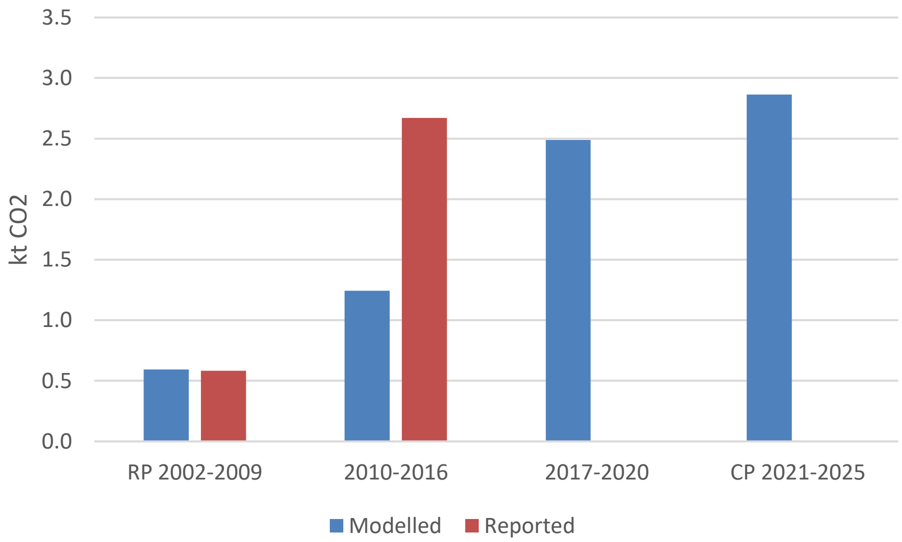

Figure 17. Modelled and reported mean annual C-stock loss to wood production from CF divided in periods including historical periods for both reported figures and modelled estimates and modelled estimates for future periods.

4.1.5 CsC in deadwood

The estimated CsC in DW in the RP (2002-2009) was -7.9 t CO_2. Mean CF area in 2005-2009 was 1385 ha. Mean annual CsC in DW was -5.7 kg CO_2/ha. Table 11 shows estimated CsC in DW in the CP.

Table 11: C stock change in Dead wood of CF.

Year	Area	DW CsC
	ha	kt CO_2
2020	2761	-0.016
2021	2817	-0.016
2022	2873	-0.016
2023	2873	-0.016
2024	2873	-0.016
2025	3310	-0.019

Increase (gain) of C-stock of DW is reported as loss of C-stock from the biomass stock.

4.1.6 C-stock in harvested wood products

Figure 18 shows the reported and modelled inflow of C-stock into the only domestic HWP pool in Iceland, the sawnwood pool. Modelled figures were estimated on the basis of modelled harvest production from FrF assuming same mean ratio of the C-stock between non-energy use and energy use in the RP (2002-2009) (3.2%). It should be noted that the market for domestic sawn timber is both young and small and therefore prone to proportionally large annual fluctuations. Because of huge interannual variation in the modelled wood removals, it is more informative to show the mean annual input in periods as was done in Figure 17.

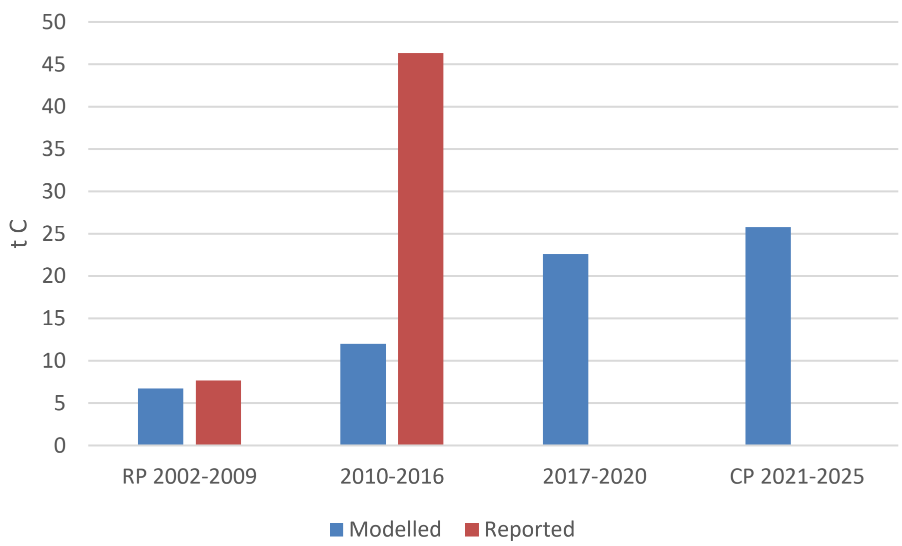

Figure 18. Modelled and reported mean annual inflow of the C-stock into the HWP pool from both CF and NBF divided into periods including historical periods for both reported figures and modelled estimates and modelled estimates for future periods.

In Figure 19 the development of the CsC in modelled HWP is illustrated. In the decay model, reported input values of sawnwood C-stock were used until 2009. Modelled input values were used in the period 2010-2025.

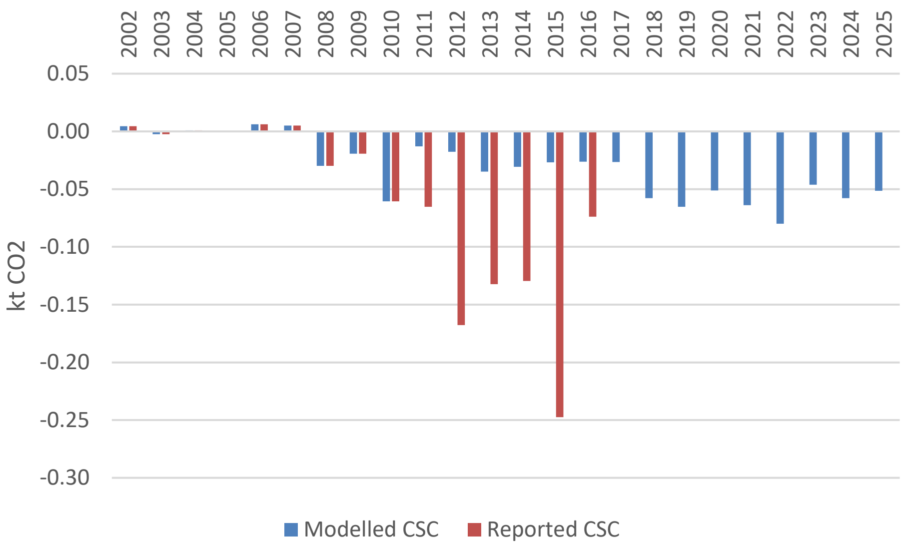

Figure 19. Development of the CsC in HWP for both modelled HWP CsC from 2010 and onward and as reported in the IC-GHGR-2016.

4.2 Consistency between the FRL and the latest national inventory report

Verification between modelled or predicted values and reported values in the IC-GHGR-2016 is done in this chapter. If CsC in C-pools differ, verification was done in accordance with methods described in Chapter 2.4. in G-FRL. The first step was verification of level and trend and the second step an adjustment of predicted estimates.

4.2.1 C-stock in biomass in stratum CF

As described in Chapter 3.3.2, the growth curves used only estimate the living biomass stock each year in CF, not the production or yield of the forest. Thinning and natural mortality are not detected, and annual gross gain is therefore not estimated, just the net annual biomass changes from year one to the end of rotation. This will obviously lead to underestimation when compared to gain estimation in the IC-GHGR. To verify the consistency of the two estimates, wood production, stem residues (30% of wood production) and crown, stump and belowground fractions (85% of stem C-stock) of harvested trees from actual management practice were subtracted from the CsC gain estimate in IC-GHGR-2016. Figure 20 shows comparison of reported and modelled net C-stock change of biomass in 2002-2016. In addition, increase in CsC with change in rotation length on plot segments that should have been clearcut before 2016 according to Table 7 will add to the net biomass CsC although the size of this effect is not calculated here. A possible explanation of the difference between modelled and reported net CsC value can be the incompleteness of the CsC estimates of biomass in the IC-GHGR-2016, where loss calculation of other parts of cut trees than harvested wood and natural mortality is lacking as pointed out in Chapter 2.1.3.2 above. Future improvement of these estimates will possibly reduce the difference between modelled and reported values.

The differences in level was rather big were average reported net CsC was around 61% of the size of modelled average value with absolute mean differences of -3.3 kt CO_2. Compared to the estimated FRL of -34 kt CO_2, the difference is around 10%.

Despite these differences, the comparison of reported and modelled values passed the verification test of level, described on pages 72-73 in the G-FRL, with the upper level of standard deviation of modelled net CsC (1.826 Kt C) overlapping the lower level of standard deviation of reported net CsC (1.595 Kt C), as shown in the average column in Figure 20. Verification of trend passed as well since inter-annual variability was much higher in the reported values than in the modelled values, as can be seen in Figure 20, and trendlines of 5-year moving averages turned out to have very similar slope of linear regression as shown in Figure 21.

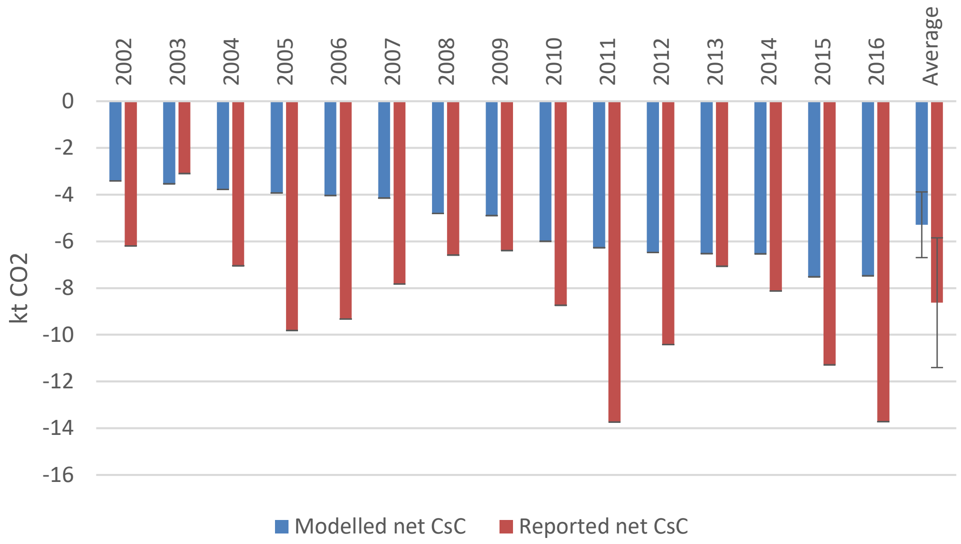

Figure 20. Reported and modelled net C-stock change in biomass in 2002-2016. Average is the average of the CsC values for the 2002-2016. Error bars on Average column denote the standard deviation of CsC values.

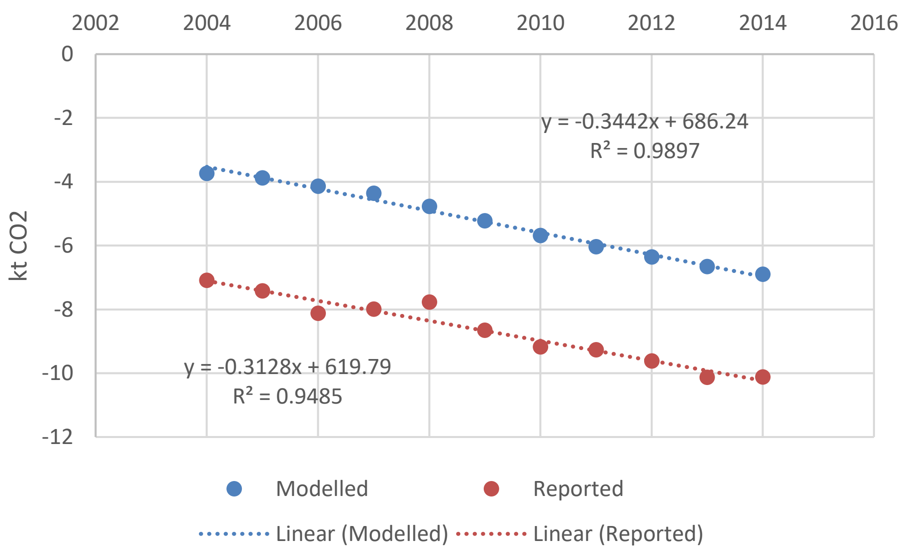

Figure 21. Five-year moving averages of reported and modelled net C-stock change of biomass in 2002-2016 with linear regressions.

Considering the consistency in trend, adjustment of the time series was done by moving the modelled values by the average difference between reported and modelled values in RP (2002-2009) (offset method). This value is in this case -2.968 kt CO_2 and its relative impact on the FRL is 9.6%. The adjusted time series of net CsC of biomass together with modelled, reported and 5 years moving average of the reported series is shown graphically in Figure 22 below.

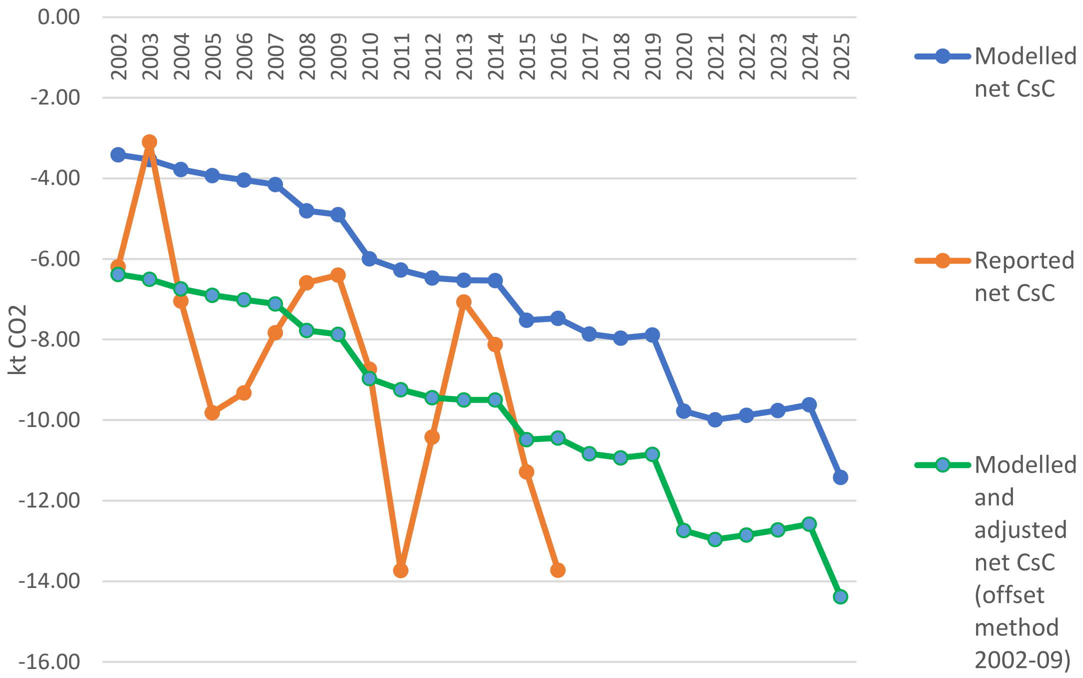

Figure 22. The adjusted time series of net CsC of biomass together with modelled and reported series.

Further, to get an estimate for gross CsC to biomass (biomass gain), modelled C-stock removals from biomass caused by felling must be added to the adjusted net biomass CsC for the model period 2010-2025. Figure 23 shows then projected value of the C-stock gain in biomass from 2010-2025.

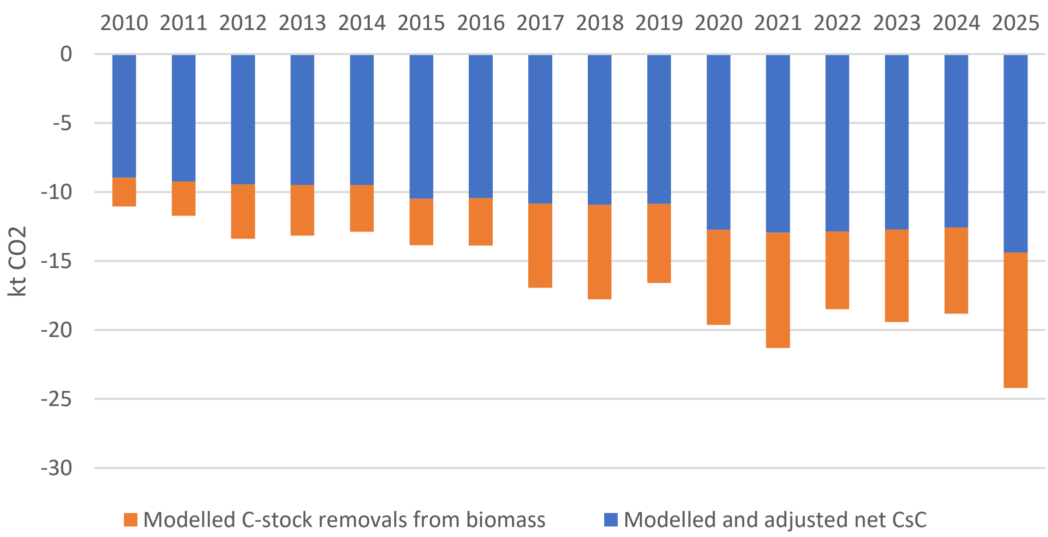

Figure 23. Projected value of the C-stock gain (gross CsC) to biomass for 2010-2025 consisting of adjusted model of net CsC of biomass and total C-stock removals from modelled cutting activity.

4.2.2 CsC and GHG fluxes in other pools and sources than in biomass in stratum CF

C-stock of wood production from CF was modelled almost the same size in the RP as the reported value (Figure 17). An average annual figure for 2002-2009 was modelled 0.594 kt CO_2 compared to 0.582 kt CO_2 for the reported value, so the conclusion was not to adjust the modelled value against the reported one.

Modelled and reported value of HWP input was also rather similar with an average annual figure for the RP of 6.7 t C modelled versus 7.7 t C reported (Figure 18). It was decided not to make any adjustment of the model as these figures are very small and would cause immeasurable change to the estimated FRL. Furthermore, the HWP will be recalulated due to the known error of the conversion of m^3 to tonnes C as described in Chapter 3.3.3 above. Technical correction of the HWP CsC estimate is therefore already planned.

Other pools and sources had their predictions as direct products of reported values or were calculated by the same methods as reported values and consequently needed no special verification or adjustment:

1. CsC in biomass in NBF. Projected by extrapolation with identical annual CsC in modelled period (2010-2025) as in the RP (2002-2009) (See chapter 3.3.1 above).
2. CsC of harvest in NBF. Projected by the ratio between mean annual harvested and living C-stock in RP (0.0073%). The ratio was used to calculate projected harvest (See chapter 3.3.1 above). Modelled figures are identical to reported figures in the RP.
3. Emissions from drained organic soil. Calculated as in the IC-GHGR-2016 with fixed emission factors per area unit. (See Chapter 3.3.1., 4.1.2 and Table 9 above). Modelled figures are identical to reported figures in the RP.
4. CsC in dead wood in the CF. Projected by using ratio between mean annual CsC of DW as estimated and reported in the IC-GHGR-2016 for the RP (2002-2009) and the mean area in of CF in RP. (See chapter 4.1.5 above). Modelled figures are identical to reported figures in the RP.

4.3 Historical and projected harvest rates in FrF

Historical harvest rates for both FrF and LcF are shown in Table 4 (Chapter 2.1.4 above). The only non-energy use wood product is sawnwood. Other wood use is defined as for energy use. As mentioned in Chapter 3.2.4 above, thinnings in LcF were estimated to be 21% of the total wood production in the RP (2002-2009). We assume that sawnwood originates only from FrF, as only late thinning and final harvest yield roundwood of size and quality suitable for sawnwood production. Sawnwood production from birch wood and accordingly NBF is indiscernible. Figure 24 shows the historical harvesting rates in FrF disaggregated between energy and non-energy uses. The ratio of the C-stock between non-energy and energy use is kept constant at 3.2 % as it was in the RP (2002-2009) as shown in Chapter 4.1.6 above.

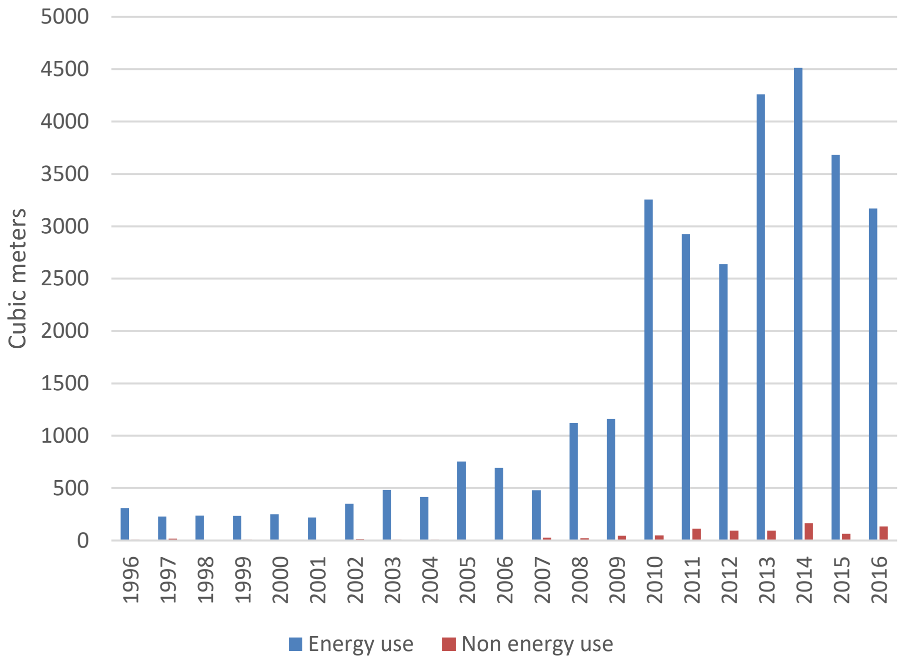

Figure 24. Historical harvesting rates in FrF disaggregated between energy and non-energy uses. The volume of wood for energy use is measured on bark but the non-energy use volume is without bark.

Figures 16, 17 and 18 (Chapter 4.1.4 and 4.1.6 above) show the projected and reported (Fig. 17 and 18) CsC from biomass to wood production and from wood production to sawnwood, the only non-energy HWP produced from domestic harvest in Iceland.

To illustrate CsC as a volume, C-content was multiplied with 1/0.5 (C content of the biomass of wood = 0.5) and the biomass was multiplied with 1/0.458 (biomass of a cubic meter = 0.458). Figure 25 shows reported and predicted harvesting rates for FrF divided into wood for energy use and wood for non-energy use.

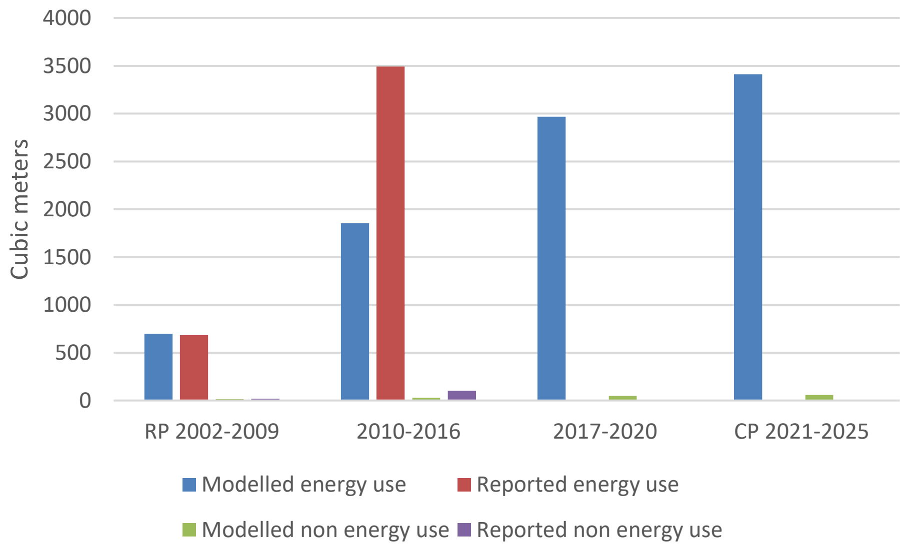

Figure 25. Average historical and predicted annual harvesting rates in FrF disaggregated between energy and non-energy uses for four time periods including RP and CP.

4.4 Calculated CsC and GHG emission for the forest reference level

The result in estimating the Forest Reference Level (FRL) for Iceland is shown in Table 12, the final column showing the mean value for each component of the FRL for the first Compliance Period. FRL was calculated with and without HWP CsC as requested in the regulation.

Table 12: The Forest Reference Level for Forest remaining Forest divided into strata and summarized with and without projected Harvested Wood Products CsC.

Stratum Natural birch forest (NBF)	**2021**	**2022**	**2023**	**2024**	**2025**	**Mean**
Area kha	**87.712**	**87.712**	**87.712**	**87.712**	**87.711**	
Net C stock change in biomass kt CO_2	-13.138	-13.138	-13.138	-13.138	-13.138	-13.138
C stock in wood production kt CO_2 *	0.190	0.191	0.192	0.193	0.194	0.192
Direct CO_2 emission from drained organic soils kt CO_2	0.109	0.109	0.109	0.109	0.109	0.109
Off-site CO_2 emission from drained organic soils kt CO_2	0.035	0.035	0.035	0.035	0.035	0.035
N_2O emission from drained organic soils kt CO_2 eq.	0.016	0.016	0.016	0.016	0.016	0.016
CH_4 emission from drained organic soils kt CO_2 eq.	0.015	0.015	0.015	0.015	0.015	0.015
Sum net C-stock change for NBF kt CO_2 eq.	**-12.963**	**-12.963**	**-12.963**	**-12.963**	**-12.963**	**-12.963**
*Included in the net C-stock change in biomass						

Stratum Cultivated forest (CF)	**2021**	**2022**	**2023**	**2024**	**2025**	**Mean**
Area kha	**2.866**	**2.922**	**2.922**	**2.922**	**3.359**	
C stock gain in biomass kt CO_2	-21.310	-18.499	-19.414	-18.828	-24.203	-20.451
C stock loss in wood production kt CO_2	3.254	2.201	2.606	2.433	3.825	2.864
C stock change in dead wood kt CO_2	-0.016	-0.016	-0.016	-0.016	-0.019	-0.017
Direct CO_2 emission from drained organic soils kt CO_2	0.138	0.138	0.138	0.138	0.138	0.138
Off-site CO_2 emission from drained organic soils kt CO_2	0.045	0.045	0.045	0.045	0.045	0.045
N_2O emission from drained organic soils kt CO_2 eq.	0.021	0.021	0.021	0.021	0.021	0.021
CH_4 emission from drained organic soils kt CO_2 eq.	0.019	0.019	0.019	0.019	0.019	0.019
Sum net C-stock change for CF kt CO_2 eq.	**-17.851**	**-16.093**	**-16.602**	**-16.189**	**-20.175**	**-17.382**

Forest remaining Forest (FrF) excluding HWP	**2021**	**2022**	**2023**	**2024**	**2025**	**Mean**
Sum net C stock change kt CO_2 eq.	**-30.814**	**-29.056**	**-29.565**	**-29.152**	**-33.138**	**-30.345**

	2021	**2022**	**2023**	**2024**	**2025**	**Mean**
C stock change to Harvested Wood Products kt CO_2	**-0.064**	**-0.080**	**-0.046**	**-0.058**	**-0.051**	**-0.060**

Forest remaining Forest (FrF) including HWP	**2021**	**2022**	**2023**	**2024**	**2025**	**Mean**
Sum net C stock change kt CO_2 eq.	**-30.877**	**-29.136**	**-29.611**	**-29.210**	**-33.189**	**-30.405**

As highlighted before it is clear that IC-GHGR has to go through thorough restructuring and recalculation as some sources are incomplete or missing. The solution will probably be to incorporate tools, such as a CsC simulation model, such as the Canadian Forest Service Carbon Balance Model. Improvement of the IC-GHGR is therefore expected in the nearest future and the FRL reported here will consequently go through technical correction.

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ANNEX 1. Stands from the cultivated forest of Icelandic Forest Service with cutting activity in the period 2002-2009

Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
LcF	Birch	B	1970	2005	36	0,04											
FrF-P.inNBF	Birch	B	1973	2009	37	0,09											
FrF-P.inNBF	Birch	B	1963	2003	41	0,71											
FrF-P.inNBF	Birch	B	1949	2004	56	0,26											
FrF-A.old.th.50yrs	Birch	B	1941	2005	65	1,56											
LcF	Black cottonwood	BC	1989	2009	21	0,19					11,7	60,0	0,33	19,6	C0	60,6	32%
FrF-P.inNBF	Black cottonwood	BC	1970	2003	34	0,57											
LcF	Larch	L	1997	2007	11	0,61											
FrF-P.inNBF	Larch	L	1997	2007	11	0,15											
LcF	Larch	L	1987	2006	20	1,40					7,1	5,1	0,40	2,0	G10	17,7	11%
LcF	Larch	L	1982	2002	21	1,50					35,7	23,8	0,40	9,4	G10	18,7	51%
LcF	Larch	L	1986	2007	22	4,10					1,4	0,3	0,40	0,1	G10	19,7	1%
LcF	Larch	L	1984	2005	22	0,70					4,3	6,1	0,40	2,4	G10	19,7	12%
LcF	Larch	L	1982	2003	22	0,80					14,3	17,9	0,40	7,1	G10	19,7	36%
LcF	Larch	L	1983	2004	22	3,70											
LcF	Larch	L	1985	2006	22	0,27											
FrF-P.inNBF	Larch	L	1981	2002	22	3,75											
FrF-P.inNBF	Larch	L	1981	2002	22	6,74											
LcF	Larch	L	1985	2007	23	1,50	Yes										
LcF	Larch	L	1984	2006	23	1,00											
FrF-P.inNBF	Larch	L	1979	2002	24	0,51											
LcF	Larch	L	1985	2009	25	0,71											
LcF	Larch	L	1984	2009	26	1,43											
LcF	Larch	L	1978	2004	27	0,50					5,7	11,4	0,40	4,5	G10	25,2	18%
LcF	Larch	L	1983	2009	27	0,58	No	67	41	38%							
LcF	Larch	L	1983	2009	27	0,92	No	81	50	39%							
LcF	Larch	L	1983	2009	27	1,00	No	106	75	29%							
LcF	Larch	L	1983	2009	27	1,75	No	107	53	51%							
LcF	Larch	L	1983	2009	27	0,99	No	108	50	54%							

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LcF	Larch	L	1983	2009	27	0,64	No	112	49	56%							
LcF	Larch	L	1978	2005	28	1,02											
LcF	Larch	L	1980	2007	28	1,71											
FrF-P.inNBF	Larch	L	1973	2002	30	11,34											
FrF-P.inNBF	Larch	L	1970	2002	33	2,75											
LcF	Larch	L	1968	2003	36	2,77											
LcF	Larch	L	1969	2004	36	0,62											
LcF	Larch	L	1968	2004	37	0,38											
LcF	Larch	L	1968	2004	37	1,30											
FrF-P.inNBF	Larch	L	1967	2003	37	2,40											
LcF	Larch	L	1966	2003	38	0,35											
LcF	Larch	L	1970	2009	40	1,10											
FrF-P.inNBF	Larch	L	1970	2009	40	0,10					4,3	42,9	0,40	17,0	G10	44,5	38%
LcF	Larch	L	1968	2009	42	2,20	Yes	179	77	57%							
LcF	Larch	L	1968	2009	42	0,22	Yes	186	82	56%							
FrF-P.inNBF	Larch	L	1963	2005	43	0,29											
FrF-P.inNBF	Larch	L	1967	2009	43	0,25											
FrF-P.inNBF	Larch	L	1960	2003	44	0,18											
FrF-P.inNBF	Larch	L	1959	2003	45	0,24											
FrF-P.inNBF	Larch	L	1963	2009	47	0,36	No	169	116	32%							
FrF-P.inNBF	Larch	L	1963	2009	47	0,54	No	210	88	58%							
FrF-P.inNBF	Larch	L	1957	2003	47	1,04											
FrF-P.inNBF	Larch	L	1957	2003	47	0,65											
FrF-P.inNBF	Larch	L	1962	2009	48	0,91	Yes	133	68	49%							
FrF-P.inNBF	Larch	L	1962	2009	48	0,17	Yes	146	118	19%							
FrF-P.inNBF	Larch	L	1962	2009	48	1,10											
FrF-P.inNBF	Larch	L	1955	2003	49	0,21											
FrF-P.inNBF	Larch	L	1955	2003	49	1,59											
FrF-P.inNBF	Larch	L	1956	2004	49	0,03											
FrF-P.inNBF	Larch	L	1959	2007	49	2,60											

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Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
LcF	Larch	L	1955	2004	50	0,14											
FrF-P.inNBF	Larch	L	1959	2008	50	1,24	Yes										
FrF-P.inNBF	Larch	L	1959	2008	50	0,42	Yes										
LcF	Larch	L	1959	2009	51	1,13											
FrF-P.inNBF	Larch	L	1956	2007	52	0,76	Yes										
FrF-P.inNBF	Larch	L	1956	2008	53	0,50					85,7	171,4	0,40	67,9	G15	103,6	66%
FrF-P.inNBF	Larch	L	1957	2009	53	0,94	Yes	Clearcut			183,0	194,7	0,40	77,2	G15	103,6	
FrF-P.inNBF	Larch	L	1953	2007	55	2,73											
FrF-P.inNBF	Larch	L	1951	2008	58	3,56	Yes	Clearcut			445,0	125,0	0,40	49,5	G15	113,2	
FrF-P.inNBF	Larch	L	1938	2009	72	0,80	Yes	277	209	25%							
FrF-P.inNBF	Larch	L	1937	2009	73	0,39											
LcF	Pine	P	1998	2006	9	0,47											
FrF-P.inNBF	Pine	P	1981	2004	24	0,11											
LcF	Pine	P	1981	2007	27	0,56											
LcF	Pine	P	1981	2008	28	1,41											
FrF-P.inNBF	Pine	P	1973	2002	30	1,25											
LcF	Pine	P	1979	2009	31	0,82											
LcF	Pine	P	1979	2009	31	0,38											
LcF	Pine	P	1979	2009	31	0,14											
LcF	Pine	P	1973	2004	32	0,28											
FrF-P.inNBF	Pine	P	1974	2005	32	1,10											
LcF	Pine	P	1973	2005	33	0,11											
LcF	Pine	P	1977	2009	33	1,45											
FrF-P.inNBF	Pine	P	1977	2009	33	0,27											
FrF-P.inNBF	Pine	P	1977	2009	33	0,88											
LcF	Pine	P	1973	2007	35	0,12											
LcF	Pine	P	1973	2009	37	0,52	Yes	154	52	66%							
LcF	Pine	P	1973	2009	37	0,07											

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Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
LcF	Pine	P	1973	2009	37	0,08											
FrF-P.inNBF	Pine	P	1967	2005	39	0,22											
FrF-P.inNBF	Pine	P	1968	2007	40	0,62											
FrF-P.inNBF	Pine	P	1965	2005	41	0,20					4,3	21,4	0,45	9,6	G0	51,3	19%
FrF-P.inNBF	Pine	P	1965	2005	41	0,20											
FrF-P.inNBF	Pine	P	1968	2008	41	0,08											
FrF-P.inNBF	Pine	P	1963	2004	42	2,00					25,7	12,9	0,45	5,7	G0	52,7	11%
FrF-P.inNBF	Pine	P	1960	2002	43	1,00					14,3	14,3	0,45	6,4	G0	53,8	12%
FrF-P.inNBF	Pine	P	1965	2007	43	0,30					8,6	28,6	0,45	12,8	G0	53,8	24%
FrF-P.inNBF	Pine	P	1963	2005	43	0,46											
FrF-P.inNBF	Pine	P	1963	2005	43	0,70											
FrF-P.inNBF	Pine	P	1963	2005	43	0,75											
FrF-P.inNBF	Pine	P	1963	2005	43	0,13											
FrF-P.inNBF	Pine	P	1960	2003	44	4,47					50,0	11,2	0,45	5,0	G0	54,7	9%
FrF-P.inNBF	Pine	P	1966	2009	44	0,05											
FrF-P.inNBF	Pine	P	1962	2006	45	0,30					5,7	19,0	0,45	8,5	G0	55,5	15%
FrF-P.inNBF	Pine	P	1965	2009	45	1,00					132,0	132,0	0,45	59,0	G4	113,6	52%
FrF-P.inNBF	Pine	P	1960	2005	46	0,35											
FrF-P.inNBF	Pine	P	1957	2003	47	0,52											
LcF	Pine	P	1962	2009	48	0,55	Yes	285	146	51%							
FrF-P.inNBF	Pine	P	1962	2009	48	0,90											
FrF-P.inNBF	Pine	P	1957	2005	49	0,15											
FrF-P.inNBF	Pine	P	1959	2008	50	2,00					81,4	40,7	0,45	18,2	G0	57,5	32%
FrF-P.inNBF	Pine	P	1959	2009	51	1,50					194,0	129,3	0,45	57,8	G4	121,3	48%
FrF-P.inNBF	Pine	P	1959	2009	51	2,50					208,3	83,3	0,45	37,2	G0	57,7	65%
FrF-P.inNBF	Pine	P	1958	2009	52	0,50					106,0	212,0	0,45	94,7	G4	122,1	78%
FrF-P.inNBF	Pine	P	1956	2009	54	0,95								0,0			
LcF	Slow growing spruce	S	1994	2003	10	0,29											
LcF	Slow growing spruce	S	1994	2008	15	0,67											

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Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
LcF	Slow growing spruce	S	1994	2008	15	0,15											
FrF-P.inNBF	Slow growing spruce	S	1990	2005	16	2,14											
FrF-P.inNBF	Slow growing spruce	S	1987	2003	17	1,79											
FrF-P.inNBF	Slow growing spruce	S	1986	2003	18	2,40											
FrF-P.inNBF	Slow growing spruce	S	1988	2005	18	0,27											
FrF-P.inNBF	Slow growing spruce	S	1982	2005	24	3,00											
FrF-P.inNBF	Slow growing spruce	S	1983	2006	24	0,60											
FrF-P.inNBF	Slow growing spruce	S	1978	2004	27	0,04											
FrF-P.inNBF	Slow growing spruce	S	1976	2004	29	1,66											
FrF-P.inNBF	Slow growing spruce	S	1972	2004	33	0,22											
LcF	Slow growing spruce	S	1973	2007	35	0,10											
FrF-P.inNBF	Slow growing spruce	S	1969	2003	35	0,95											
FrF-P.inNBF	Slow growing spruce	S	1973	2008	36	0,40											
FrF-P.inNBF	Slow growing spruce	S	1972	2008	37	0,67											
FrF-P.inNBF	Slow growing spruce	S	1972	2008	37	0,67											
FrF-P.inNBF	Slow growing spruce	S	1972	2008	37	0,24											
FrF-P.inNBF	Slow growing spruce	S	1972	2008	37	0,16											
FrF-P.inNBF	Slow growing spruce	S	1964	2002	39	0,29											
FrF-P.inNBF	Slow growing spruce	S	1963	2002	40	1,09											
FrF-P.inNBF	Slow growing spruce	S	1966	2005	40	0,24											
LcF	Slow growing spruce	S	1964	2004	41	1,49											
FrF-P.inNBF	Slow growing spruce	S	1967	2008	42	0,30											
FrF-P.inNBF	Slow growing spruce	S	1967	2008	42	0,06											
FrF-P.inNBF	Slow growing spruce	S	1962	2004	43	2,00					28,6	14,3	0,33	4,7	G	45,7	10%
FrF-P.inNBF	Slow growing spruce	S	1965	2007	43	0,30					20,2	67,3	0,33	22,2	G	45,7	49%
FrF-P.inNBF	Slow growing spruce	S	1961	2003	43	0,16											
FrF-P.inNBF	Slow growing spruce	S	1961	2003	43	0,07											
FrF-P.inNBF	Slow growing spruce	S	1963	2005	43	0,03											
LcF	Slow growing spruce	S	1961	2004	44	0,40											

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FrF-P.inNBF	Slow growing spruce	S	1960	2003	44	3,00					35,7	11,9	0,33	3,9	G	47,0	8%
FrF-P.inNBF	Slow growing spruce	S	1966	2009	44	0,25	No	323	144	55%	15,0	60,0	0,33	19,8	G	47,0	42%
FrF-P.inNBF	Slow growing spruce	S	1959	2002	44	0,21											
FrF-P.inNBF	Slow growing spruce	S	1961	2004	44	0,10											
FrF-P.inNBF	Slow growing spruce	S	1961	2004	44	0,10											
FrF-P.inNBF	Slow growing spruce	S	1966	2009	44	0,06											
LcF	Slow growing spruce	S	1960	2004	45	0,32											
FrF-P.inNBF	Slow growing spruce	S	1958	2002	45	1,37											
FrF-P.inNBF	Slow growing spruce	S	1958	2002	45	0,45											
FrF-P.inNBF	Slow growing spruce	S	1958	2002	45	0,20											
FrF-P.inNBF	Slow growing spruce	S	1959	2003	45	1,23											
FrF-P.inNBF	Slow growing spruce	S	1959	2003	45	1,18											
LcF	Slow growing spruce	S	1962	2007	46	0,50	No										
FrF-P.inNBF	Slow growing spruce	S	1960	2005	46	2,00					21,4	10,7	0,33	3,5	G	49,6	7%
FrF-P.inNBF	Slow growing spruce	S	1958	2003	46	0,67											
FrF-P.inNBF	Slow growing spruce	S	1958	2003	46	0,68											
LcF	Slow growing spruce	S	1961	2007	47	0,20											
FrF-P.inNBF	Slow growing spruce	S	1960	2006	47	0,50					5,7	11,4	0,33	3,8	G	50,9	7%
LcF	Slow growing spruce	S	1962	2009	48	0,07											
FrF-P.inNBF	Slow growing spruce	S	1960	2007	48	1,00					7,1	7,1	0,33	2,4	G	52,2	5%
FrF-P.inNBF	Slow growing spruce	S	1955	2002	48	1,00					21,4	21,4	0,33	7,1	G	52,2	14%
FrF-P.inNBF	Slow growing spruce	S	1959	2006	48	1,08					86,0	79,6	0,33	26,3	G	52,2	50%
FrF-P.inNBF	Slow growing spruce	S	1962	2009	48	0,06	No	117	49	58%							
FrF-P.inNBF	Slow growing spruce	S	1962	2009	48	0,20	No	243	62	75%							
FrF-P.inNBF	Slow growing spruce	S	1956	2003	48	0,81											
FrF-P.inNBF	Slow growing spruce	S	1956	2003	48	0,14											
FrF-P.inNBF	Slow growing spruce	S	1956	2003	48	0,11											
FrF-P.inNBF	Slow growing spruce	S	1958	2006	49	1,08					52,0	48,1	0,33	15,9	G	53,6	30%
FrF-P.inNBF	Slow growing spruce	S	1961	2009	49	0,08											

ANNEX 1. Stands from the cultivated forest of Icelandic Forest Service with cutting activity in the period 2002-2009

Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
FrF-P.inNBF	Slow growing spruce	S	1961	2009	49	0,22											
FrF-P.inNBF	Slow growing spruce	S	1954	2003	50	0,20											
FrF-P.inNBF	Slow growing spruce	S	1957	2006	50	0,25											
FrF-P.inNBF	Slow growing spruce	S	1953	2003	51	0,39											
FrF-P.inNBF	Slow growing spruce	S	1954	2004	51	0,45											
FrF-P.inNBF	Slow growing spruce	S	1958	2009	52	0,51	No	166	62	63%	39,0	76,5	0,33	25,2	G	57,7	44%
FrF-P.inNBF	Slow growing spruce	S	1958	2009	52	0,80	No	229	102	55%	101,0	126,3	0,33	41,6	G	57,7	72%
FrF-P.inNBF	Slow growing spruce	S	1957	2008	52	0,48	No	149	63	58%							
FrF-P.inNBF	Slow growing spruce	S	1954	2005	52	1,37											
FrF-P.inNBF	Slow growing spruce	S	1955	2006	52	0,10											
FrF-P.inNBF	Slow growing spruce	S	1954	2006	53	0,73											
FrF-P.inNBF	Slow growing spruce	S	1956	2009	54	1,50					75,0	50,0	0,33	16,5	G	60,6	27%
FrF-P.inNBF	Slow growing spruce	S	1952	2007	56	0,37	No	261	181	31%	107,0	289,2	0,33	95,4	G	63,4	
FrF-P.inNBF	Slow growing spruce	S	1948	2004	57	0,98											
FrF-P.inNBF	Slow growing spruce	S	1941	2002	62	0,02											
FrF-P.inNBF	Slow growing spruce	S	1937	2004	68	1,01											
FrF-P.inNBF	Slow growing spruce	S	0	2006	0	0,10											
FrF-P.inNBF	Sitka spruce	SS	1987	2008	22	1,69											
FrF-P.inNBF	Sitka spruce	SS	1986	2008	23	0,30											
FrF-P.inNBF	Sitka spruce	SS	1979	2002	24	0,15											
FrF-P.inNBF	Sitka spruce	SS	1979	2002	24	0,62											
FrF-P.inNBF	Sitka spruce	SS	1984	2007	24	4,00											
FrF-P.inNBF	Sitka spruce	SS	1973	2003	31	0,45											
LcF	Sitka spruce	SS	1973	2009	37	0,75		221	73	67%							
FrF-P.inNBF	Sitka spruce	SS	1967	2004	38	0,21											
LcF	Sitka spruce	SS	1970	2009	40	0,54		123	77	38%	25,0	46,3	0,38	17,6	G2	64,7	27%
LcF	Sitka spruce	SS	1970	2009	40	0,57											
LcF	Sitka spruce	SS	1970	2009	40	0,56											
FrF-P.inNBF	Sitka spruce	SS	1970	2009	40	0,28											

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Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
LcF	Sitka spruce	SS	1967	2007	41	1,16											
LcF	Sitka spruce	SS	1962	2003	42	1,52											
FrF-P.inNBF	Sitka spruce	SS	1962	2003	42	0,24											
FrF-P.inNBF	Sitka spruce	SS	1967	2008	42	1,01											
LcF	Sitka spruce	SS	1967	2009	43	0,76											
FrF-P.inNBF	Sitka spruce	SS	1966	2008	43	0,05											
LcF	Sitka spruce	SS	1961	2004	44	1,04											
LcF	Sitka spruce	SS	1961	2004	44	0,32											
LcF	Sitka spruce	SS	1961	2004	44	0,26											
LcF	Sitka spruce	SS	1962	2005	44	0,46											
LcF	Sitka spruce	SS	1966	2009	44	0,75											
FrF-P.inNBF	Sitka spruce	SS	1966	2009	44	0,23	No	181	111	39%	23,0	100,0	0,38	38,0	G2	79,8	48%
FrF-P.inNBF	Sitka spruce	SS	1966	2009	44	0,07	No	304	173	43%	11,0	157,1	0,38	59,6	G6	112,4	53%
FrF-P.inNBF	Sitka spruce	SS	1960	2003	44	0,45											
FrF-P.inNBF	Sitka spruce	SS	1962	2005	44	0,17											
FrF-P.inNBF	Sitka spruce	SS	1962	2005	44	0,34											
FrF-P.inNBF	Sitka spruce	SS	1962	2005	44	0,06											
FrF-P.inNBF	Sitka spruce	SS	1963	2007	45	0,24	No										
FrF-P.inNBF	Sitka spruce	SS	1960	2004	45	1,23											
LcF	Sitka spruce	SS	1959	2004	46	1,07											
FrF-P.inNBF	Sitka spruce	SS	1960	2005	46	0,19											
FrF-P.inNBF	Sitka spruce	SS	1960	2006	47	0,20											
FrF-P.inNBF	Sitka spruce	SS	1960	2006	47	0,30											
LcF	Sitka spruce	SS	1962	2009	48	1,01	Yes	85	26	69%	50,7	50,2					
LcF	Sitka spruce	SS	1961	2008	48	1,02											
LcF	Sitka spruce	SS	1962	2009	48	0,06											
LcF	Sitka spruce	SS	1962	2009	48	1,90											
LcF	Sitka spruce	SS	1962	2009	48	1,11											

ANNEX 1. Stands from the cultivated forest of Icelandic Forest Service with cutting activity in the period 2002-2009

Land category	Species group	Species code	Year of planting	Year of thinning	Age	ha	thinned before	m3 before thinning	m3 after thinning	% thinned	m3 thinning	m3/ha thinning	C-factor	C t/ha thinning	Yield class	C-stock t/ha	% thinned
LcF	Sitka spruce	SS	1962	2009	48	0,87											
FrF-P.inNBF	Sitka spruce	SS	1962	2009	48	0,45	No	367	110	70%	94,0	208,9	0,38	79,3	G6	129,5	61%
FrF-P.inNBF	Sitka spruce	SS	1962	2009	48	0,51											
LcF	Sitka spruce	SS	1961	2009	49	0,04											
FrF-P.inNBF	Sitka spruce	SS	1961	2009	49	0,25					20,0	80,0	0,38	30,4	G2	99,3	31%
FrF-P.inNBF	Sitka spruce	SS	1961	2009	49	1,26	Yes	277	119	57%	150,0	119,0	0,38	45,2	G2	99,3	46%
FrF-P.inNBF	Sitka spruce	SS	1961	2009	49	4,28	Yes	396	208	47%	542,0	126,6	0,38	48,1	G2	99,3	48%
FrF-P.inNBF	Sitka spruce	SS	1961	2009	49	0,62	Yes	243	118	52%	86,0	138,7	0,38	52,6	G2	99,3	53%
FrF-P.inNBF	Sitka spruce	SS	1961	2009	49	0,82	Yes	324	149	54%	141,0	172,0	0,38	65,3	G2	99,3	66%
FrF-P.inNBF	Sitka spruce	SS	1956	2004	49	0,01											
LcF	Sitka spruce	SS	1955	2004	50	0,45											
FrF-P.inNBF	Sitka spruce	SS	1958	2007	50	0,30	Yes	234	73	31%	23,8	79,3	0,38	30,1	G2	103,1	29%
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,94	Yes	175	92	47%							
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,08											
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,11											
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,18											
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,00											
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,00											
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	0,04											
FrF-P.inNBF	Sitka spruce	SS	1960	2009	50	1,70											
FrF-P.inNBF	Sitka spruce	SS	1959	2009	51	0,53	No	323	124	62%	83,0	156,6	0,38	59,4	G2	106,9	56%
FrF-P.inNBF	Sitka spruce	SS	1956	2007	52	0,36	Yes	374	199	47%	45,5	126,4	0,38	48,0	G2	110,5	43%
FrF-P.inNBF	Sitka spruce	SS	1958	2009	52	0,89	No	384	68	82%	216,0	242,7	0,38	92,1	G6	145,3	63%
FrF-P.inNBF	Sitka spruce	SS	1953	2006	54	0,60											
FrF-A.old.th.50yrs	Sitka spruce	SS	1950	2004	55	1,38											
FrF-P.inNBF	Sitka spruce	SS	1954	2009	56	0,72	Yes	436	225	48%	155,0	215,3	0,38	81,7	G0	79,9	
FrF-A.old.th.50yrs	Sitka spruce	SS	1944	2009	66	0,22											