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Land areas and biomass production for current and future use in the Nordic and Baltic countries

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Content

1. Summary

This report was written with the aim to compile information on wood resources in the ENERWOODS-project countries, i.e. Denmark, Finland, Norway, Sweden, Estonia and Latvia, with a focus on availability for energy purposes. ENERWOODS, or wood based energy systems from Nordic forests, is a joint Nordic and Baltic project financed by Nordic Energy Research. The aim is to review and provide scientific results to strengthen the role of Nordic forestry in feeding biomass into cost-effective and renewable energy systems.

A summary of forest land and other potential land areas for tree growth shows that the forest areas are large and that substantial agriculture land areas are also available. Although some forest areas are protected, 75–92 % of them can still be used for wood production. In total, the forest area of the ENERWOODS countries is 62.4 million ha, of which 16.9 million ha is owned by the state and public and 45.5 million ha is private land.

Coniferous species dominate the forests in Finland, Norway and Sweden, while areas and volumes are more evenly distributed between conifers and deciduous species in Denmark, Estonia and Latvia. The total standing volume in the ENERWOODS countries is around 7 300 million m^3 and the annual increment can be estimated to about 275 million m^3 yr^{-1}. Transferred to energy units these figures correspond to c. 16 PWh and 600 TWh, respectively.

Figures on current harvest show a clear discrepancy between annual growth and harvest, leading to the conclusion that some of the difference probably can be used for energy purposes in the near future. Fertilization on forest land has a tradition in Finland and Sweden but is used to a very low extent in the other countries. The potential for increased growth through increased fertilizer supply is most probably high, especially if the concept with balanced nutrient addition in young forests is used.

The Danish potential of forest energy resources were studied with four scenarios. An unchanged forest management will result in about 5.0 TWh yr^{-1} by the year 2050, while other more active scenarios resulted in 12–13 TWh at the same time. In Finland current potential for forest energy biomass is up to 35 million tons yr^{-1} (186 TWh) in a maximum cutting scenario. The potential by 2050 is varying between 22 and 30 million tons yr^{-1} (117–159 TWh), depending on forest management and climate change. In Norway 5 million tons DM yr^{-1} (c. 27 TWh) should be possible to use when no restrictions are considered. The Swedish figure on potential harvest levels for energy is 29 million tons yr^{-1} (143 TWh, 155 TWh with the transfer assumptions in this report) without restrictions. Analyses in Estonia show that 15 million m^3 (~33 TWh) is available annually without restrictions, while in Latvia almost 50 TWh is annually extractable as forest biofuel. However, probable restrictions will reduce the figures for all countries, but they will still be of utmost importance for the energy supply of the respective country.

The changing climate and increased standing volumes will affect the future growth and further increase the potential harvest levels. Estimates from Finland, Sweden and Estonia for different periods show a growth increase of over 30 % on country levels but substantially higher for specific locations.

Wood for energy is extensively used and has a large potential for increasing the share of renewable energy in the ENERWOODS countries. The potential may be further increased when applying measures like increased fertilization, extended breeding for enhanced biomass production, larger cultivation areas and changes of tree species and management systems.

2. Introduction

The forests of the Nordic and Baltic countries contain large amounts of wood which support the forestry and energy sectors as well as other purposes. This resource is extensively utilized and contributes to a high degree to the welfare of our countries. However, increased future demand for renewable sources of energy may not be met by the current forest production and management. This report is produced within the framework of the ENERWOODS project, supported by the Nordic Energy Research, and including the countries Denmark, Finland, Norway, Sweden, Estonia and Latvia. The aim of the project is to review and provide scientific results to strengthen the role of Nordic forestry in feeding biomass into cost-effective and renewable energy systems. The report aims to compile, describe and analyse the current forest situation in the Nordic and Baltic countries with focus on woody biomass for energy purposes Data are presented on forest land areas, standing biomass, growth increment rates and the use of wood. We allocate these figures on regions of the ENERWOODS countries and also on site indices and different tree species. A main objective is to create a basis from which future measures to improve growth can be compared.

3. Methods

The majority of data and information are collected from official statistics from recent years and from primary sources (e.g. Bekeris 2011, Danmarks Statistik 2012, Finnish Forest Research Institute 2012, Johannsen *et al.* 2013, Latvian State Forest Service 2012, Statistics Estonia 2012, Statistics Norway 2011, Swedish Energy Agency 2012, Swedish Forest Agency 2013). We have also used other compilations like FAO (2010) and Forest Europe (2011). To handle the forecasts about climate change we have used analyses from participating countries. In Finland, these calculations have been done by Kellomäki *et al.* (2008) and Alam *et al.* (2010), in Norway by Astrup *et al.* (2010) and in Sweden by the Swedish University of Agricultural Sciences and the Swedish Forest Agency (Bergh *et al.* 2006, Swedish Forest Agency 2008, Bergh *et al.* 2010). When collecting data from the different countries it was obvious that they didn't correspond easily to each other. Therefore efforts have been made to translate them to the same units and land areas. We also express the same data with different units to facilitate the connection between the forestry and energy sectors.

The most common way of expression of forest data is in cubic metres (m^3) of stem wood. To facilitate translation to weight and energy units we need conversion factors for wood from volume to weight, i.e. basic density. Basic density means dry weight of fresh volume ($R = W_D/V_F$, where R = basic density, W_D = dry weight of wood, V_F = volume of wood in fresh condition), which is the most useful measurement in this case. Wood density is different for different species and varies with growth rate and age. In Table 3.1 we propose density values from the literature which have been used for translation from volume to weight. We have focused on medium to old stand figures since these are most accurate when most energy from the forest is taken out during thinning and final felling. However, for new silviculture systems and for outtake of young trees in dense stands there are possibly better figures to use. There exist also more detailed functions for density estimations, and for example in Denmark they can be found for beech (Skovsgaard & Nord-Larsen 2012) and Norway spruce (Skovsgaard *et al.* 2011). However, for the purpose of this report Table 3.1 is regarded appropriate.

Because the heating values for different species are fairly similar expressed on a weight basis (e.g. Nurmi 1991) we can use the same conversion factors for all species if we go from dry weight to energy content. For the translation from dry weight of wood to energy we use 1 ton DM = 5.3 MWh = 19.2 GJ. The heating value for dry biomass from the forest is thus set to 19.2 MJ kg^{-1}. Energy wood generally contains moisture, which reduces the energy values in relation to weight. Since the moisture content fluctuates we found it most relevant to base the calculations on dry weight of wood even if this high heating value can seldom be used in practice.

Table 3.1. Basic density of wood for different species in northern Europe. The values represent the stem, including bark, which has a basic density different from pure wood. Some values are averages from the given references.

Tree species	Basic density (kg DM m^{-3})	References
Norway spruce	380	Hakkila 1979, Moltesen 1988, Lundgren & Persson 2002
Scots pine	415	Hakkila 1979, Moltesen 1988
Larch, hybrid, Siberian	411, 476	Pâcques 2004, Chauret & Zhang 2002
Birch	483	Hakkila 1979
Aspen	402	Nagoda 1981
Black alder	375	Elfving 1986, Södra 2009
Grey alder	362	Nagoda 1968, Hakkila 1971, Johansson 2005
Oak	575	Sveriges Skogsvårdsförbund 1994, Moltesen 1988
Beech	570	Sveriges Skogsvårdsförbund 1994, Moltesen 1988
Ash	560	Moltesen 1988
Salix sp.	350	Moltesen 1988
Sitka spruce	370	Moltesen 1988
Douglas fir	410	Moltesen 1988
Lodgepole pine	370	Moltesen 1988

4. Land areas allocated to land use classes

The land area of the Nordic and Baltic countries is generally dominated by forest land (Table 4.1). The total forest land area is about 66 million ha in the ENERWOODS countries, which is more than 56 % of the total land area. There are, however, differences among the countries, where the large forest dominated countries Sweden and Finland have 67–69 % of the land area as forest land. These countries also dominate in absolute terms with over 48 million ha forest land and 74 % of the forest area in the region. Denmark has comparably small areas with forest, both in absolute (0.6 million ha) and relative terms (~14 %). Estonia has 52 % and Latvia 46 % of their land area on forest land, which gives 5.2 million ha together. In Norway large areas are classified as mountains and plateaus without forest and forest land constitutes 38 % of total land area.

Table 4.1. Land areas distributed on land use classes in Nordic and Baltic countries. Sources: Danmarks Statistik (2012) and Johannsen *et al.* (2013), Estonian Environment Information Centre (2012), Finnish Forest Research Institute (2012), Latvian State Forest Service[1] (2012), Latvian State Land Service[2] (2012), Statistics Norway (2011) and Swedish Forest Agency (2013).

Country	Forest land	Other wooded land (EST, S, DK) poorly productive forest land (FIN), mountains, plateaus etc. (N), naturally afforested and bushes (LV)	Barren land (S), unproductive land (FIN), marsh/wetlands (N), wetlands, dunes etc. (DK), other land (EST, LV)	Other land (S, FIN), agriculture, build-up areas (N), artificial, agricultural areas etc. (DK), agriculture land (EST, LV)	Total land area	Forest land of total land area
	1 000 ha	1 000 ha	1 000 ha	1 000 ha	1 000 ha	%
Denmark	608	45	227	3 383	4 263	14.3
Finland	20 259	2 518	3 196	4 442	30 414	66.6
Norway	11 622	15 638	1 765	1 400	30 425	38.2
Sweden	28 094	2 392	4 941	5 370	40 797	68.9
Estonia	2 212	79	604	1 374	4 269	51.8
Latvia	2 986[1]/2 962[2]	113[2]	946[2]	2 403[2]	6 448[2]	46.3
TOTAL	65 781	20 785	11 679	18 372	116 616	56.4

5. Forest land

The forests in the Nordic and Baltic countries have generally the ability to produce large amounts of wood for different purposes. However, data on forest land can be presented in different ways which may make comparisons between countries difficult. Here we have chosen to present them according to ownership, site fertility, tree species and age classes which we believe are the most relevant data as a base for discussing potential improvements on forest production.

5.1. OWNERSHIP

The largest share of private owned forest is found in Norway with more than 84 %, followed by Denmark (70 %), Latvia (68 %), Finland (60 %), and Sweden (54 %). Also in Estonia the share of private owned forest (45 %) exceeds the share of state owned forests, and there it will continue to increase as today the privatization process is still going on. A further 15 % of forest land is subject to privatization. The figures on total forest areas are lower in Table 5.1.1 than in Table 4.1 for Norway, Sweden and Latvia, because protected and not used areas are not included in Table 5.1.1. Both poor and unproductive land is included for Finland in table 5.1.1.

Table 5.1.1. Forest land area by ownership. Sources: Johannsen *et al.* (2013), Finnish Forest Research Institute (2012), Statistics Norway (2011, Swedish Forest Agency (2013), Estonian Environment Information Centre (2012), Latvian State Forest Service (http://www.vmd.gov.lv) and Latvian State Land Service (http://www.vzd.gov.lv). [1] Private and private companies are presented together, [2] All areas which are not state-owned.

Country	Region	State and public, 1 000 ha (%)	Private companies, 1 000 ha (%)	Private, 1 000 ha (%)	Others, including other private owners and unknown, 1 000 ha (%)	Total forest area, 1 000 ha
Denmark[1]	TOTAL	144 (23.6)	-	427 (70.1)	38 (6.2)	608
Finland	Southern	1 046 (8.7)	1 458 (12.1)	8 753 (72.8)	768 (6.4)	12 025
	Northern	8 183 (57.5)	577 (4.1)	4 927 (34.6)	551 (3.9)	14 238
	TOTAL	9 229 (35.1)	2 035 (7.7)	13 681 (52.1)	1 319 (5.0)	26 263
Norway	TOTAL	960 (12.0)	320 (4.0)	6 400 (80.0)	320 (4.0)	8 000
Sweden	N Norrland	2 615 (39.1)	1 130 (16.9)	2 500 (37.4)	439 (6.6)	6 684
	S Norrland	382 (6.6)	2 735 (47.4)	2 473 (42.9)	175 (3.0)	5 769
	Svealand	720 (13.7)	1 458 (27.8)	2 534 (48.4)	525 (10.0)	5 239
	Götaland	457 (9.7)	314 (6.7)	3 656 (77.6)	280 (5.9)	4 710
	TOTAL	4 178 (18.6)	5 638 (25.2)	11 165 (49.8)	1 421 (6.3)	22 405
Estonia	TOTAL	882 (39.9)	245 (11.1)	757 (34.2)	328 (14.8)	2 212
Latvia	TOTAL	624 (30.2)	348 (16.8)	1 058 (51.2)	38 (1.8)[2]	2 068
TOTAL		16 017 (26.0)	8 586 (13.9)	33 488 (54.4)	3 464 (5.6)	61 556

5.2. FOREST TYPES AND TREE SPECIES

Areas for forest types and tree species are presented differently for the countries involved. Therefore these areas are only presented country wise in this section. One reason for difficulties in giving areas for tree species is that we often have stands with a mixture of species and these mixtures can be treated and defined in different ways. For example, in Sweden (Riksskogstaxeringen 2010) all stands which have one species with over 65 % of the basal areas are regarded as pure stands (monocultures). When no species has more than 65 % of basal area it is regarded as a mixed forest. With more than 65 % conifers or deciduous trees it is regarded as a coniferous or deciduous mixed forest respectively. Thus, in "pure" stands in Sweden it is possible to have up to 35 % of other species.

One useful way of presenting forest data for productivity discussions is to divide the forest areas into productivity or site index classes. Tables 5.2.1–5.2.7 show different ways to give information about forest types and tree species, ways that have historical and biological backgrounds.

In Denmark, the forest area is both divided into different land use classes as well as into tree species or species groups (Table 5.2.1). The distribution of forest area according to tree species cover is based on the basal area distribution. Dominating species in the Danish forests are Norway spruce and beech.

Table 5.2.1. Forest area by forest type and by tree species in Denmark, including other wooded land, semi-natural areas and uncovered/auxiliary areas, respectively. There may be some overlap between other wooded land and the semi natural areas. Sources: Danmarks Statistik (2012) and Johannsen *et al.* (2013).

Forest land use classes and semi-natural areas (designation)	(area, 1 000 ha)	**Tree species and tree species groups on forest land** (species)	(area, 1 000 ha)
Forest	608.1	Beech	79
Coniferous forest	*240.2*	Oak	62
Broad-leaved forest	*248.2*	Ash	19
Mixed forest	*68.7*	Sycamore	23
Christmas trees	*30.6*	Birch	42
Temporarily uncovered area	*12.1*	Other broadleaved	57
Auxiliary areas	*8.3*	Norway spruce	95
Natural grassland	39.2	Sitka spruce etc.	36
Moors and heath land	98.2	Noble fir, Caucasian fir and other fir	60
Beaches, dunes and sand plains	5.1	Other conifer species	73
Sparsely vegetated areas	6.9	Temporarily uncovered, auxiliary and unknown areas	20
TOTAL	757.5	TOTAL	608

The Finnish data on tree species and site fertility types reveal that Scots pine is dominating and found on 64 % of the forested area. Pine and spruce together cover almost 88 % of the forest land (Table 5.2.2). Fresh (mesic) and somewhat drier (sub-xeric) forests are the most common forest types with nearly 59 % of the forest land area. The most obvious difference between southern and northern Finland is a higher share of drier (sub-xeric and xeric) forests in the northern part.

Table 5.2.2. Finnish site fertility classes on mineral soils and mires, and tree species dominance, expressed in *per cent* and areas, on forest land. Data are divided into southern and northern Finland. Source: Finnish Forest Research Institute (2012).

Site fertility classes (1 000 ha)	S Finland	N Finland	**Total**	**Tree species dominance**	S Finland	N Finland	**Total**
Herb-rich forests	326	42	**368**	Pine – share of conifers			
Herb-rich heat forests	2 181	164	**2 345**	*>95 %*	*58*	*60*	*59*
Mesic forests	4 090	3 645	**7 735**	*75–95 %*	*32*	*31*	*32*
Sub-xeric forests	1 674	2 403	**4 077**	*<75 %*	*10*	*9*	*10*
Xeric forests	202	386	**587**	Area (1 000 ha)	6 224	6 859	**13 083**
Barren forests	9	16	**25**	Spruce – share of conifers			
Rocky, sandy, alluvial land	73	17	**89**	*>95 %*	*49*	*25*	*43*
Eutrophic mires	61	82	**143**	*75–95 %*	*37*	*45*	*39*
Mesotrophic mires	373	390	**763**	*<75 %*	*14*	*29*	*18*
Meso-oligotrophic eutrophic mires	816	530	**1 347**	Area (1 000 ha)	3 473	1 336	**4 809**
Oligotrophic eutrophic mires	800	1 042	**1 842**	Broadleaved – share of broadleaved			
Oligo-ombrotrophic mires	467	284	**751**	*>95 %*	*35*	*16*	*28*
Sphagnum fuscum dominated mires	10	1	**11**	*75–95 %*	*33*	*34*	*33*
				<75 %	*32*	*50*	*39*
				Area (1 000 ha)	1 206	701	**1 907**
				Treeless (1 000 ha)	2	1	**1**
TOTAL	**11 083**	**9 002**	**20 085**	**TOTAL (1 000 ha)**	**11 083**	**9 002**	**20 085**

Granhus *et al.* (2012) compiled forest area for site quality class and forest type in Norway (Table 5.2.3). The dominating productive forest areas are found on low and medium site quality classes with big differences among regions. The forest types spruce, pine and hardwoods are all common and found with 29–36 % each on productive forest areas. On non-productive land pine and hardwoods are more common than spruce.

Table 5.2.3. Forest land distributed by site quality class (upper part) and forest type (lower part) and expressed in 1 000 ha. Source: Granhus *et al.* (2012). h = hardwood.

Site quality class		**Region** Östfold, Akershus, Oslo, Hedmark		**Oppland, Buskerud, Vestfold**		**Telemark, A-Agder, V-Agder**		**Rogaland, Hordaland, Sogn & F, Möre & R**		**Sor-Tröndelag, Nord-Tröndelag**		**Nordland Troms**		**All regions**	
		(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)
Low	6	174.6	8.9	194.0	12.7	118.4	10.0	119.2	11.4	161.5	14.9	284.8	25.2	1 052.5	13.3
	8	467.4	23.8	444.5	29.0	368.4	31.2	283.7	27.0	324.3	29.9	475.3	42.0	2 363.7	29.8
Medium	11	475.1	24.2	327.7	21.4	270.4	22.9	294.2	28.0	264.6	24.4	257.2	22.7	1 889.2	23.8
	14	403.1	20.6	288.7	18.9	230.7	19.5	150.8	14.4	223.1	20.5	85.5	7.6	1 381.9	17.4
High	17	282.6	14.4	171.5	11.2	126.7	10.7	90.9	8.7	98.1	9.0	27.7	2.4	797.6	10.0
	20	123.1	6.3	77.1	5.0	49.7	4.2	64.4	6.1	12.6	1.2	1.3	0.1	328.3	4.1
Very high	23–26	34.9	1.8	27.8	1.8	17.1	1.4	46.6	4.4	1.8	0.2	-	-	128.2	1.6
Sum		**1 960.9**	**100**	**1 531.3**	**100**	**1 181.5**	**100**	**1 049.9**	**100**	**1 086.0**	**100**	**1 131.8**	**100**	**7 941.3**	**100**

Land type	Forest type	Region: Östfold, Akershus, Oslo, Hedmark (area)	(%)	Oppland, Buskerud, Vestfold (area)	(%)	Telemark, A-Agder, V-Agder (area)	(%)	Rogaland, Hordaland, Sogn & F, Möre & R (area)	(%)	Sor-Tröndelag, Nord-Tröndelag (area)	(%)	Nordland Troms (area)	(%)	All regions (area)	(%)
Productive forest	Spruce	804.6	41.0	742.1	48.5	347.1	29.4	173.3	16.5	584.4	53.8	185.3	16.4	2 836.8	35.7
	Pine	803.6	41.0	362.1	23.6	513.6	43.5	336.3	32.0	199.1	18.3	80.2	7.1	2 295.0	28.9
	Noble h.	2.3	0.1	18.8	1.2	49.9	4.2	28.2	2.7	-	-	-	-	99.3	1.3
	Other h.	297.9	15.2	364.9	23.8	243.1	20.6	476.4	45.4	284.2	26.2	839.0	74.1	2 505.6	31.6
	No cover	52.4	2.7	43.3	2.8	27.7	2.3	35.8	3.4	18.2	1.7	27.3	2.4	204.7	2.6
	Sum	**1 961**	**100**	**1 531**	**100**	**1 181**	**100**	**1 050**	**100**	**1 086**	**100**	**1 132**	**100**	**7 941**	**100**
Non-productive forest	Spruce	51.5	19.5	75.9	26.9	72.4	16.3	4.5	1.0	95.1	19.7	22.8	3.5	322.2	12.5
	Pine	106.9	40.6	68.9	24.4	270.8	61.1	175.9	39.0	261.8	54.3	97.8	14.9	982.0	38.1
	Noble h.	-	-	0.9	0.3	3.0	0.7	1.8	0.4	-	-	-	-	5.7	0.2
	Other h.	105.1	39.9	136.4	48.3	97.1	21.9	266.6	59.1	124.8	25.9	534.1	81.6	1 264.1	49.1
	No cover	-	-	-	-	-	-	2.7	0.6	-	-	-	-	2.7	0.1
	Sum	**263**	**100**	**282**	**100**	**443**	**100**	**452**	**100**	**482**	**100**	**655**	**100**	**2 577**	**100**
Total sum		**2 224**		**1 814**		**1 625**		**1 501**		**1 586**		**1 786**		**10 518**	

Swedish area-based data show how soil fertility is distributed into site index and site productivity classes (Table 5.2.4). Data are distributed on counties and larger regions, which are used in this report. The regions are from north to south: Norra Norrland, Södra Norrland, Svealand and Götaland. It is clearly seen for both site classes that fertility is higher in the southern parts of the country than in the north. Concerning tree species, they are presented as growing stocks in volumes (see below). A major reason for this is that tree species are often mixed both in mixed forests, but also in what is defined as pure stands (e.g. Stener 1998), which make area estimates for single tree species difficult to calculate. However, data are available for forest types where pine and spruce are presented as homogenous single-species stands (Table 5.2.5). Stands defined as spruce or pine are dominating with about 66 % of the total productive forest land area.

Table 5.2.4. Productive forest land area in Sweden by site productivity and site index classes expressed in 1 000 ha. The figures exclude protected productive forest land. Calculated from Swedish Forest Agency (2013).

Site productivity class ($m^3sk\ ha^{-1}\ yr^{-1}$)	N Norrl.	S. Norrl	Svealand	Götaland	TOTAL	Site index class (G/T =spruce / pine)	N Norrl.	S Norrl.	Svealand	Götaland	TOTAL
1–	522	114	105	0	741	0–	92/47	0/29	0/28	0/0	105/119
2–	2 546	795	314	99	3 754	12–	403/235	84/58	0/83	0/0	523/358
3–	2 350	1 761	575	247	4 933	14–	494/611	253/144	25/166	0/64	732/954
4–	979	1 591	523	148	3 241	16–	421/1 128	393/288	49/249	0/176	
5–	131	852	1 098	593	2 674	18–	256/1 316	617/460	98/332	34/160	
6–	0	341	680	445	1 466	20–	110/1 128	533/834	148/387	67/144	
7–	0	170	680	395	1 245	22–	37/188	477/719	197/581	67/288	
8–	0	57	680	445	1 182	24–	0/0	281/259	320/581	134/400	
9–	0	0	261	445	706	26–	0/0	112/58	566/332	269/352	941/715
10–	0	0	261	1 038	1 299	28–	0/0	28/0	640/28	705/16	1 359/0
11–	0	0	52	692	744	30–	0/0	0/0	345/0	1 041/0	1 359/0
12–	0	0	0	346	346	32–	0/0	0/0	49/0	705/0	732/0
						34–	0/0	0/0	0/0	269/0	317/0
						36–	0/0	0/0	0/0	67/0	105/0
TOTAL	6 529	5 681	5 228	4 941	22 379	TOTAL	1 830 /	2 806 /	2 462 /	3 358 /	10 456 /
Average ($m^3sk\ ha^{-1}\ yr^{-1}$)	3.1	4.2	6.2	8.6	5.3						

Table 5.2.5. Productive forest area in 1 000 ha, outside national parks and nature reserves, for different forest types 2008–2012. Source: SLU (2013)

Forest type	N Norrl.	S. Norrl	Svealand	Götaland	TOTAL
Pine	3 402	1 903	2 149	1 220	8 683
Spruce	1 032	1 699	1 406	1 892	6 020
Lodgepole pine	183	261	37	0	470
Mixed conifer	908	903	800	613	3 223
Mixed conifer/broadleaves	555	466	324	346	1 678
Other broadleaves	294	256	314	474	1 343
Valuable broadleaves	0	0	16	193	201
Bare	163	187	188	203	739
TOTAL	6 529	5 681	5 228	4 941	22 379

In Estonia tree species has been distributed to forest types. Table 5.2.6 shows that Scots pine and birch are the major species followed by Norway spruce and grey alder. The most common forest types are mesotrophic (with moderate nutrient levels in the soil) and mesoeutrophic (more nutrient rich soils) forests.

Table 5.2.6. Area distribution of forest types and tree species in Estonia expressed in 1 000 ha. Source: Estonian Environmental Information Centre (2012).

Forest site type	Pine	Spruce	Birch	Aspen	Black alder	Grey alder	Others	TOTAL	TOTAL (%)
Alvar forest	29.5	8.5	5.0	1.9	0.2	3.8	3.7	52.6	2.4
Heath forest	8.3	0	0.5	0	0	0	0	8.8	0.4
Mesotrophic forest	299.9	93.9	81.7	17.4	1.6	2.1	0.8	497.4	22.5
Mesoeutrophic forest	108.1	167.8	126.4	45.8	2.3	52.9	17.2	520.5	23.5
Nemoral forest	1.9	28.3	73.9	33.7	4.6	88.7	9.8	240.9	10.9
Herb-rich on gley soil forest	37.1	31.2	189.2	22.0	46.6	35.6	4.7	366.4	16.6
Sphagnum paludified forest	11.7	0.6	1.2	0	0	0	0	13.5	0.6
Grass swamp forest	1.5	1.0	38.6	0	9.3	0.3	0	50.7	2.3
Drained peatland forest	129.8	37.3	149.8	2.5	6.0	2.9	0	328.3	14.8
Bog moss forest	103.8	0.6	12.1	0	0	0	0	116.5	5.3
Forest on reclamationed pits	12.2	0.4	2.3	0.3	0	0.3	1.1	16.6	0.8
TOTAL	**743.8**	**369.6**	**680.7**	**123.6**	**70.6**	**186.6**	**37.3**	**2 212.2**	**100**
TOTAL (%)	**33.6**	**16.7**	**30.8**	**5.6**	**3.2**	**8.4**	**1.7**	**100**	

Latvian forest area has been distributed on different tree species. The data shows that pine, birch and spruce are the dominating tree species (Table 5.2.7) and that deciduous trees cover 46 % of the forested area. Deciduous tree species dominate in private forests, whereas conifers are most common in state and municipal forests.

Table 5.2.7. Tree species coverage in the Latvian forests 2012 expressed in 1 000 ha. Source: Latvian State Forest Service (2012)

Species	Total area	Municipal	Private	State
Aspen	137.2	1.7	89.0	46.4
Grey alder	202.6	3.2	189.1	10.4
Birch	870.8	13.6	525.5	331.7
Lime	2.0	0.07	1.3	0.6
Black alder	80.5	1.5	40.9	38.1
Other softwoods	1.9	0.07	1.7	0.1
Beech	0.04	0	0	0.04
Ash	15.6	0.3	7.9	7.3
Oak	9.8	0.2	6.8	2.8
Other hardwoods	2.5	0.07	2.2	0.3
Spruce	520.6	5.1	205.3	310.2
Larch	1.2	0.02	0.4	0.8
Pine	1009.2	25.4	296.4	687.4
Other coniferous	0.1	0.01	0.03	0.1
Total	**2854.0**	**51.1**	**1366.6**	**1436.3**

5.3. CLASSIFICATION INTO AGE CLASSES

The classification into age classes of the forest areas gives a clue to how large areas can be harvested in the future. Our focus is the situation in 2050 and knowledge about available areas makes it possible to estimate potential harvests. The growth can be increased by introducing species with shorter rotation periods like hybrid aspen and poplar, by speeding up rotations with fertilization, and by taking agriculture land into production of woody biomass. Thus, productivity as well as available area could be increased in a reasonable short time.

The overall situation in the ENERWOODS countries show that most forest areas have young to middle aged stands, i.e. 20–60 years old (Table 5.3.1). In a 2050 perspective this means there will be large forest areas that are mature and accessible for wood harvests at that time, provided that the stands are managed in a conventional way with thinning and final harvest. There are some differences between countries. Finland, Norway and Sweden have large shares with old forest compared to the other countries.

Table 5.3.1. Age distribution of Nordic and Baltic forests expressed in 1 000 ha and percentage (within parentheses). Sources: se tables for respective country below. * = productive forest land.

Age class	Country						TOTAL
	Denmark	Finland	Norway	Sweden*	Estonia	Latvia	
Unknown/Varying	70 (27.8)	-	-	-	-	-	70 (0.1)
0	20 (3.3)	254 (1.3)	204 (1.9)	-	-	-	478 (0.8)
1-20	123 (17.1)	3 311 (16.3)	1 183 (11.2)	4 891 (21.9)	279 (13.5)	1 074 (18.8)	10 861 (17.7)
21-40	159 (20.6)	3 723 (18.4)	1 284 (12.2)	4 822 (21.5)	400 (19.4)	765 (13.4)	11 153 (18.1)
41-60	136 (18.3)	4 048 (20.0)	1 779 (16.9)	3 891 (17.4)	619 (30.0)	1 133 (19.8)	11 606 (18.9)
61-80	46 (5.8)	3 268 (16.1)	1 615 (15.4)	2 334 (10.4)	445 (21.6)	1 287 (22.5)	8 995 (14.6)
81-100	24 (3.1)	2 339 (11.5)	1 520 (14.5)	1 964 (8.8)	199 (9.6)	828 (14.5)	6 874 (11.2)
101-120	12 (1.8)	1 156 (5.7)	1 170 (11.1)	1 588 (7.1)	72 (3.5)	376 (6.6)	4 374 (7.1)
121-140	8 (0.8)	622 (3.1)	1 043 (9.9)	1 321 (5.9)	49 (2.4)	135 (2.4)	3 178 (5.2)
>140	10 (1.3)	1 538 (7.6)	717 (6.8)	1 568 (7.0)	-	110 (1.9)	3 943 (6.4)
Total	608	20 259	10 518	22 379	2 063	5 708	61 532

Data on age and species class distribution for the Danish forests show that a large proportion of the beech forests are approaching maturity, that only quite small areas are being rejuvenated with Norway spruce and that large areas are being planted with oak (Table 5.3.2). Many stands have an unknown age, especially beech and oak stands.

Table 5.3.2. Age and species distribution for the Danish forests expressed in 1 000 ha Source: Johannsen *et al.* (2013).

Age class	Beech	Oak	Ash	Syca-more	Birch	Other broadl	Norway spruce	Sitka spruce	Noble fir	Kauk. fir	Other fir	Pine	Other conif.	Unknown	TOTAL
Unknown	16.0	8.1	5.8	7.1	7.2	10.3	3.2	1.8	1.6	3.5	2.2	0.7	0.7	1.6	69.8
1-10	3.2	4.3	0.3	0.8	5.3	5.4	2.6	1.5	12.9	2.9	4.1	0.1	1.2	0.0	44.6
11-20	6.6	8.3	0.9	1.4	9.7	7.9	8.1	4.9	9.2	9.2	7.6	0.9	4.2	0.0	78.8
21-30	4.0	7.4	1.4	2.5	6.3	4.7	20.1	8.2	3.0	11.7	5.9	1.3	2.8	0.0	79.4
31-40	2.3	6.0	2.0	3.2	6.8	6.0	21.4	5.6	2.0	12.5	6.5	2.8	2.0	0.0	79.1
41-50	4.8	7.9	2.0	3.3	6.7	4.2	22.1	5.3	0.8	9.5	6.1	4.8	0.8	0.0	78.3
51-60	5.2	5.3	2.0	1.4	2.5	3.0	14.6	4.0	0.4	9.1	5.9	3.9	0.7	0.0	58.1
61-70	3.1	3.8	1.6	1.3	0.3	0.7	4.7	1.8	0.0	5.1	1.8	2.1	0.1	0.0	26.4
71-80	5.9	3.2	1.0	0.9	0.2	0.9	2.1	1.1	0.2	2.6	0.7	0.5	0.1	0.0	19.3
81-90	5.8	2.9	1.2	0.6	0.1	0.7	0.4	0.4	0.0	1.6	0.2	0.1	0.0	0.0	14.0
91-100	6.2	1.3	0.4	0.0	0.1	0.2	0.1	0.0	0.0	0.8	0.3	0.1	0.0	0.0	9.6
101-110	6.1	0.9	0.4	0.0	0.0	0.0	0.1	0.1	0.0	1.3	0.0	0.1	0.0	0.0	8.9
111-120	2.0	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.7	0.0	0.0	0.0	0.0	3.4
121-130	3.9	1.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	5.4
131-140	1.7	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.4
141-150	4.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	4.8
>150	4.2	1.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
Total	85.5	63.2	19.1	22.3	45.2	44.5	99.6	34.8	30.2	70.5	41.4	17.4	12.6	1.6	587.7

In Finland forest land has been distributed both on development and age classes (Table 5.3.3). The age class distribution is fairly even from the plant stage up to 80 years and then gradually decreases. Young and advanced thinning stands dominate when data are expressed in stand development classes.

Table 5.3.3. Forest land by development and age classes in Finland expressed in 1 000 ha. Source: Finnish Forest Research Institute (2012).

Stand development class	S Finl.	N.Finl.	TOTAL	Age class (years)	S Finl.	N Finl.	TOTAL
Temporarily unstocked area	159	92	251	Unstocked	161	93	254
Young seedling stand	775	612	1 387	1– 20	2 170	1 141	3 311
Advanced seedling stand	1 370	872	2 243	21– 40	2 455	1 268	3 723
Young thinning stand	3 098	3 501	6 598	41– 60	2 389	1 659	4 048
Advanced thinning stand	3 374	1 743	5 517	61– 80	1 552	1 716	3 268
Mature stand	1 563	954	2 516	81–100	1 195	1 144	2 339
Shelter tree stand	10	17	27	101–120	693	463	1 156
Seed tree stand	31	100	132	121–140	295	327	622
				141–	176	1 363	1 538
TOTAL	10 781	7 890	18 671	TOTAL	11 086	9 172	20 259

Also Norwegian forest data has been distributed in development and age classes. More than 38 % of the productive forest land area has stands mature for final felling (Table 5.3.4). The share among young, young production and old production forests are similar and about 20 % each. The age class 41–60 years is most frequent in productive forest and especially so in the area around Oslo. However, the age class distribution is fairly even up to 100 years, after which the areas decrease (Table 5.3.5).

Table 5.3.4. Productive forest land in Norway distributed by development classes (1 000 ha). Source: Granhus *et al.* (2012).

Development class	Region: Östfold. Akershus. Oslo. Hedmark		Oppland. Buskerud. Vestfold		Telemark. A-Agder. V-Agder		Rogaland. Hordaland. Sogn & F. Möre & R		Sor-Tröndelag. Nord-Tröndelag		Nordland Troms		All regions	
	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)
1. Bare forest land	52.4	2.7	42.4	2.8	27.7	2.3	35.8	3.4	18.2	1.7	27.3	2.4	203.8	2.6
2. Young forest	451.6	23.0	330.8	21.6	226.8	10.3	108.2	10.3	228.9	21.1	167.8	14.8	1 514.2	19.1
3. Young prod. forest	465.5	23.7	292.2	19.1	202.5	17.1	217.2	20.7	197.2	18.2	154.0	13.6	1 528.6	19.2
4. Old prod. forest	405.0	20.7	316.6	20.7	214.8	18.2	270.9	25.8	200.0	18.4	253.5	22.4	1 660.9	20.9
5. Mature for final felling	586.5	29.9	549.2	35.9	509.6	43.1	417.8	39.8	441.7	40.7	529.1	46.8	3 033.9	38.2
Sum	**1 961**	**100**	**1 531**	**100**	**1 181**	**100**	**1 050**	**100**	**1 086**	**100**	**1 132**	**100**	**7 941**	**100**

Table 5.3.5. Forest land area in Norway distributed on age classes and land types (1 000 ha). Source: Granhus *et al.* (2012).

Land type	Age class	Region: Östfold. Akershus. Oslo. Hedmark		Oppland. Buskerud. Vestfold		Telemark. A-Agder. V-Agder		Rogaland. Hordaland. Sogn & F. Möre & R		Sor-Tröndelag. Nord-Tröndelag		Nordland Troms		All regions	
		(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)	(area)	(%)
Productive forest	0	52.4	2.7	42.4	2.8	27.7	2.3	35.8	3.4	18.2	1.7	27.3	2.4	203.8	2.6
	1–20	348.1	17.7	266.5	17.4	170.7	14.4	79.6	7.6	162.3	14.9	121.6	10.7	1 148.7	14.5
	21–40	271.5	13.8	188.1	12.3	152.4	12.9	167.7	16.0	152.8	14.1	122.5	10.8	1 055.0	13.3
	41–60	397.0	20.2	256.9	16.8	171.3	14.5	195.7	18.6	146.8	13.5	147.7	13.0	1 315.4	16.6
	61–80	210.8	10.8	174.3	11.4	119.4	10.1	168.4	16.0	102.5	9.4	245.8	21.7	1 021.2	12.9
	81–100	155.0	7.9	156.4	10.2	141.7	12.0	188.3	17.9	133.9	12.3	283.6	25.1	1 059.0	13.3
	101–120	214.3	10.9	162.8	10.6	165.9	14.0	117.4	11.2	114.7	10.6	124.7	11.0	899.8	11.3
	121–140	179.0	9.1	174.8	11.4	137.8	11.7	66.9	6.4	163.1	15.0	43.2	3.8	764.8	9.6
	141–160	89.4	4.6	82.6	5.4	64.3	5.4	25.7	2.4	79.4	7.3	13.5	1.2	354.9	4.5
	>160	43.4	2.2	26.5	1.7	30.3	2.6	4.5	0.4	12.3	1.1	1.8	0.2	118.8	1.5
	Sum	**1 961**	**100**	**1 531**	**100**	**1 181**	**100**	**1 050**	**100**	**1 086**		**1 132**	**100**	**7 941**	**100**
Non-productive forest	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1–20	0.9	0.3	1.8	0.6	2.7	0.6	13.0	2.9	4.4	0.9	11.9	1.8	34.7	1.3
	21–40	4.2	1.6	9.9	3.5	18.9	4.3	101.9	22.7	13.5	2.8	80.9	12.4	229.3	8.9
	41–60	38.4	14.6	41.9	14.9	54.3	12.2	101.0	22.5	48.4	10.1	179.8	27.5	463.8	18.0
	61–80	57.7	21.9	71.0	25.2	91.4	20.6	80.8	18.0	94.6	19.6	198.6	30.3	594.2	23.1
	81–100	61.3	23.3	71.7	25.4	58.2	13.1	50.3	11.2	109.1	22.6	110.1	16.8	460.7	17.9
	101–120	28.9	11.0	23.8	8.4	64.1	14.5	42.0	9.4	73.0	15.1	38.3	5.8	270.1	10.5
	121–140	38.3	14.5	31.4	11.1	62.9	14.2	29.7	6.6	90.7	18.8	25.1	3.8	278.3	10.8
	141–160	18.4	7.0	16.2	5.7	50.0	11.3	20.5	4.6	32.9	6.8	8.1	1.2	146.2	5.7
	>160	15.3	5.8	14.4	5.1	40.7	9.2	9.6	2.1	15.1	3.1	1.8	0.3	96.9	3.8
	Sum	**263**	**100**	**282**	**100**	**443**	**100**	**452**	**100**	**482**		**655**	**100**	**2 577**	**100**
Total sum		**2 224**		**1 814**		**1 625**		**1 501**		**1 586**		**1 786**		**10 518**	

Swedish forest area data is presented both for age classes and for maturity classes (Table 5.3.6). Forest in thinning stage is the most common maturity class over the whole country covering 39 % of the productive forest land. The most common age classes, seen in a 10-year interval perspective, are 21–30 and 31–40 years. It can also be seen that the oldest age classes are less common in the southern parts of the country (Götaland and Svealand) than in the north. This was expected since the rotation time is substantially shorter in the southern part of the country.

Table 5.3.6. Productive forest land area by maturity and age classes for different regions in Sweden expressed in 1 000 ha. Source: Swedish Forest Agency (2013).

Maturity class	Norra Norrland	Södra Norrland	Svealand	Götaland	Total country	Total (%)
Bare forest land	231	248	243	269	991	**4.4**
Thicket stage/young forest	1 518	1 384	1 153	985	5 039	**22.5**
Forest in thinning age	2 638	2 161	2 093	1 843	8 735	**39.0**
Older forest not mature for final felling	714	545	508	495	2 262	**10.1**
Forest mature for final felling	1 429	1 343	1 231	1 349	5 352	**23.9**
TOTAL	**6 529**	**5 681**	**5 228**	**4 941**	**22 379**	
Age class (years)	**Norra Norrland**	**Södra Norrland**	**Svealand**	**Götaland**	**Total country**	**Total (%)**
0– 2	211	240	225	236	911	**4.1**
3– 10	476	462	456	483	1 877	**8.4**
11– 20	471	581	547	503	2 103	**9.4**
21– 30	655	673	614	492	2 434	**10.9**
31– 40	587	611	612	578	2 388	**10.7**
41– 60	1 141	882	968	900	3 891	**17.4**
61– 80	757	392	503	682	2 334	**10.4**
81–100	581	428	417	538	1 964	**8.8**
101–120	472	454	342	321	1 588	**7.1**
121–140	486	437	267	131	1 321	**5.9**
141–	693	521	276	78	1 568	**7.0**
TOTAL	**6 529**	**5 681**	**5 228**	**4 941**	**22 379**	

The Estonian statistics present areas both as development classes and by age classes for dominant trees (Table 5.3.7). Middle-aged stands are most common with 38.1 % of the forest area followed by mature stands with 27.9 %, and 12.1 % can be classified as premature stands. So, 40 % of the forest area is covered by mature and premature stands which have a potential for harvesting in the near future. The most frequent age classes are 41–50 and 51–60 years. Pines are generally older than other tree species while grey alder stands are seldom more than 50 years old.

Table 5.3.7. Distribution of forest land and forest stands by development classes and age classes for dominant tree species, respectively, in Estonia. Figures are given as 1 000 ha when not otherwise stated. Source: Estonian Environmental Information Centre (2012).

Development class	Pine	Spruce	Birch	Aspen	Black alder	Grey alder	Others	Total	Total (%)
Treeless area	12.3	19.8	15.5	2.4	2.4	2.4	0.2	**55.1**	2.5
Under regeneration	18.3	17.0	17.5	9.0	2.7	5.3	1.0	**70.8**	3.2
Young forest	40.7	26.7	101.3	26.7	8.2	36.1	5.7	**245.4**	11.1
Pole stand	33.1	18.2	57.2	2.4	1.7	0	0.7	**113.3**	5.1
Middle-aged stands	417.1	167.5	214.2	2.6	13.8	7.9	19.1	**842.2**	38.1
Premature stands	72.2	38.6	108.3	3.6	14.3	26.6	4.0	**267.6**	12.1
Mature stands	150.2	81.7	166.6	76.8	27.4	108.2	6.5	**617.4**	27.9
TOTAL	**743.9**	**369.5**	**680.6**	**123.5**	**70.5**	**186.5**	**37.2**	**2 212.0**	100
TOTAL (%)	33.6	16.7	30.8	5.6	3.2	8.4	1.7	100	
Age class (years)	**Pine**	**Spruce**	**Birch**	**Aspen**	**Black alder**	**Grey alder**	**Others**	**Total**	Total (%)
≤10	10.3	9.0	65.7	24.7	5.5	28.3	4.3	**147.8**	7.2
11–20	22.0	16.8	54.2	7.3	2.5	24.5	4.0	**131.3**	6.4
21–30	27.6	33.8	49.5	4.8	2.2	36.1	2.4	**156.4**	7.6
31–40	48.8	45.8	77.2	9.1	9.5	49.0	3.7	**243.1**	11.8
41–50	77.2	43.1	122.7	17.9	14.8	28.4	5.3	**309.4**	15.0
51–60	102.4	40.7	119.3	25.6	12.1	3.0	6.2	**309.3**	15.0
61–70	106.9	44.6	66.9	14.6	10.6	0.4	2.1	**246.1**	11.9
71–80	87.4	43.0	49.9	8.1	6.9	0.3	3.5	**199.1**	9.7
81–90	68.1	25.7	15.0	2.5	1.8		2.1	**115.2**	5.6
91–100	60.2	15.5	6.6	0.7	0.1		1.0	**84.1**	4.1
101–110	35.3	8.2	1.9		0.3		1.3	**47.0**	2.3
111–120	20.6	3.8	0.2		0.1		0.6	**25.3**	1.2
121–130	17.0	2.3			0.1		0.0	**19.4**	0.9
>130	26.7	2.1					0.6	**29.4**	1.4
TOTAL	**710.5**	**334.4**	**629.1**	**115.3**	**66.5**	**170.0**	**37.1**	**2 062.9**	100
TOTAL (%)	34.4	16.2	30.5	5.6	3.2	8.2	1.8	100	

Tree species have been distributed on age classes of 10-year intervals in Latvia (Table 5.3.8). Like in Estonia, grey alder stands are young also in Latvia, and this is also the case for spruce. Aspen, birch and pine stands have more medium-aged averages.

Table 5.3.8.Main tree species and their area occurrence. expressed in 1 000 ha. in Latvian forests 2012. Source: Latvian State Forest Service (2012; www.vmd.gov.lv)

Age class / Species	Aspen	Grey alder	Birch	Lime	Black alder	Other soft-woods	Beech	Ash	Oak	Other hard-woods	Spruce	Larch	Pine	Other conife-rous	Total
1-10	76.09	41.98	153.06	0.09	7.08	0.10	0.01	0.54	0.85	0.21	163.31	0.08	107.49	0.01	**550.8**
11-20	60.02	38.88	208.15	0.03	8.40	0.63	0.01	1.92	0.50	0.26	117.03	0.28	86.75	0.03	**522.8**
21-30	11.96	68.88	89.98	0.05	8.77	0.85	0.01	2.13	0.20	0.12	120.74	0.75	41.87	0.06	**346.3**
31-40	9.51	89.41	104.17	0.12	12.61	0.96	0.04	2.32	0.35	0.13	146.10	0.15	52.67	0.06	**418.5**
41-50	13.64	108.22	166.20	0.20	17.65	0.94	0.01	3.20	0.67	0.27	152.99	0.61	76.18	0.04	**540.7**
51-60	23.71	49.17	281.12	0.32	26.05	0.65	0.01	3.95	0.76	0.44	63.56	0.12	142.63	0.07	**592.5**
61-70	26.07	8.66	336.85	0.33	27.71	0.45	0.01	4.90	1.09	0.59	51.95	0.04	251.28	0.03	**709.9**
71-80	23.69	0	194.91	0.41	22.66	0.26	0.01	4.05	1.08	0.58	54.40	0.05	275.32	0.01	**577.4**
81-90	15.75	0	104.40	0.43	14.40	0.15	0.01	2.99	1.59	0.48	52.12	0.04	269.28	0.01	**461.6**
91-100	8.35	0	63.61	0.40	7.82	0.08	0.01	1.98	2.42	0.32	48.37	0.04	233.10	0.02	**366.4**
101-110	3.81	0	27.75	0.43	4.82	0.04	0.01	1.27	2.11	0.21	31.42	0.03	170.41	0.01	**242.3**
111-120	1.21	0	8.25	0.49	1.67	0.01	0.01	0.79	2.24	0.08	17.13	0.05	102.30	0.03	**134.2**
121-130	0.34	0	2.49	0.29	1.04	0.01	0.01	0.34	1.36	0.07	8.89	0.08	67.58	0.03	**82.5**
131-140	0.23	0	0.61	0.23	0.30	0.01	0	0.24	1.07	0.03	5.86	0.03	44.03	0.01	**52.6**
141 +	0.04	0	0.14	0.26	0.08	0.01	0	0.58	3.40	0.07	7.43	0.06	97.54	0.01	**109.6**
Total	**274.42**	**405.20**	**1 741.69**	**4.08**	**161.06**	**5.15**	**0.16**	**31.20**	**19.69**	**3.86**	**1 041.30**	**2.41**	**2 018.43**	**0.43**	**5 708.0**

5.4. STANDING VOLUMES

Estimates of standing volumes are more closely related to potential amounts of biomass available for harvest than areas, but area based and standing crop data complement each other for a more complete picture of the current availability of forest biomass. The standing volume per unit of area, i.e. hectare, is also a valuable figure when evaluating potentially available biomass resources.

In table 5.4.1 it is clearly seen that the ENERWOODS region is dominated by Scots pine and Norway spruce. They constitute almost 77 % of the growing stock. The third most common species is birch. Thus, for nearest future these three species is the base for forestry, whether the raw material is sawn timber, pulp wood or energy biomass. Denmark is different from the other countries since the volume of broadleaves is higher than the growing stock of conifers.

Table 5.4.1. Growing stock in the Nordic and Baltic countries distributed on main tree species and expressed in million m^3 on bark. Sources: the same as for respective countries below. [1] including all pine species; [2] Latvia not included.

Tree species	Country						Total
	Denmark	Finland	Norway	Sweden	Estonia	Latvia	
Scots pine	8.4[1]	1 145	266	1 173.7	173.8		2 767[2]
Norway spruce	22.0	698	395	1 246.8	80.7		2 443[2]
Birch	4.8	384	140	362.9	120.5		1 012[2]
Other broadleaves	64.5	78	68	181.7	83.4		476[2]
Other conifers	25.4	.	10	36.7	.		72[2]
Total	125.1	2 305.0	879	3 001.8	458.4	631.0	6 769

In Denmark the total growing stock is 125 million m^3 or 206 m^3 ha^{-1}.(Table 5.4.2) The highest stocking is found in beech, fir and ash forests (396, 330 and 283 m^3 ha^{-1}, respectively) and the lowest is found for Nordmann fir (50 m^3 ha^{-1}). The latter species is mostly grown for Christmas trees. The standing volume is also low in birch and pine stands. The age classes up to 30 years contain over 60 % of the growing stock (Table 5.4.3), indicating that the Danish forests are comparably young.

Table 5.4.2. Growing stock in million m³ and (*m³ ha⁻¹*) in Denmark distributed on forest land owner groups and tree species. Source: Johannsen *et al.* (2013).

	Private	Foundations	State forest	Other state owned	Other public	Unknown	Total
Deciduous	51.12 (*245*)	3.46 (*268*)	10.00 (*268*)	0.607 (*150*)	3.32 (*215*)	0.84 (*216*)	69.33 (*246*)
Beech	21.94 (*403*)	1.76 (*340*)	5.92 (*401*)	0.15 (*260*)	1.27 (*366*)	0.42 (*454*)	31.45 (*396*)
Oak	9.07 (*206*)	0.64 (*256*)	1.75 (*188*)	0.16 (*130*)	0.59 (*168*)	0.13 (*127*)	12.35 (*200*)
Ash	4.29 (*284*)	0.16 (*218*)	0.44 (*290*)	0.05 (*241*)	0.36 (*315*)	0.11 (*284*)	5.40 (*283*)
Sycamore	4.78 (*265*)	0.36 (*284*)	0.61 (*301*)	0.05 (*275*)	0.26 (*178*)	0.07 (*238*)	6.11 (*263*)
Birch	3.48 (*113*)	0.19 (*131*)	0.73 (*123*)	0.09 (*123*)	0.25 (*113*)	0.06 (*99*)	4.81 (*115*)
Other broadl	7.56 (*165*)	0.34 (*200*)	0.55 (*147*)	0.10 (*94*)	0.59 (*164*)	0.05 (*77*)	9.20 (*163*)
Conifers	36.88 (*179*)	1.99 (*223*)	13.30 (*193*)	0.51 (*163*)	2.08 (*188*)	1.07 (*207*)	55.84 (*184*)
Norway spruce	14.67 (*217*)	0.96 (*314*)	5.31 (*277*)	0.17 (*186*)	0.66 (*215*)	0.27 (*276*)	22.04 (*233*)
Sitka spruce	4.70 (*211*)	0.43 (*223*)	1.77 (*181*)	0.11 (*210*)	0.21 (*263*)	0.29 (*426*)	7.52 (*208*)
Fir species	3.959 (*346*)	0.17 (*314*)	1.22 (*290*)	0.05 (*318*)	0.31 (*334*)	0.13 (*326*)	5.83 (*330*)
Pine species	4.88 (*121*)	0.07 (*91*)	2.74 (*107*)	0.06 (*81*)	0.52 (*119*)	0.12 (*80*)	8.38 (*115*)
Nordmann fir	1.21 (*46*)	0.04 (*53*)	0.14 (*126*)	0.00 (*155*)	0.02 (*109*)	0.02 (*45*)	1.43 (*50*)
Noble fir	1.52 (*144*)	0.03 (*42*)	0.33 (*375*)	0.04 (*462*)	0.02 (*210*)	0.00 (*15*)	1.94 (*155*)
Other conifers	5.96 (*213*)	0.29 (*235*)	1.79 (*215*)	0.08 (*115*)	0.34 (*205*)	0.24 (*272*)	8.70 (*213*)
Total	**88.00 (*206*)**	**5.44 (*243*)**	**23.31 (*213*)**	**1.11 (*149*)**	**5.39 (*201*)**	**1.92 (*124*)**	**125.16 (*206*)**

Table 5.4.3. Growing stock (million m³) in Denmark distributed on tree species and age classes. Source: Johannsen *et al.* (2013).

Age class	Beech	Oak	Ash	Sycamore	Birch	Other broadl	N spruce	S spruce	Noble fir	Nordm fir	Other fir	Pine	Other conifers	Total
1-10	1.65	1.48	0.50	1.15	1.52	1.89	5.66	1.63	0.52	0.50	0.63	1.93	1.54	20.60
11-20	3.07	2.08	1.03	1.75	1.46	2.49	8.60	2.58	0.50	0.54	1.47	2.92	2.25	30.72
21-30	4.95	2.26	1.49	1.61	0.89	1.96	5.23	1.81	0.15	0.45	1.83	2.08	2.21	26.91
31-40	5.03	1.58	1.04	0.75	0.26	0.90	1.21	0.68	0.06	0.24	0.92	0.57	1.17	14.43
41-50	0.58	0.47	0.14	0.37	0.51	0.71	0.74	0.23	0.17	0.06	0.09	0.47	0.20	4.74
51-60	6.06	1.51	0.73	0.37	0.11	0.52	0.33	0.32	0.02	0.11	0.52	0.21	0.74	11.54
61-70	4.47	1.15	0.38	0.06	0.04	0.24	0.11	0.12	-	0.02	0.16	0.09	0.31	7.16
71-80	2.73	0.70	0.09	0.04	-	0.14	0.03	0.06	-	0.01	0.14	0.02	0.14	4.10
81-90	1.71	0.35	0.03	0.05	-	0.16	-	0.01	-	-	0.01	0.01	0.04	2.36
91-100	0.65	0.22	0.02	0.02	-	0.06	-	0.01	-	-	-	-	0.02	1.00
>100	0.82	0.60	-	-	-	0.17	-	0.02	-	-	-	-	0.02	1.62
Total	**31.72**	**12.40**	**5.44**	**6.17**	**4.79**	**9.24**	**21.91**	**7.46**	**1.43**	**1.93**	**5.78**	**8.28**	**8.62**	**125.17**

Total growing stock in Finland is 2 306 million m³. Pine dominates with 1 145 million m³, followed by spruce with 698 million m³ (Table 5.4.4). Mean growing stock over the whole country was 111 m³ ha⁻¹, with higher volumes in the southern (137 m³ ha⁻¹) compared with the northern part of the country (79 m³ ha⁻¹). The figures of mean growing stock for different species are distributed on the total forest area and together they show the total mean growing stock. In Table 5.4.5 mean growing stock has been distributed by development classes on available forest land, thereof the small differences compared to Table 5.4.4. There is a large difference in mean growing stock in mature stand between southern and northern Finland, with 252 m³ ha⁻¹ in the south and 131 m³ ha⁻¹ in the north. A difference in mean growing stock between the two country parts could be seen also for all other development classes.

Table 5.4.4. Growing stock volumes and mean growing stock on forest land and poorly productive forest land by tree species. Source: Finnish Forest Research Institute (2012).

Growing stock (million m³)			
Tree species	**Southern Finland**	**Northern Finland**	**Total**
Scots pine	676	469	**1 145**
Norway spruce	542	156	**698**
Birch	250	135	**384**
Other broadleaved	65	13	**78**
Total volume	**1 533**	**773**	**2 306**
Available part (%)	**96.1**	**81.4**	**91.2**
Mean growing stock (m³ ha⁻¹)			
Tree species	**Southern Finland**	**Northern Finland**	**Total**
Scots pine	60	48	**55**
Norway spruce	49	16	**34**
Birch	22	13	**18**
Other broadleaved	6	1	**4**
Total volume	**137**	**79**	**111**

Table 5.4.5. Mean growing stock volumes by stand development classes on forest land available for wood production. Source: Finnish Forest Research Institute (2012).

Mean growing stock (m³ ha⁻¹) **Stand development class**	**Southern Finland**	**Northern Finland**	**Total**
Temporarily unstocked area	6	5	**6**
Young seedling stand	9	12	**10**
Advance seedling stand	28	22	**26**
Young thinning stand	106	72	**88**
Advanced thinning stand	183	114	**162**
Mature stand	252	131	**206**
Shelter tree stand	117	71	**88**
Seed tree stand	35	22	**25**
Total volume	**136**	**77**	**111**

In Norway volumes are expressed under bark, which mean that the figures should be multiplied by ~1.18 (cf. Granhus *et al.* 2012) to be comparable to data from other countries. In Table 5.4.6 the volumes are distributed on tree species and regions. Spruce is the dominant species with almost 335 million m^3, followed by Scots pine and birch. In total, the growing stock on forest land in Norway was 745 million m^3 under bark as an average during the period 2005–2009, corresponding to c. 879 million m^3 on bark. To this should be added about 80 million m^3 growing on other types of land (Statistics Norway 2011).

Table 5.4.6. Growing stock under bark on forest land by tree species and regions 2005–2009 in Norway, expressed in million m^3 under bark. Source: Granhus *et al.* (2012).

Region	**Tree species**									**Total**
	Norway spruce	Introd. spruces	Scots pine	Introd. pines	Birch	Aspen	Grey alder	Oak	Other broadl.	
Østfold, Akershus, Oslo, Hedmark	108.1	-	75.1	0.1	20.2	2.0	2.6	0.1	2.3	**210.4**
Oppland, Buskerud, Vestfold	86,7	0.1	42.0	0.0	19.0	2.2	1.7	0.3	4.6	**156.7**
Telemark, Aust- and Vest-Agder	45.6	0.5	54.2	0.0	15.8	5.0	0.4	5.6	4.3	**130.3**
Rogaland, Hordaland. Sogn & F, Møre & F	28.5	4.8	34.9	0.9	23.3	2.3	4.1	0.8	7.7	**107.2**
Sør-Trøndelag, Nord-Trøndelag	53.4	0.1	14.8	0.5	11.9	0.7	2.5	-	2.2	**85.9**
Nordland, Troms	13.3	1.2	4.8	0.5	28.3	1.0	1.8	-	3.3	**54.2**
Total	**334.6**	**6.7**	**225.7**	**2.0**	**118.5**	**13.1**	**13.1**	**6.8**	**24.3**	**744.8**

Scots pine and Norway spruce are the dominating tree species in Sweden with just under and over 1 200 million m^3, respectively (Table 5.4.7). Birch is the third most common species with 360 million m^3, whereas other species are found with up to maximum 50 million m^3. Table 5.4.8 shows the average growing stocks in Sweden. The highest standing volume per hectare, 222 m^3 ha^{-1}, is found in the age class 81–100 years. The volume is about twice as high in the southernmost region (Götaland) compared to Norra Norrland in the very north. A comparison between tables 5.4.7 and 5.2.5 also shows that Götaland has the smallest forest land area but the highest standing volume.

Table 5.4.7. Standing volume in million m^3 on productive forest land area, excluding protected productive forest land, in Sweden 2008–2012. Source: Swedish Forest Agency (2013).

Tree species	**Region** N Norrland	S Norrland	Svealand	Götaland	**TOTAL**
Scots pine	303.4	276.1	335.4	258.8	**1 173.7**
Norway spruce	182.3	334.7	323.9	405.9	**1 246.8**
Lodgepole pine	8.8	23.7	3.1	0.0	**35.5**
Larch	0.0	0.1	0.3	0.7	**1.2**
Birch	95.2	93.1	81.2	93.4	**362.9**
Aspen	4.5	9.1	18.6	18.0	**50.3**
Alder	1.6	9.1	13.3	20.7	**44.6**
Other broad-leaved	3.7	5.9	5.8	8.3	**23.7**
Oak	0.0	0.0	4.5	30.0	**34.5**
Beech	0.0	0.0	0.0	17.6	**17.6**
Ash	0.0	0.0	0.9	4.2	**5.1**
Other noble broad-leaved	0.0	0.1	1.3	4.5	**5.9**
Total	**599.4**	**751.9**	**788.2**	**862.2**	**3 001.7**
Total (%)	20.0	25.0	26.3	28.7	

Table 5.4.8. Standing volume per hectare on productive forest land by age classes in Sweden 2008–2012. Protected productive forest land is excluded. Source: Swedish Forest Agency (2013).

Age class (year)	Region				
	N Norrland	S Norrland	Svealand	Götaland	Total average
0 – 2	13	9	18	19	15
3 – 10	8	9	17	17	13
11 – 20	15	26	34	42	30
21 – 30	40	68	80	107	71
31 – 40	63	119	133	171	121
41 – 60	92	159	195	227	164
61 – 80	121	200	252	259	203
81 – 100	136	220	265	283	222
101–120	152	222	249	285	220
121 – 140	163	219	226	266	204
141 –	138	197	201	225	173
Total average	92	132	151	174	134

In Estonia figures are available on growing stock for different species and also different counties. Table 5.4.9 shows the volumes allocated to species and ownership. In total, there is almost 460 million m^3 of standing volume in Estonia, and pine is dominating with 38 % of this volume. It is followed by birch (26 %) and spruce (18 %). Standing volume per unit of area (Table 5.4.10) is in average 207 m^3 ha^{-1}, with the highest figure for the minor tree species larch, with 241 m^3 ha^{-1}, and the lowest in grey alder forests with 166 m^3 ha^{-1}. The figures for state forests and other owners are mostly similar, although species differences occur. These are most obvious for spruce where the category other owners had higher volume and aspen, where state forest had higher volume.

Table 5.4.9. Distribution of growing stock by dominant tree species and ownership in Estonia expressed in million m^3. Source: Estonian Environmental Information Centre (2012).

Tree species	**State forest**	**Other owners**	**Total**	Total (%)
Scots pine	88.17	85.60	**173.77**	37.9
Norway spruce	31.75	48.94	**80.69**	17.6
Birch	39.67	80.87	**120.54**	26.3
Aspen	11.54	18.27	**29.81**	6.5
Black alder	4.88	11.40	**16.28**	3.6
Grey alder	1.95	28.97	**30.92**	6.7
Others	0.91	5.53	**6.44**	1.4
TOTAL	**178.87**	**279.58**	**458.45**	
TOTAL (%)	39.02	60.98		

Table 5.4.10. Average standing volume per hectare of stands by dominant trees species and ownership in Estonia expressed in m^3 ha^{-1}. Source: Estonian Environmental Information Centre (2012).

Tree species	**State forest**	**Other owners**	**Total**
Scots pine	243	224	**234**
Norway spruce	204	229	**218**
Birch	187	173	**177**
Aspen	310	212	**241**
Black alder	225	233	**230**
Grey alder	145	167	**166**
Others	273	163	**173**
TOTAL	**222**	**199**	**207**

In Latvia the total standing volume in 2010 was 577 million m^3 according to State Forest Service (VMD) data and 631 million m^3 with National Forest Inventory (NFI) data (Bekeris 2011). There is scarce information on how these amounts are distributed to species, forest types and ownership.

5.5. CURRENT GROWTH

The productivity of the forests in the Nordic and Baltic countries is crucial for the future harvest possibilities. In this section we compile the current growth figures from statistical sources. Thus, this level acts as a direct base for comparison when introducing growth increasing measures like fertilization, tree species changes and implementation of breeding progress.

An overall view reveals that the total annual increment on Nordic and Baltic forest land is over 275 million $m^3\ yr^{-1}$ (Table 5.5.1). Finland and Sweden are the two dominating countries with almost 75 % of the stem growth. Pine and spruce are together responsible for nearly 70 % of the increment.

Table 5.5.1. Annual increment of stem volumes in the Nordic and Baltic countries distributed on main tree species and expressed in million $m^3\ yr^{-1}$. Sources: the same as found for respective country below. [1] the figure is for all conifers; [2] the figure is for all broadleaves; [3] data from Latvia are not included.

Tree species	**Country** Denmark	**Finland**	**Norway**	**Sweden**	**Estonia**	**Latvia**	**Total**
Scots pine	3.5[1]	47.4	5.2[1]	41.5	3.7		98.7[3]
Norway spruce		32.5	12.6	50.0	2.6		103.4[3]
Birch	3.2[2]	19.6	3.2	15.3	3.3		47.5[3]
Other broadleaves		4.5	2.0	6.7	2.8		14.0[3]
Total	**6.7**	**104.0**	**23.0**	**113.5**	**12.4**	**16.5**	**276.1**

Gross annual increment is estimated to 6.7 million m^3 in Denmark (Table 5.5.2). Conifer and broadleaf dominated stands make up the major share of the total increment, whereas mixed stands and Christmas trees only account for a minor part of the total increment. Due to changes in forest area, estimates of average annual increment are based on five-year changes in average growing stock and average thinning on permanent plots. Mean annual increment is estimated at 8.8 $m^3 ha^{-1} yr^{-1}$ and is larger for coniferous stands than for broadleaves.

Table 5.5.2. Aennual gross increment for the Danish forests distributed to different land use classes. Source: Johannsen *et al.* (2013).

	Total	**Conifers**	**Broadleaves**	**Mixtures**	**Christmas trees**	**Temporarily stocked**	**Auxillary areas**
Annual gross increment (1 000 m^3)	6 711	3 273	3 178	67	203	11	-22
Annual gross increment ($m^3\ ha^{-1}$)	8.8	13.9	5.4	6.0	5.9	0.6	-2.7

Finnish data present both absolute and per hectare values on annual increment (Table 5.5.3). The total annual increment is 104 million $m^3\ yr^{-1}$, with 73 million m^3 in southern and 31 million m^3 in northern Finland. Mean annual increment is on average 5.1 $m^3\ ha^{-1}\ yr^{-1}$. Divided between south and north Finland the figures are 6.6 and 3.2 $m^3\ ha^{-1}\ yr^{-1}$, respectively.

Table 5.5.3. Annual and mean annual increments by tree species in Finland 2004–2008. Mean annual increments for respective tree species are distributed on the total productive forest area, thereby the low values. Source: Finnish Forest Research Institute (2012).

Region	**Scots pine**	**Norway spruce**	**Birch**	**Other broad-leaved**	**Total**	**MAI (%)**
	(million $m^3\ yr^{-1}$)					
S Finland	28.88	26.70	13.84	3.80	73.22	
N Finland	18.53	5.81	5.75	0.73	30.83	
Total	47.42	32.51	19.59	4.53	104.05	
	($m^3\ ha^{-1}\ yr^{-1}$)					
S Finland	2.6	2.4	1.2	0.3	6.6	4.8
N Finland	1.9	0.6	0.6	0.1	3.2	4.0
Total	2.3	1.6	0.9	0.2	5.1	4.6

Like the growing stock, data on increment is also expressed under bark in Norway. Thus, figures should be multiplied by about 1.18 to be comparable with data from other countries. In Table 5.5.4 the increments on productive forest land are distributed on tree species and regions. Spruce dominates with 12.1 million $m^3\ yr^{-1}$, while Scots pine grew with 5.0 and birch with 3.2 million m^3 annually. The total annual increment was 23.0 million $m^3\ yr^{-1}$ under bark. Annual increment on other types of land amounted to 1.8 million $m^3\ yr^{-1}$ (Statistics Norway 2011).

Table 5.5.4. Mean annual increment in Norwegian forest land by tree species and regions 2005–2009 in Norway, expressed in million m³ under bark. Source: Granhus *et al.* (2012).

Region	Tree species									Total
	Norway spruce	Introd. spruces	Scots pine	Introd. pines	Birch	Aspen	Grey alder	Oak	Other broadl.	
Østfold, Akershus, Oslo, Hedmark	4.15	-	1.96	0.01	0.68	0.06	0.11	0.00	0.11	**7.07**
Oppland, Buskerud, Vestfold	2.84	0.01	0.86	0.00	0.60	0.06	0.07	0.01	0.19	**4.64**
Telemark, Aust- and Vest-Agder	1.72	0.03	1.20	0.00	0.40	0.13	0.02	0.13	0.15	**3.77**
Rogaland, Hordaland. Sogn & F, Møre & F	1.35	0.26	0.63	0.06	0.59	0.05	0.15	0.02	0.28	**3.40**
Sør-Trøndelag, Nord-Trøndelag	1.58	0.01	0.28	0.02	0.35	0.02	0.14	-	0.10	**2.50**
Nordland, Troms	0.51	0.11	0.11	0.02	0.60	0.03	0.09	-	0.12	**1.60**
Total	**12.15**	**0.42**	**5.05**	**0.11**	**3.21**	**0.35**	**0.57**	**0.17**	**0.95**	**22.98**

Mean annual volume increment in Sweden was estimated to 113 million m³ yr⁻¹ during the period 2008–2012 (Table 5.5.5). Over 91 million m³ was assigned to the conifers pine and spruce. Absolute and area based growth is higher the more to the south we are looking (from N. Norrland to Götaland).

Table 5.5.5. Mean annual volume increment by dominant tree species and regions in Sweden 2008–2012 on productive forest land. Increments are expressed in million m^3 yr^{-1}, except for Average growth which is given in m^3 ha^{-1} yr^{-1}. Source: Swedish Forest Agency (2013).

Region	Scots pine	Norway spruce	Birch	Other broad-leaved	Total	Average growth
N Norrland	10.24	5.54	3.91	0.41	20.01	3.1
S Norrland	11.55	11.68	4.50	1.21	28.94	5.1
Svealand	11.94	13.48	3.38	1.68	30.48	5.8
Götaland	7.78	19.32	3.53	3.36	33.99	6.9
Total	41.51	50.02	15.31	6.67	113.52	5.1

In Estonia increment figures are presented as gross annual increment per hectare (Table 5.5.6). The most productive species are Norway spruce, grey alder and larch in the order mentioned. There is no difference between state and private forest in average increment with a level of 5.8–5.9 m^3 ha^{-1} yr^{-1}. However, there are growth differences between species when comparing private and state forests.

Table 5.5.6. Gross annual increment per hectare (m^3 ha^{-1} yr^{-1}) of stands by dominant tree species and ownership. Source: Estonian Environmental Information Centre (2012).

Tree species	State forest	Private forest	Total
Scots pine	4.8	5.2	5.0
Norway spruce	8.9	7.8	8.3
Larch	7.3	7.6	7.5
Oak	3.0	2.3	2.6
Ash	5.0	3.7	4.2
Birch	5.0	4.9	4.9
Aspen	7.0	6.5	6.7
Black alder	5.5	5.1	5.2
Grey alder	8.5	7.5	7.6
Total	5.8	5.9	5.8

In Latvia the total annual volume increment has been estimated to 16.5 million m^3 yr^{-1} but no further resolution on species or regions is available.

5.6. AVAILABLE AREAS AND VOLUMES

Not all areas and volumes of wood are available for harvesting. They can be excluded due to protection, growing on other land use classes or being technically unavailable. In this section we assume that wood on unprotected productive forest land can possibly be used in the future for wood supply, including for energy purposes. A more detailed discussion of available wood for energy is found in section 12 below.

The vast majority of the forest area is available for wood supply in Denmark.. A total of about 40 000 hectares (6.6 %) is set aside as non-intervention forests, or with the aim of protection of specific forest types (old oak scrubs) in reference to the Strategy for Natural Forests, or are part of protected forest nature types according to the Habitat directive in the Natura 2000.

Finnish data present availability of forestry area and of growing stock (Table 5.6.1). A high share of the area on forest land can be used (92 %), while the figures are lower on poorly productive forest land and unproductive land. Concerning wood volumes, over 90 % of standing volume and over 97 % of the annual increment is currently available for the Finnish forestry.

Table 5.6.1. Areas of forestry land classes, growing stock and annual increment by species and their availability for wood production in Finland. Source: Finnish Forest Research Institute (2012).

Category	Area (1 000 ha)				
	Forest land	Poorly productive forest land	Unproductive land	Forest roads. deposits. etc.	Total
Total area	20 259	2 518	3 196	200	26 172
Available area	18 671	1 307	1 044	192	21 214
Availability (%)	*92.2*	*51.9*	*32.7*	*96.0*	*81.1*
Category	Growing stock volume (million m^3)				
	Scots pine	Norway spruce	Broad-leaved		Total
Total volume	1 145	698	463		2 306
Available volume	1 047	632	422		2 102
Availability (%)	*91.4*	*90.5*	*91.1*		*91.2*
Category	Annual increment (million m^3)				
	Scots pine	Norway spruce	Broad-leaved		Total
Total growth	47.4	32.5	24.1		104.0
Available growth	46.0	31.6	23.4		101.1
Availability (%)	*97.0*	*97.2*	*97.1*		*97.2*

In Norway the forest land area is 11.6 million ha (Table 4.1). Of this area 23.3 % (~2.7 million ha) is classified as protection forest (Nordic Family Forestry: www.nordicforestry.org/facts/Norway.asp) and 1.7 % (~0.2 million ha) is protected under The Nature Conservation Act. About 12 000 ha is also voluntary protected by the forest owners themselves, leaving about 8.7 million ha available for use.

Protected and for forestry not used areas are placed in different categories in Sweden (Table 5.6.2). The formally protected forest land amounts to 3.6 %, with the highest share in the northern part of the country (6.4 % in Norra Norrland). The area exempted from forestry is 10.0 % and more equally distributed over the country. The voluntarily set aside areas are substantial with over 1.1 million ha.

Table 5.6.2. Forest land and areas exempted from forestry in Sweden. The Ecoparks of Sveaskog are included in the total figure for Forest land voluntarily set aside. Source: Swedish Forest Agency (2013).

Category	Areas (1 000 ha)				
	N Norrland	S Norrland	Svealand	Götaland	Total
Productive forest land in total	**7 126**	**5 744**	**5 335**	**5 018**	**23 223**
Productive forest land with other use	57	30	123	156	366
Productive forest land in Nat. Parks and Nat. Reserves	453	113	143	97	805
Habitat protection in productive forest land	3.7	3.5	7.3	7.0	21.5
Nature conservation agreements	4.8	4.9	8.8	9.4	27.9
Forest land voluntarily set aside for conservation	331	261	255	200	1 112
Productive forest land not protected and available	**6 276**	**5 332**	**4 798**	**4 549**	**20 891**
Formally protected productive forest land	6.4 %	2.1 %	2.9 %	2.2 %	3.6 %
Productive forest exempted from forestry	11.9 %	7.2 %	10.1 %	9.3 %	10.0 %

In Estonia forest land area is distributed on areas under protection and commercial forest area (Table 5.6.3). From these data it is seen that 75 % of forest land area is available for wood production. There are no estimates from Estonia on available volumes in this context.

In Latvia 190 000 ha are protective forest zones and 66 000 ha are natural forest biotopes (Bekeris 2011). This is about 5.7 % and 2.0 % of the forest land area, respectively. The total forest land area is 3 354 000 ha in the country, thus leaving 3 098 000 ha for commercial use (Latvian State Forest Service: www.vmd.gov.lv/).

Table 5.6.3. Distribution of forest land area by forest categories. Source: Estonian Environmental Information Centre (2012).

Forest category	Area (1 000 ha)	Area (%)
Protected forests	*216.3*	*9.8*
Protection forests	*339.7*	*15.4*
Habitat protection forests	*6.4*	*0.3*
Total forests under protection	**562.4**	**25.4**
of this strictly protected	*222.9*	*10.1*
Commercial forest	**1 649.6**	**74.6**

6. Other available land

During the last century arable land has been used for afforestation. The trend of decreasing arable land, partly depending on afforestation, has continued to this day and the agricultural area of Europe has diminished by about 13 % since 1960. This has happen despite a policy framework that has promoted both increased production and production areas, i.e. by subsidising agriculture on marginal lands. There is some debate about using agriculture land for other purposes than producing food. However, if the need of land for producing food is not there today (a result of increased cultivation efficiency) it seems more advantageous to use this land for production of a demanded commodity, like producing woody biomass that can substitute fossil fuels. If the need should be changed, there are already technologies that can transfer forest back to agriculture land. In addition, scenarios have shown that if technology continues to progress at current rates, the area of agriculture land would need to decline substantially (Rounsevell *et al.* 2005). According to some scenarios the decline in agricultural land needed would be as much as 50 %. For Finland, Norway and Sweden the declines in cropland need were 33–67 % and for Denmark 8–47 % depending on scenario. The figures for grassland were 0–64 % for the Nordic countries (Rounsevell *et al.* 2005). The reduction of agriculture land will, however, be lower if the technology development rate decreases (Eckersten *et al.* 2008). According to the review by Eckersten *et al.* (2008) observed changes of land use that can be related to climate changes are difficult to see.

In Denmark, it became a political goal in 1994 to obtain 20–25 % forest land within a tree generation, which is usually interpreted as 100 years. Based on this goal 250 000–470 000 ha is available for afforestation.

Land areas for afforestation are limited in Finland due to the high share of forested land. During the years 1969–1998 afforestation of abandoned agricultural areas varied between 2 000–18 000 ha per year (Tilli & Toivanen 2000). The peaks were seen in early 1970´s and 1990´s, 12 500 ha and 15 000 ha per year, respectively, due to changes in law and subsidies available for afforestation of abandoned agricultural land. During the period 2004–2011 the afforestation of agricultural areas has annually been varying between 2 000 and 3 600 ha per ha. The total area of fallows and uncultivated arable land was estimated to around 276 000 ha in Finland in 2011 (Ministry of Agriculture and Forestry in Finland 2012a).

Areas available for afforestation are limited in Norway, e.g. due to low productivity and restrictions on converting areas to forest. Agricultural areas of abandoned farms are usually taken over by neighbouring farms and, consequently, farming continues (SSB 2009). However, afforestation of former agricultural land in Norway is generally higher than the transfer of forest to agriculture land, and is annually about 80 ha in six counties in Southeast Norway (SSB 2008). In addition, 175 000 ha of coastal heathland may potentially be afforested (Granhus *et al.* 2012). Areas not actively used or not used for normal farming are about 20 000 ha in Norway (SSB 2012a).

For forest rich countries like Sweden and Finland forest land is still the main area for producing biofuels, but afforestation of arable land can nevertheless produce substantial amounts of biomass in all Nordic and Baltic countries. Recent estimates on absolute figures on areas which are not actively used and still available for afforestation show that Sweden has approximately 300 000–500 000 ha (Anon. 2006. Larsson *et al.* 2009).

It should also be noticed that use of some woody species, i.e. *Salix* and *Populus* in Sweden, does not change land use class to forest land if used as short rotation forestry for energy purposes, i.e. with rotations <10 and <20 years, respectively.

A rapid decline in agricultural land use occurred in Estonia after the restoration of independence in 1991. Today the use of abandoned agricultural areas is considered as one potential way of increasing bioenergy production. A study to estimate the available land resources was carried out in 2007 (Landresource 2007). Abandoned agricultural areas were identified and in 2007 there were about 123 000 ha without any applications for CAP (Common Agriculture Policy) area payments, and they were consequently considered entirely as abandoned land. Additionally, about 163 000 ha were located on fields which were partially in use. An entirely abandoned field average size was only 3.0 ha, which was about 2–3 times less than in the case of utilized fields. The small areas can complicate the reuse of these areas for production of agricultural products but has a potential for forest management. Soils of abandoned areas are generally of comparably low quality and therefore the soil crop suitability analyses could be the basis of bioenergy planning. The suitable areas for bioenergy production using willow (*Salix* spp.), grey alder (*Alnus incana* (L.) Moench), hybrid aspen (*Populus tremula* L. × *Populus tremuloides* Michx.), reed canary grass (*Phalaris arundinacea* L.) and Caucasian goat's rue (*Galega orientalis* Lam.) were studied in Tartu County (Kukk *et al.* 2010). The highest energy potentials were demonstrated by reed canary grass and grey alder.

According to Rural Support Service of Latvia (2012) the total area of agricultural land potentially available for bioenergy production is approximately 260 000 ha. Of this, 86 % (226 000 ha) is unmanaged agricultural land and 14 % (35 000 ha) is overgrown agricultural land. According to the law, a landowner or lawful possessor have the right to afforest land, if such rights are not restricted by regulatory enactments.

7. Effects of changes in climate and standing volume on future productivity

As mentioned above this report aims at presenting the present state of the Nordic forests and forestry with special focus on production of biomass for energy purposes. However, there are two components that will change with time irrespective of unaltered methods and species. When considering future growth in our forests we cannot ignore the effects on growth of a changing climate and the current forest composition itself will also affect the forthcoming growth.

Increases in annual mean temperature and changes in precipitation patterns are expected in the future along with the increase in CO_2 concentration in the atmosphere (Jylhä *et al.* 2004, Carter *et al.* 2005, Ruosteenoja *et al.* 2005, Kjellström *et al.* 2011, Poudel *et al.* 2011). A changing climate is likely to increase forest growth directly through intensified physiological processes in trees due to elevated temperature and CO_2 concentration, but also through longer growing seasons. The increase in nitrogen mineralization may also affect the future growth of Nordic forests (e.g. Melillo *et al.* 1993). Increased sequestration and accumulation of carbon into forests may further have an influence on species composition in boreal forests in the long run (e.g. Kellomäki *et al.* 2008, Garcia-Gonzalo *et al.* 2007).

Forest growth is estimated to increase under future climatic conditions in Finland (Kellomäki *et al.* 2008). The largest relative changes will be found in northern Finland, although the absolute values are higher in southern Finland. By 2050, growth of forests in southern Finland is forecasted to increase with 11% (from 5.5 to 6.3 m^3 ha^{-1} yr^{-1}) compared to current growth. In northern Finland, the increase for the same period will be 68 % (from 2.2 to 3.7 m^3 ha^{-1} yr^{-1}). The total increase in growth is estimated to 29 % by 2050 compared to current growth values (from 4.1 to 5.3 m^3 ha^{-1} yr^{-1}). However, the growth increase of Norway spruce is in many sites expected to be small or even negative in southern Finland, when the forest growth simulations are made until the end of the 21st century. This is mainly due to an increase in the occurrence of drought periods along with the increases in temperature.

The effect of a changed climate may increase total standing volumes in Finland by 31 %. The relative change compared to current situation will be higher in northern Finland (59 %) than in southern Finland (20 %) by 2050 (Kellomäki *et al.* 2008). With respect to tree species, the share of Scots pine in southern and northern Finland may increase, whereas the share of Norway spruce may decrease by 2050. However, most of the reduction occurs by the end of the 21st century when birch seems to replace Norway spruce in many places with current forest management. The share of birch may remain stable or even have a slight decrease in northern Finland when compared to the current situation (Kellomäki *et al.* 2008).

In Norway, a temperature rise of 2 °C will increase forest production and uptake of CO_2 with about 75 %, from 4 to 7 million tons annually within 100 years (Astrup *et al.* 2010). These calculations assume a forest management equal to what is done today. If the annual harvest level is increased with 50 %, the forest production increase will be only 30 % within 100 years with a temperature rise of 2 °C. However, an increased investment in planting and forest management will also lead to an increase in forest production, up to 75 % within 100 years, even if the harvests increase with 50 %.

The climate effect has been forecasted for Sweden by the Forest Agency and SLU in the SKA-08 report (Swedish Forest Agency 2008). According to this report the growth of Norway spruce will increase by 16–46 % in different regions to the period 2071–2100. The corresponding figures for Scots pine and birch are 8–36 % and 11–33 %, respectively. The highest figures were estimated for the far north and the lowest along the coast of southern Norrland and in central and eastern Götaland. The harvest in Sweden has historically been below the forest growth level. If this trend continues it will lead to a continued increase of standing volume, which in itself will lead to improved possibilities to increase harvests or environmental investments. The growth effects of a changed climate and increased standing volume together were estimated to above 30 % for whole Sweden in the year 2100 (Fig. 7.1).

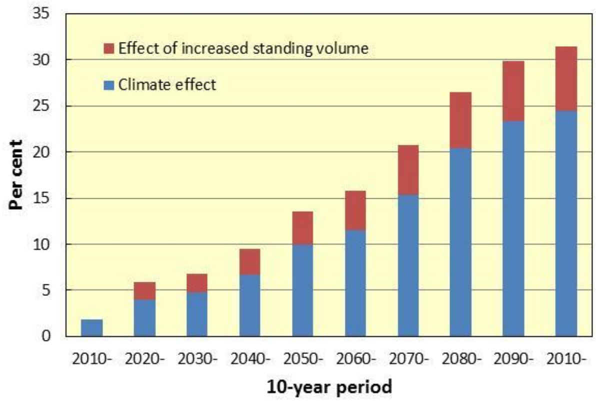

Figure 7.1. Growth increase due to changed climate in the reference alternative in the SKA-08 report (Swedish Forest Agency 2008) for all land use and ownership classes. The growth increase is divided into a direct effect of climate and the effect of a successively increasing standing volume. The figure shows an average for the regions Västerbotten (ACL, ACK), Dalarna övrigt (WÖ), Värmland (S) and Jönköping (F).

According to the study by Poudel *et al.* (2011), a temperature rise of 4 °C over the next 100 years may increase forest production in north-central Sweden by 33 % compared to a reference alternative without climate change. This temperature rise will allow an increase of the potential annual harvest by 32 % in the region.

The possible impact of recent and predicted future climate change on forestry in Estonia was studied in the end of 1990s (Nilson *et al.* 1999, Kiviste 1998). It was verified by statistical analysis of growth patterns observed in more than 50 000 stands during the period 1950 – 1990 that forest growth had accelerated by 15 %, where climate change is probably one factor together with others like changes in management, changes in species composition and breeding improvements.

In Latvia climatic factors have shown significant effects on height increment of Scots pine, suggesting that height increment can be used as an additional proxy for dendroclimatological studies (Jansons *et al.* 2013). Elferts (2008) reported that the impact of chronological climate conditions on pine growth in Latvia could be explained with 35 % and is mainly due to temperature changes during February and March leading to earlier start of the vegetation period.

8. Harvests and assortments

Annual harvests in the Nordic and Baltic States are almost always below the annual growth giving possibilities to some increase of the future harvest level. In Table 8.1 data are compiled showing availability of the growing stock for wood supply and how much of annual increment that is available. In general, a large part of the growing stock is considered available for wood biomass supply. The figures oscillate between 88 and 92 % with the lowest values for Finland and Sweden. The use of annual increment for wood harvest differs among the countries. Norway only uses 35 % of the annual growth while Estonia uses 84 %.

Table 8.1. Wood volumes in Nordic and Baltic States on forest land and the share available for wood biomass supply. Data are taken from below and the sections 5.4 (Standing volumes) and 5.5 (Current growth). The estimates of available growing stock for wood supply were presented in Forest Europe (2011).

Country	Growing stock			Increment	Feelings	Used share
	Total	Available for wood supply	Availability	Annual	Annual	Fellings of increment
	(million m^3)	(million m^3)	(%)	(million m^3)	(million m^3)	(%)
Denmark	125	112	90	6.71	2.57	38
Finland	2 305	2 024	88	104.05	58.12	56
Norway	879	797	91	22.98	8.07	35
Sweden	3 002	2 651	88	113.52	87.40	77
Estonia	441	398	90	12.40	10.47	84
Latvia	633	584	92	16.50	12.50	76
Total	**7 385**	**6 566**	**89**	**276.16**	**179.12**	**65**

In Denmark the felling during 2011 was 2.57 million m^3, distributed with 0.69 million m^3 on hardwoods and 1.88 million m^3 on conifers (Table 8.2). Wood for energy was the dominating assortment. It should be noted that the figures on annual harvest presented here are produced by Statistics Denmark and estimated from an annual questionnaire survey to forest owners. Volumes represent felled and processed volume "at roadside". The harvest volumes estimated based on repeated measurements of permanent plots in the Danish NFI are 4.33 million m^3 (Table 8.3), but are not comparable to the before mentioned estimates because they represent entire tree volumes (including all branches of broadleaves but only stem volume of conifers).

Table 8.2. Fellings in forests in Denmark 2011 by assortments in 1 000 m^3. Source: Statistics Denmark (2013).

Tree group	Veneer and sawnwood logs.	Short timber	Other timber	Industrial wood	Firewood.	Wood for energy.	TOTAL
Broadleaves	124.9	0.0	8.2	56.1	338.7	161.7	689.6
Conifers	108.0	478.5	21.6	351.3	71.4	844.8	1 875.6
TOTAL	232.9	478.5	29.8	407.4	410.1	1 006.5	2 565.2

Table 8.3. Annual fellings in the Danish forests distributed to different land use classes. Source: Johannsen *et al.* (2013)

	Total	Conifers	Broadleaves	Mixtures	Chrismas trees	Temporarily stocked	Auxillary areas
	Annual increment and fellings (1000 m³)						
Fellings	**4 333**	**2 722**	**1 081**	**500**	**9**	**1**	**20**
Missing	550	398	75	58	0	-	20
Thinning	3 393	2 160	843	382	8	-	-
Dead	352	161	131	59	0	1	-
Windthrow	37	3	32	1	-	-	-
	Mean annual increment and fellings (m³/ha)						
Fellings	**7.7**	**11.2**	**5.2**	**6.1**	**0.6**	**0.1**	**2.4**
Missing	1.0	1.6	0.4	0.7	0.0	-	2.4
Thinning	6.0	8.9	4.1	4.6	0.5	-	-
Dead	0.6	0.7	0.6	0.7	0.0	0.1	-
Windthrow	0.1	0.0	0.2	0.0	-	-	-

Roundwood harvest in Finland amounted to 52 million m^3 in 2011 (Table 8.4). By adding fuelwood of 6 million m^3, about 56 % of annual stem growth was harvested (cf. Table 5.5.3). On an area basis, about 235 000 ha were cleaned, 457 000 ha were thinned and 127 000 ha were subjected to final felling. To these areas 15 000 ha of other felling should be added.

Table 8.4. Removals of industrial roundwood by species and assortments in Finland 2011. Source: Finnish Forest Research Institute (2012).

Assortment	Tree species			
	Spruce (mill m³)	Pine (mill m³)	Broad-leaved (mill m³)	**Total** (mill m³)
Logs	11.41	9.68	0.99	**22.08**
Pulpwood	8.28	14.41	7.30	**29.99**
Fuelwood				**6.04**
TOTAL	**19.69**	**24.09**	**8.29**	**58.12**

The Norwegian statistics show that about 8 million m^3 of industrial roundwood was harvested in 2008. Harvests of saw logs and pulpwood were of about the same order, i.e. 4 million m^3 (Table 8.5). Spruce dominated among species and constituted 75 % of the harvest. Final felling was the dominating felling type with almost 85 % of the total harvesting of roundwood (Table 8.6). Since the annual increment on forest land was almost 23 million m^3 (Table 5.5.4), harvested volume amounted to only 35 % (8.1 million m^3) of annual increment.

Table 8.5. Removals of industrial roundwood by species and assortments in Norway 2008. Source: Statistics Norway (2011).

Assortment	Tree species			
	Spruce (1 000 m³)	Pine (1 000 m³)	Broad-leaved (1 000 m³)	**Total** (1 000 m³)
Timber and saw logs	2 753	1 064	4	**3 821**
Unsorted sawlogs and pulpwood	269	26	-	**295**
Pulpwood	3 042	794	84	**3 920**
Other roundwood	1	34	-	**34**
TOTAL	**6 065**	**1 918**	**88**	**8 071**

Table 8.6. Removals for sale by county and method in Norway 2007. Source: Statistics Norway (2011).

Region	Type of felling			
	Final cuts (1 000 m³)	Thinning (1 000 m³)	Others (1 000 m³)	**Total** (1 000 m³)
Østfold. Akershus. Oslo. Hedmark	2 632	759	58	**3 449**
Oppland. Buskerud. Vestfold	2 101	180	60	**2 344**
Telemark. Aust- and Vest-Agder	905	68	9	**982**
Rogaland. Hordaland. Sogn/Fjordane. Møre/Romsdal	204	6	9	**220**
Sør-Trøndelag. Nord-Trøndelag	707	24	5	**735**
Nordland. Troms Romsa	132	15	6	**153**
Total	**6 680**	**1 052**	**147**	**7 882**

The gross felling in Sweden was 87 million m^3 yr^{-1} during the period 2010–2012 (Table 8.7), which is 77 % of the annual increment of 113 million m^3 (Table 5.5.5). Conifer saw logs and pulpwood were the dominating assortments. Final felling was carried out on about 186 000 ha, while thinning was performed on 364 000 ha and cleaning on 260 000 ha (Table 8.8). Tops and branches were collected on 92 000 ha.

Table 8.7. Calculated gross felling by assortments in Sweden as annual averages over the period 2010–2012. Source: Swedish Forest Agency (2013). * estimated from the total figures.

Assortment	Net fellings (million m^3 solid volume under bark)	(million m^3 standing volume)	Gross fellings (million m^3 standing volume)	Forest fuel (million m^3 loose volume)
Coniferous sawlogs	33.4	40.1*		
Broad-leaved sawlogs	0.2	0.2*		
Pulpwood (coniferous and broad-leaved)	31.0	37.2*		
Fuelwood of stemwood	5.9	7.1*		
Other roundwood	0.5	0.6*		
Cut whole trees left in the forest			2.2	
Grot in final fellings 2007–2010				10.6
Grot in thinnings 2007–2010				1.5
Total	**71.0**	**85.2**	**87.4**	**12.1**

Table 8.8. Annual areas subjected to final felling, thinning and cleaning in Sweden during the period 2008–2012. Source: Swedish Forest Agency (2013).

Region	Final felling	Forest fuel Final fellings	Thinnings	Thinning	Cleaning
	(1 000 ha)	(1 000 ha)	(1 000 ha)	(1 000 ha)	(1 000 ha)
N Norrland	46	-	-	49	39
S Norrland	51	-	-	78	70
Svealand	41	-	-	108	76
Götaland	48	-	-	129	74
Total	**186**	**75**	**17**	**364**	**260**

Statistics from Estonia show that regeneration felling was performed on 37 000 ha, while maintenance measures (cleaning, thinning and sanitation) covered 89 000 ha (Table 8.9). The total harvested volume 2010 was 10.5 million m³ with 7.9 million m³ in regeneration felling. The net felling during the period 2002–2009 was 5.9 million m³ where logs were most common followed by fuelwood and pulpwood (Table 8.10). Spruce, pine and birch were the dominating tree species with together over 75 % of the total volume.

Table 8.9. Felling area and volume by types in 2010 in Estonia. Source: Estonian Environmental Information Centre (2012).

Ownership	Type of felling *Regeneration felling* Clear felling	Shelterwood felling	Total	*Maintenance felling* Cleaning	Thinning	Sanitation	Total	*Other felling*	*Total*
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
State forest	7 937	247	8 184	14 066	11 133	6 120	31 319	318	**39 821**
Private forest	29 014	3 345	32 359	11 635	22 469	22 104	56 208	912	**89 479**
Other forest	329	2	331	272	167	666	1 105	257	**1 693**
TOTAL	**37 279**	**3 594**	**40 874**	**25 974**	**33 769**	**28 890**	**88 632**	**1 488**	**130 994**
	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)	(1 000 m^3)
State forest	2 237	24	2 261	168	715	150	1 034	42	**3 337**
Private forest	5 596	198	5 795	35	765	307	1 107	82	**6 984**
Other forest	86		86	4	7	15	26	34	**146**
TOTAL	**7 920**	**223**	**8 143**	**208**	**1 488**	**471**	**2 167**	**158**	**10 468**

Table 8.10. Average annual felling by assortment and tree species in Estonia 2002–2009. Source: Estonian Environmental Information Centre (2012).

Tree species	Assortment					
	Logs (1 000 m^3)	Small logs (1 000 m^3)	Pulpwood (1 000 m^3)	Fuelwood (1 000 m^3)	Residuals (1 000 m^3)	**Total** (1 000 m^3)
Pine	558	254	167	87	201	**1 267**
Spruce	603	251	455	440	334	**2 082**
Birch	187	93	461	180	198	**1 120**
Aspen	87	22	196	148	96	**550**
Black alder	34	18		227	58	**338**
Grey alder	6	14		324	64	**408**
Others	16	6		81	24	**128**
TOTAL	**1 491**	**658**	**1 279**	**1 487**	**976**	**5 892**

In Latvia final felling was performed on 38 189 ha in 2007 and 30 841 ha in 2008. In 2010 about 12.5 million m^3 were removed as roundwood, which is about 76 % of total annual increment. Of this, 2.3 million m^3 was firewood, 6.7 million m^3 was sawn timber, 2.7 million m^3 was pulpwood and 0.8 million m^3 was other industrial timber (Bekeris 2011).

9. Fertilization potential in northern Europe

Fertilization is a common measure in Swedish and Finnish forestry and has been so since the mid-sixties. Fertilization in Norway, Denmark and Baltic countries has only been conducted on a small scale. The fertilization in Sweden peaked in 1979, when c. 190 000 ha (0.8 % of the forested area) were fertilized annually. Fertilization in Finland peaked a few years earlier and reached a higher level compared to Sweden with c. 240 000 ha yr^{-1}. After that, fertilization decreased substantially in both countries to a very low level in the nineties and the first years of the new millennium. Recently, fertilization has increased again and in 2010 amounted to 80 000 ha fertilized in northern Sweden (Swedish Forest Agency 2011, Lindkvist *et al.* 2011) and c. 65 000 ha in Finland. For economic reasons, fertilization is usually conducted in mature coniferous forests in operational forestry.

The forestry impact analysis SKA08 (Swedish Forest Agency 2011) indicated that an annual fertilization on maximum 1.5 % (400 000 ha) of the total forest area in Sweden can be considered long-term sustainable. In productivity terms it means an extra growth of c. 6 million m^3 during a 10-year period. There are possibilities to increase the level of fertilization in Norway, Estonia and Latvia but it is difficult to estimate the potential for the future.

9.1. STANDARD FERTILIZATION PROCEDURE

Fertilization practice in Sweden is generally performed with a nitrogen rich fertilizer, commonly based on ammonium nitrate, with an N supply of c. 150 kg N ha^{-1} at one or more occasions. Forest land suitable for fertilization is characterized by sandy-silty moraine, mesic soil moisture, moderate soil fertility and a deep soil layer. Application of fertilizer should only be carried out in stands that do not have high nature values. It is important to avoid shallow soils and soils with high fertility. It is also recommended to avoid fertilization with N on peat land. Fertilization in southern Sweden and Denmark has earlier shown small or no effects. This is likely due to high N deposition and soils with high fertility. If all these considerations are taken into account and the recommendations/regulations by Swedish Forest Agency are followed, c. 50% of the total forest land area in Sweden is suitable for fertilization (Fig. 9.1.1). The largest areas for fertilization are found in northern Sweden, while only small areas are found in the southern part. Conditions and amounts of forest land suitable for fertilization in northern Sweden might be similar for the situation in Finland.

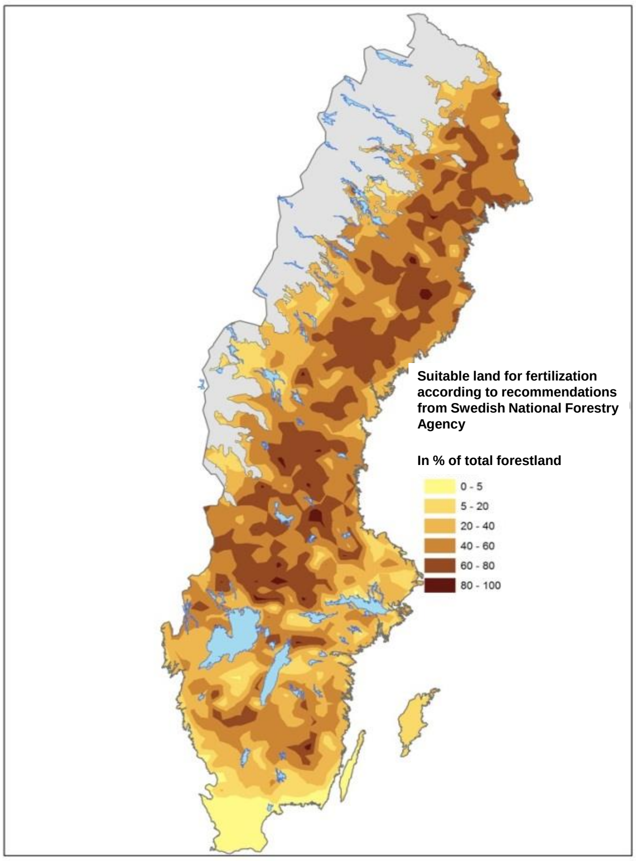

Figure 9.1.1. Forest land suitable for fertilization according to guidelines (30§ SVL) by the Swedish Forest Agency. Data from the Swedish forest inventory.

9.2. BALANCED SUPPLY OF NUTRIENTS IN YOUNG FORESTS

Fertilization has a potential to substantially increase biomass production, especially when applied as frequent doses with a balanced supply of essential nutrients in young forests. There are fundamental differences between this kind of management and standard fertilization as described above. Frequent fertilization in young stands may give a large reduction in rotation length compared with conventional management. The rotation periods may be shortened by 10 to 30 years in the southern parts of Scandinavia and 30 to 60 years in the north (Bergh *et al.* 2005). The first fertilization is suggested to be performed at 2 to 4 meter tree height and then it will be repeated frequently until the canopy closes. Experiments with balanced fertilization show that fertilization of Norway spruce can be done every second year and still maintain the same level of production as fertilization each year (Bergh *et al.* 2008), which is advantageous for the profitability of the operation. After canopy closure fertilization is conducted every 7th to every 10th year in a similar way as standard fertilization. Fertilization needs to be repeated 1 to 3 times after first thinning in closed and mature stands. Last fertilization should be carried out at least 10 years before final felling to exhaust the effects of the fertilization before the stand is cut. The total amount of nitrogen during a whole rotation will be 800 to 1 500 kg N ha^{-1} (lower amounts in southern parts of Scandinavia and higher in the north), of which about 3/4 are supplied before canopy closure (Bergh *et al.* 2006).

Estimations of forest land suitable for balanced nutrient supply (Larsson *et al.* 2009) show that 5.5 million ha of forest land in Sweden is suitable and 2.6 million ha will become available within 50 years (Table 9.2.1). This means it will take 50 years before this management method can be applied on 10 % of the forest land in Sweden.

Table 9.2.1. Total area (1 000 ha) of forest land in Sweden suitable for balanced nutrient supply and the area that will become available during the next 50 years. The following criteria has been used to identify suitable forest land: (1) Mesic soil moisture on mineral soil with sandy-silt or finer soil texture, with a deep to moderate deep soil layer; (2) site index G18–G32.

Region	Total area	Area available for the next 50 years
1	199	56
2	416	181
3	1 207	379
4	1 425	661
5	2 028	1 189
6	248	140
Total	**5 523**	**2 607**

Regional selection from north to south: 1 = Norr- and Västerbottens lappmark; 2 = Norr- och Västerbottens coastal area, Härjedalens community with Särna and Idre in Dalarnas county; 3 = Jämtlands county exclusive Härjedalens and Västernorrlands community; 4 = Gävleborgs, Dalarnas (excl. Särna-Idre) and Värmlands community; 5 = Stockholms, Södermanlands, Uppsala, Västmanlands, Örebro, Östergötlands, Jönköpings, Kronobergs, Kalmar and Västra Götalands community exclusive Göteborg and Bohuslän; 6 = Gotlands, Blekinge, Skåne and Hallands community as well as Göteborg and Bohuslän.

The SKA08 analysis in Sweden (Swedish Forest Agency 2008) indicated that a balanced supply of nutrients on 5 % (c. 1.3 million ha) of Sweden's forest area would imply increased growth by 7–9 million m^3 annually for the next 100 years. In terms of bioenergy the increased stem-wood corresponds to about 15 TWh yr^{-1}. It should be noted that these prognoses are based on stands with Norway spruce. New experiments with other, fast-growing species have also been established.

10. Energy use and energy sources

The energy use and energy carriers in the region differ substantially among the countries. Electricity is regarded as a "primary" source in Norway and Sweden, while it is distributed on nuclear energy, hydro power, bio fuels etc. in Denmark and Finland. Bio fuels provide a substantial share of the energy use in Denmark. Finland and Sweden but so far is of less importance in Norway (Table 10.1).

The Nordic countries have adopted the ambitious strategy of reaching an independence of fossil energy sources in the energy sector by 2050 (Nordenenergi 2010, OECD/IEA 2013). Today the shares of renewable energy for the countries are: Denmark – 22 %, Finland – 32 %, Norway – 61 % and Sweden – 48 %. In addition, the corresponding figures for Estonia and Latvia are 24 % and 33 %, respectively according to Eurostat (2012). The figures on renewable energy are under continuous increase.

Table 10.1. Total end use of energy in Denmark, Finland, Norway, Sweden, Estonia and Latvia by energy carriers expressed in TWh and percentage distribution. Sources: Danish Energy Agency (2013), Finnish Forest Research Institute (2012), Statistics Norway (2013), Swedish Energy Agency (2012), Statistics Estonia (2012) and Ministry of Economics of the Republic of Latvia (2013). *Import of electricity

Energy sources	Denmark		Finland		Norway		Sweden		Estonia		Latvia	
	(TWh)	(%)	(TWh)	(%)	(TWh)	(%)	(TWh)	(%)	(TWh)	(%)	(TWh)	(%)
Oil products	84	38	87	24	92	39	112	28	11.2	35.3	16.0	34.8
Fossil and town gas	44	20	35	10	14	6	7	2	2.5	7.9	4.6	10.0
Coal. coke	38	17	39	11	8	3	16	4	0.5	1.6	1.2	2.6
Bio fuels. peat. refuse	41	19	105	29	13	6	75	19	4.7	14.8	12.2	26.5
Electricity	1	1	13*	4	106	45	130	33	6.5	20.5	6.2	13.5
Hydro power	-	-	11	3	-	-	-	-	-		-	
Wind power	10	4	0.5	0.1	-	-	-	-	-		-	
Nuclear energy	-	-	63	17	-	-	-	-	-		-	
Other	3	1	9	2	-	-	-	-	-		-	
District heating	-	-	-	-	5	2	54	14	6.3	19.9	5.8	12.6
Total	**220**	**100**	**363**	**100**	**238**	**100**	**394**	**100**	**31.7**	**100**	**46.0**	**100**

Compilations from the European Union on the distribution of primary supply of renewable energy (Table 10.2) show that biomass and waste dominates in all ENERWOODS countries except in Norway. The percentage in 2010 was 65–97 %, while in Norway it was 12 %. Other energy sources of significance for the countries are hydropower in Norway and Sweden, and wind energy in Denmark.

Table 10.2. Primary supply of renewable energy in 2010 in ENERWOODS countries. Source: Eurostat (2012): http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Primary_production_of_renewable_energy,_2000_and_2010.png&filetimestamp=20121012133631.

Country	Total primary supply (TWh)	Solar energy (TWh)	Biomass & waste (TWh)	Geothermic energy (TWh)	Hydropower energy (TWh)	Wind energy (TWh)
Denmark	36.3	0.8	28.2	0.1	0	7.8
Finland	105.0	0	91.8	0	12.9	0.3
Norway	134.4	0	16.0	0.4	117.6	0.9
Sweden	202.5	0.2	132.4	0	66.4	3.4
Estonia	11.5	0	11.2	0	0	0.3
Latvia	24.4	0	20.9	0	3.5	0
ENERWOODS total	**514.1**	**1.0**	**300.4**	**0.5**	**200.5**	**12.8**

A closer look at the use of biofuels and related sources show that it is an important contributor to the energy sources and to the renewables. Possibilities to increase its share will have a significant influence on the possibilities to substitute the fossil sources.

Danish data reveal that biomass and waste are almost 78 % of renewable energy and 17 % of total energy use (Danish Energy Agency 2013). Data from Finland show that biomass and waste are more than 87 % of the renewable energy use (Table 10.2), and 28 % of total energy use (Table 10.1).

Hydropower is a dominating energy source in Norway. Thus, the biofuel and waste share of the total energy use is therefore lower than in the other ENERWOODS countries with a mere 7 %. Biofuels constitute about 12 % of renewables. The Norwegian bio fuel production was about 15 TWh in 2009 (SSB 2012a). In cold winters like 2010, the energy use is higher. The share of renewable energy is now 47 % in the country (SSB 2012b). The most important biofuel source in Norway is wood fuel in household dwellings which constitutes 48 % of the renewables (Table 10.3).

In Sweden bio fuels is the largest energy carrier with 129 TWh in 2011 (Melin 2012). In 2010, with a colder winter, the corresponding figure was 142 TWh. The bioenergy now constitutes almost 32 % of the energy use in Sweden and the share of renewable energy is 48 %. This is only 2 % from the goal of the Swedish government (Regeringskansliet 2009) and only 1 % from the EU demand (European Union 2009). In table 10.3 the use in Finland, Norway and Sweden of renewable energy in industry, district heating and small houses is shown. The largest assortments of the biofuel sources are black liquors and wood fuels.

Table 10.3. Use of biofuels, peat etc. for energy by user in Finland, Norway and Sweden 2009. Source: Finnish Forest Research Institute (2012), SSB (2012a) and Swedish Forest Agency (2013).

User	Finland TWh	Finland %	Norway TWh	Norway %	Sweden TWh	Sweden %
Industry use	**31.2**	**42.2**	**4.6**	**30.1**	**61.8**	**51.1**
Pulp industry. black liquors			1.7	11.1	36.6	30.3
Pulp industry. other byproducts			1.0	6.5	9.8	8.1
Sawmill industry byproducts			1.3	8.5	3.9	3.2
Other sectors			0.6	3.9	3.7	3.1
Biofuels. peat etc. for electricity production					7.8	6.5
District heating	**25.9**	**35.0**	**3.3**	**21.6**	**47.0**	**38.9**
Refuse					10.6	8.8
Wood fuels					21.0	17.4
Tall oil pitch					1.0	0.8
Peat					2.2	1.8
Other fuels and statistical difference					3.5	2.9
Biofuels. peat etc. for electricity production					8.7	7.2
Wood fuel in 1- and 2-households dwellings	**16.8**	**22.7**	**7.4**	**48.4**	**12.0**	**9.9**
TOTAL	**73.9**	**100**	**15.3**	**100**	**120.8**	**100**

Biomass and waste constitute over 97 % of renewable energy in Estonia (Statistics Estonia 2012), which in turn is about 23 % of total energy use. The Latvian figure for the biomass and waste share of total energy use was 25 % in 2011 (Ministry of Economics of the Republic of Latvia 2013) of the total energy consumption.

11. Regulations – legislations, directives and certifications

Suggested improvements for increasing the biomass production, i.e. breeding, fertilization, introduction of clone material and exotic tree species etc., cannot be implemented without considering different kind of regulations. Legislations, directives and certification demands must be followed in each country, although they are also subjected to change with time.

In Denmark, the Forest Law provide the framework for forest management on the 72 % of the forest area declared as forest reserve (in Danish: Fredskov). On forest reserves the land must be stocked with trees that potentially can develop into high forest within reasonable time, which is usually understood as within 10 years from clear felling of the forest. Within forest reserves, up to 10 % of the area may be stocked with Christmas trees or other short rotation crops such as willow or poplar energy crops. In addition, up to 10 % may be managed as open land, including forage areas for game, and up to 10 % may be managed with ancient management forms such as forest grazing or coppice. Consequently, up to 30 % may be managed with other management forms than high forest.

Only few restrictions exist in the Danish Forest Law regarding the choice of management practises, except for the restrictions on land use within forest reserves. For example, there are no restrictions on annual allowable cut, choice of rotation age or choice of species or regeneration methods. An exception are forest nature types according to the Habitat directive that lies within Natura 2000 areas (20 000 ha). Forest on these areas much be managed without loss of the nature type.

Forest management practices are certified in Denmark according to FSC or PEFC standards on 252 696 ha of forest land. On certified forest land, which includes the state forests, the certification agreements impose specific restrictions to the forest management practises. Within the state forests, which cover about 17 % of the forest land, sustainable forest management and implementation of near natural forest practises has been a strategy since the Rio Conference in 1992, and is expressed in the strategy and subsequent management plans for the state forests (Ministry of Environment 1994, Ministry of Environment 2005).

Introduction of clone material and foreign tree species are regulated in Finland by Forest Act (1093/1996) and by Act on Trade in Forest Reproductive Material (241/2002). In the production of forest reproductive material only basic material which meets the requirements laid down in Annex II-V to Directive 1999/105/EC and has been classified accordingly and approved by the Plant Production Inspection Centre (or by a competent authority of another member state of EU) may be used.

Finland's environmental administration has prepared a national strategy for foreign species (Ministry of Agriculture and Forestry in Finland 2012b). The strategy was adopted by a Government Resolution on March 2012. The purpose of the strategy is for example to prevent damages and risks to the Finnish nature caused by non-indigenous species. According to the strategy the Finnish legislation in the area of invasive alien species is not comprehensive. Therefore, the action plan for the Strategy includes a legislative reform either by amending existing legislation or by enacting a new Act on invasive alien species.

PEFC certification does not set up further restrictions for exotic tree species in Finland. FSC requires that during a 5-year period, the forest owner may use exotic tree species at maximum of 3 % of the planting or regeneration area and maximum of 5 % of the total forest land. A forest owner with less than 50 ha forest land shall use exotic tree species to a maximum area of 2.5 ha. The forest owner shall remove seedlings of exotic tree species that have spread outside the planting area.

Introduction of foreign tree species in Norway are restricted and legislations are stated by the Ministry of Environment (2012a) due to possible negative effects on the biodiversity. The legislations are detailed, but as a main rule planting of new foreign tree species is accepted in areas if the natural reproduction can be controlled and negative effects on biodiversity and other local species are negligible. In addition to these legislations, stronger restrictions are given if the species is on the black list stated by the Norwegian Biodiversity Information Centre (Artsdatabanken 2012). Here, Sitka spruce (*Picea sitchensis*) is stated as a high risk reproductive species and is almost not allowed for new planting. Planting of exotic tree species for

Christmas tree production is usually certified since this production includes harvesting before reproduction age. The County Governor is the authority for these applications.

Standards for FSC and PEFC with detailed rules for forestry in Norway are an agreement between several environmental organisations, labour unions, outdoor life organisations, forest industry organisations and forest owner associations (Levende Skog 2009). The Norwegian government wants an active forest policy by increasing several stimuli, e.g. fertilization of forest to increase carbon uptake, afforestation of new areas, strengthen the breeding program, increase plant density and prohibit harvesting of young forest (Ministry of Environment 2012b).

Several of the "new" tree species, which are of interest in a biomass production perspective, are regarded as foreign species in Sweden. Rules for the use of them are compiled in Meddelande no. 7 from the Swedish Forest Agency (Skogsstyrelsen 2009). Foreign tree species should be used cautiously and on a limited scale. This means a maximum of 25 % of the forest area of a forestry unit, although 50 ha are always allowed. Foreign species must not be used in mountain forests and must be notified to the Forest Agency if the area is 0.5 ha or more.

There are more limiting rules if vegetative produced material is used, which is most often the case with for example hybrid aspen and poplars. Then the maximum area on a forestry unit is 5 %, where 20 ha is always allowed. It is also discussed that areas around national parks, reserves, sensitive biotopes etc. up to 1 km away should not be used for these species and materials.

The certification organization FSC has set up further restrictions for foreign tree species in Sweden (FSC 2010, Södra 2011), while the PEFC organization keeps to the directives of the Swedish Forest Agency. FSC says that foreign species should be used very restrictively and may increase with maximum 5 ha of the productive forest area for an estate. If the estate area is less than 50 ha the area is maximum 2.5 ha. If forest owners use foreign tree species they must also prevent natural spread of the species.

Today there are no more subsidies in the Swedish forestry for regeneration, except for the noble broad leaved species. The noble species are oak, beech, ash, maple, elm, lime, wild cherry and hornbeam.

However, on the land use class agriculture land the situation for using trees from the genera *Populus* and *Salix* are different from forest land. It is possible to use *Salix* and *Populus* as agriculture crops if they are used for energy purposes and the rotation cycles are shorter than 10 and 20 years, respectively. Then there have been subsidies for establishing energy crops and a single payment scheme (SPS) has been available. The status of the Swedish subsidies is at the moment somewhat unclear. In addition, there are in principle no limitations on what species can be used when afforesting an agriculture land with different tree species.

According to the valid Forest Act in Estonia the following foreign tree species are allowed to be introduced (https://www.riigiteataja.ee/akt/12759372): *Picea mariana* (Mill.) Britton *et al.*; *Picea omorika* (Panč) Purk.; *Pinus contorta* Loud; *Larix decidua* Mill.; *Larix sibirica* Ledeb.; *Larix sibirica* var. rossica Scaf.; *Larix kaempferi* Carr.; *Larix gmelinii* var. japonica (Maxim ja Regel) Pilger; *Larix* × *eurolepis* Henry (*Larix* × *marschlinsii* Coaz); *Pseudotsuga menziesii* Franco; *Abies sibirica* Ledeb.; *Quercus rubra* L.; and *Populus* × *wettsteini* Hämet-Ahti.

The Latvian Forest Law divides forest in forest stand and plantation forests. For forest stands there are some harvest restrictions saying, among others, that specific tree species have minimum ages and diameters that must be fulfilled. For plantation forests there are no limitations for harvesting and dimensions. Foreign tree species may be accepted if they are suitable for cultivation in Latvia and they need permission from the state forest service and the research institute SILAVA.

12. Current and potential harvest levels for energy purposes

In this section the situation and possibilities with harvest of wood for energy purposes are presented for each country of the ENERWOODS project. Outtake of primary forest fuels may be distributed on four assortments: *roundwood*, which is subjected to competition, especially from the pulpwood industry; *slash*, logging residues from above stump (known also as "grot"); *stumps and coarse roots*, with a high potential but marred with technical and environmental implications; and *small sized trees*, also with a high potential but technical and probably environmental implications.

12.1. DENMARK

In a study on potential Danish forest energy resources (Table 12.1.1) a number of different scenarios depicting increasing intensity in production and use of forest fuels were developed and analysed (Graudal *et al.* 2013)). The four scenarios were:

BAU	Unchanged forest management, including choice of tree species with an annual afforestation of 1 900 ha.
BIO	Focus on production with the current level of afforestation. Increased growing of conifers and breeding towards fast growing varieties. Increased thinning and increased production of bioenergy assortments to some extend at the expense of the roundwood production.
ENV	Focus on environment with an increased afforestation. Conversion to more broadleaves with longer rotation ages and reduced thinnings. Reduced harvesting of forest fuel assortments in broadleaves and reduced breeding of varieties for increased growth.
Kombi	Combining scenarios for multiple use forestry. Increased afforestation with use of nurse trees for forest fuels combined with set aside of unmanaged forest areas for biodiversity. Increased harvesting of forest fuel assortments and breeding of varieties for increased growth.

In the BAU scenario 2.3 % of the current energy consumption is supplied by forest fuels, corresponding to 22.6 % of the objective stated by the Ministry of Energy. In this scenario forest fuels will provide 2.8 % of the energy consumption in 2050, corresponding to 18.0 % of the objective. In the three other scenarios, increased afforestation (ENV and Kombi), increased intensity of forest management and breeding of fast growing varieties (BIO and Kombi), increased production of forest fuel assortments (BIO), but also combined with increased consideration of biodiversity and environment (ENV and Kombi), resulted in increased production of forest fuels. In those three scenarios, 3.1–5.1 % of current energy consumption is met by forest fuels, increasing to 4.4–7.0 % in 2050, corresponding to 28.8–45.7 % of the wood for energy objectives stated by the Ministry of Energy (Graudal *et al.* 2013).

Table 12.1.1. Scenarios for future procurement of forest fuels in Denmark (cf. *Graudal et al.* 2013)

Scenario		**Year 2012**	**2020**	**2050**	**2100**
Energy consumption (PJ)		814	750	650	550
Wood for energy objective (PJ)		81	90	100	100
BAU	Biomass (million tons)	1.0	0.9	1.0	1.2
	Energy (PJ)	18.3	17.0	18.0	21.2
	Energy (TWh)	5.1	4.7	5.0	5.9
% of energy		**2.3**	**2.3**	**2.8**	**3.9**
% of wood for energy objective		**22.6**	**18.9**	**18.0**	**21.2**
BIO	Biomass (million tons)	2.3	2.0	2.5	3.7
	Energy (PJ)	41.5	35.8	45.7	66.0
	Energy (TWh)	11.5	9.9	12.6	18.2
% of energy		**5.1**	**4.8**	**7.0**	**12.0**
% of wood for energy objective		**51.2**	**39.7**	**45.7**	**66.0**
ENV	Biomass (million tons)	1.4	1.2	1.6	2.0
	Energy (PJ)	25.2	21.6	28.8	36.0
	Energy (TWh)	7.0	6.0	8.0	9.9
% of energy		**3.1**	**2.9**	**4.4**	**6.5**
% of wood for energy objective		**31.1**	**24.0**	**28.8**	**36.0**
Kombi	Biomass (million tons)	1.7	1.6	2.5	4.0
	Energy (PJ)	30.4	28.1	45.7	72.6
	Energy (TWh)	8.4	7.8	12.6	20.0
% of energy		**3.7**	**3.7**	**7.0**	**13.2**
% of wood for energy objective		**37.5**	**31.2**	**45.7**	**72.6**

12.2. FINLAND

The potential recoveries of industrial wood and raw material for forest bioenergy (roots, stumps, branches, foliage and stem + bark of waste wood) were analyzed simultaneously for Finnish conditions in a study by Kärkkäinen *et al.* (2008) over the 50-year period 2003–2052. The impacts of climate change on forests and consequent development of wood resources were also taken into account in the analyses, simultaneously with alternative future uses of forests. The forest management regimes were optimized, e.g. by maximizing the net present value or by having a net present value after the 50-year period greater than or equal to the start value, and by ensuring non-decreasing flow of wood (see Kärkkäinen *et al.* 2008 for details). The amount of potential bioenergy was, according to the results, 35 million tons yr^{-1} (186 TWh) in the maximum cutting scenario during the period 2003–2013. In the sustainable cutting scenario, the potential recovery of bioenergy during the period 2003–2013 was around 25 million tons yr^{-1} (132 TWh) and during the period 2043–2053 around 22 million tons yr^{-1} (117 TWh) in the current climate scenario. The potential recovery of bioenergy was 26 and 29 million tons yr^{-1} (138 and 154 TWh) in the sustainable and maximum cutting scenarios, respectively, in the changing climate during the period 2043–2053. Interestingly, the proportion of different bioenergy components changed during the time (see Kärkkäinen *et al.* 2008). For example, the decrease in the amounts of final felling was reflected as a decrease in the amount of waste wood from 10–13 % in the first period (2003–2012) to 4–6 % in the last period (2043–2052). As the biomass of branches and foliage in relation to the stem is generally greater in young trees than in mature trees, the proportion of logging residues will be greater compared to stems in Finland in the future. The amount of spruce-dominated mature forest will also decrease during the coming decades. Consequently, the total amount of residues from the final cuttings of spruce-dominated forests may decrease in Finland (Kärkkäinen *et al.* 2008).

With respect to forest management, the bioenergy potential of early thinnings of small trees for biomass has been found to increase over time both for current and changing climate in the whole of Finland by the end of the 21st century (Alam *et al.* 2010, Kellomäki *et al.* 2010). The potential production of bioenergy at final felling was found higher in southern Finland compared with northern Finland, which might be due to the effect of timber production in those regions (Alam *et al.* 2008, Alam *et al.* 2010, Kellomäki *et al.* 2010). In contrast, the bioenergy potential at energy biomass thinning was higher in northern than in southern Finland. Thus, the future bioenergy production potential is also affected by the variation in forest structure and growth potential in southern and northern Finland (Alam *et al.* 2008, Alam *et al.* 2010). The forests in southern Finland are currently dominated by younger stands, while in the northern Finland stands are more mature or close to that stage (Finnish Forest Research Institute 2012).

Räisänen and Nurmi (2011) found that a top diameter increase for logging residues (6 to 10 cm) resulted in an increase of total residue from 6.9 to 12.2 ton DM ha^{-1} (15.0 to 26.5 MWh) for Scots pine and from 10.2 to 14.5 ton DM ha^{-1} (22.2 to 31.5 MWh) for Norway spruce.

The bioenergy production could in general be higher by 2050 compared to the current situation with the described development of the forests, both in northern and southern Finland. However, the estimations of bioenergy potentials may differ as a result of the different cutting scenarios, logging residue components and their recovery at varying thinning stages as found in various studies in Finland (e.g. Hakkila 2004, Asikainen *et al.* 2008, Kärkkäinen *et al.* 2008, Alam *et al.* 2010, Kellomäki *et al.* 2010, Räisänen and Nurmi 2011). Results from different studies may therefore not be directly comparable. Estimated total bioenergy potentials may be affected by practical limitations and the results should mainly be considered as theoretical potentials. However, Helynen *et al.* (2007) estimated that the current technically harvestable amount of wood chips in the Finnish forests is around 16 million m^3 (36 TWh). Of this, 45 % comes from harvests of young forest and the first thinnings. The remaining 55 % represent harvesting of logging residues from final fellings, i.e. top parts of the stems, branches, stumps and coarse roots.

12.3. NORWAY

Three levels of sustainable annual harvesting prognoses have been worked out in Norway: Level 1 includes the potential of all forest areas without economical, technical or biological restrictions, and all possible wood from thinning and final felling are used; Level 2 is reduced for off road extraction distance > 1.5 km, terrain steeper than 90 % (~38°), and for environmental restrictions; Level 3 includes level 2 restrictions and additional areas with an intensive forest road building program (Gjølsjø & Hobbelstad 2009).

There is a large potential of stumps and large roots in Norway (Table 12.3.1), but the extraction is negligible due to economical, technical and environmental reasons. However, the outtake of slash for bioenergy use has increased the last years and is also stimulated by governmental subsidies. In 2012 about 110 000 m^3 loose volume of chips from forest residues were extracted with subsidies in the country (Lileng 2012). Nevertheless, other sources of forest chips for bioenergy than slash from forest residues are larger, e. g. trees from roadsides, cultivated landscape (kulturlandskap) and deciduous forest. Lileng (2012) reports a total of about 900 000 m^3 loose volume of forest chips for bioenergy purposes supported by subsidies. The thinning represents about 15 % of the stem volume in the harvesting prognosis in the first 10 year period, but is halved to 5–8 % the next 90 years (K. Andreassen 2013, unpublished data). About a third of the slash and stumps comes from thinning in the estimates in table 12.3.1. The potential of small sized trees is also considerable and they represent about 5 % more slash in the two oldest forest age classes (Løken *et al.* 2012).

In table 12.3.1, region 1 includes counties in southeast Norway, region 2 includes southern Norway, region 3 includes western Norway and region 4 includes Trøndelag and northern Norway except Finnmark, the northernmost county. The northern part of southeast Norway is included in region 2 instead of region 1, for details see Løken *et al.* (2012). As seen, 47 % of the potential is found in region 1, 19 % in region 2, 14 % in region 3 and 20 % in region 4. In northern and western Norway only 25 % of the volume is Norway spruce. In northern Norway 50 % of the volume is birch and most of the forests are low productive sites in these two counties (Granhus *et al.* 2012).

In conclusion, the harvesting potential of tree fractions additional to the conventional stem outtake is considerable in Norway with an annual amount of over 5 million tons dry matter of wood. This represents over 27 TWh for biofuel purposes. These estimates represent no restrictions of harvesting (Level 1). With environmental restrictions, reductions for long off road extraction distance and steep terrain the potential is reduced with 25 % (Level 2). However, if an intensive forest road building program is introduced, the potential will be reduced with only 10 % (Level 3).

Table 12.3.1. Annual harvest potential of slash, stumps and large roots (sum of thinning and final felling) in Norway according to estimates of Gjølsjø & Hobbelstad (2009) and Løken *et al*. (2012). Details about restriction levels and regions are given in the text. We have used the relation 1 ton DM = 5.3 MWh when transferring dry weight to energy units.

Region and restriction level	Final felling and thinning				TOTAL	
	Slash		Stumps and large roots			
	Mton DM	TWh	Mton DM	TWh	Mton DM	TWh
Region 1						
Level 1	1.57	8.3	0.82	4.3	2.39	12.7
Level 2	1.18	6.3	0.62	3.3	1.79	9.5
Level 3	1.41	7.5	0.74	3.9	2.15	11.4
Region 2						
Level 1	0.63	3.3	0.33	1.7	0.96	5.1
Level 2	0.47	2.5	0.25	1.3	0.72	3.8
Level 3	0.57	3.0	0.30	1.6	0.87	4.6
Region 3						
Level 1	0.49	2.6	0.25	1.3	0.74	3.9
Level 2	0.37	2.0	0.19	1.0	0.56	3.0
Level 3	0.44	2.3	0.22	1.2	0.67	3.6
Region 4						
Level 1	0.70	3.7	0.32	1.7	1.02	5.4
Level 2	0.52	2.8	0.24	1.3	0.76	4.0
Level 3	0.63	3.3	0.29	1.5	0.92	4.9
Norway total						
Level 1	3.39	18.0	1.73	9.2	5.11	27.1
Level 2	2.54	13.5	1.29	6.8	3.84	20.4
Level 3	3.05	16.2	1.55	8.2	4.60	24.4

12.4. SWEDEN

The most well-known and discussed assortment in Sweden is slash, which is mainly collected in connection to final harvest. The harvest of this assortment was 2.3 million tons of dry matter during 2011 (c. 12 TWh, Swedish Forest Agency 2013), which was about 57 % of the forest fuels, as given by Brunberg (2012). According to estimates presented in SKA-08 report (Swedish Forest Agency 2008), it should be possible to double this amount without serious influences on environment. Egnell and Björheden (2013) changed minimum top diameter for pulpwood from 5 to 10 cm and found that available logging residues from final felling and thinning would annually increase by 2.3–2.6 million tons of dry matter (12–14 TWh).

Energy wood accounted for 29 % of the harvest of bio fuels (Brunberg 2012), which is about 6.1 TWh. Small-sized trees constitute another primary forest fuel not included in conventional harvest systems. Here, the annual outtake was 2.3 TWh in 2011, which was about 11 % of forest fuel harvest (Brunberg 2012). It has been concluded that this assortment has an enormous potential for increase. Nordfjell *et al.* (2008) estimated that harvests of small-sized trees in Sweden could be raised to at least 5 million tons of dry matter (over 25 TWh) annually. It was also concluded that the situation with large biomass potentials in young stands is probably the same in many other countries, that this biomass resource is mainly of interest for the bioenergy industry, and that the potential can only be utilized if new techniques and new working methods are developed.

Stumps is an assortment with very high potential for increasing available biomass for energy (Thorsén *et al.* 2011). The high potential has been shown by the SKA-08 report (Swedish Forest Agency 2008). However, recently FSC has raised concerns around stump harvests and at the moment no increase from the actual harvest level of 0.6 TWh, 3 % of primary forest fuels (Brunberg 2012), can be expected. Otherwise the potential is estimated to 25–50 times the current outtake level (Swedish Forest Agency 2008, R. Björheden pers. comm. 2012). Stump biomass is high in density and can be used as bulk raw material for grinded biofuels, but problems with impurities, wood landings and clear cuts must be solved.

In the scenarios presented by the Swedish Forest Agency and SLU (Swedish Forest Agency 2008) the possibilities for bio fuel harvest were estimated for three different restrictions in the reference alternative. Level 1 implied that no restrictions were used and that all possible biofuels in thinning and final felling were used. Level 2 had ecological restrictions saying that no biofuels were removed within 25 m from other land use classes, from peat soils or from wet and moist areas on fine-grained soils. Level 3 had both ecological and technical/economic restrictions, where no biofuels were taken on areas smaller than 1 ha and where structure and slope were technically difficult. Figures for slash, stumps in thinning and final felling and small-sized trees are shown in Table 12.4.1. As can be seen, the potential levels are large, and for slash and stumps is well above the estimates for commercial outtake.

Table 12.4.1. Annual harvest potential of slash and stumps in thinning and final felling and small-sized trees in Sweden according to estimates in the SKA-08 calculations for the period 2010-2019 (Swedish Forest Agency 2008). Potentials are expressed in weight (million tons of dry matter) and energy (TWh). Details about restriction levels are given in the text. The transfer from weight to energy units was done with a lower constant (1 ton DM = 4.9 MWh) than elsewhere in this report.

Region and restriction level	**Final felling**				**Thinning**				**Small-sized trees**		**TOTAL**	
	Slash		**Stumps**		**Slash**		**Stumps**					
	Mton DM	TWh	Mton DM	TWh	Mton DM	TWh	Mton DM	TWh	Mton DM	TWh	Mton DM	TWh
Norra Norrland												
Level 1	1.33	6.5	2.24	11.0	0.60	2.9	0.95	4.7	0.1	0.7	**5.22**	**25.8**
Level 2	0.92	4.5	1.33	6.5	0.43	2.1	0.50	2.4	-	-	**3.18**	**15.5**
Level 3	0.63	3.0	0.90	4.4	0.31	1.5	0.36	1.7	-	-	**2.20**	**10.6**
Södra Norrland												
Level 1	1.81	8.9	2.88	14.1	0.90	4.4	1.28	6.3	0.2	0.8	**7.07**	**34.5**
Level 2	1.24	6.1	1.73	8.5	0.64	3.1	0.69	3.4	-	-	**4.30**	**21.1**
Level 3	0.78	3.8	1.08	5.3	0.42	2.1	0.46	2.2	-	-	**2.74**	**13.4**
Svealand												
Level 1	1.88	9.2	3.00	14.7	1.03	5.0	1.46	7.1	0.1	0.4	**7.47**	**36.4**
Level 2	1.29	6.3	1.78	8.8	0.69	3.4	0.69	3.4	-	-	**4.45**	**21.9**
Level 3	0.78	3.8	1.06	5.2	0.44	2.1	0.43	2.1	-	-	**2.71**	**13.2**
Götaland												
Level 1	2.41	11.8	3.62	17.7	1.40	6.9	2.04	10.0	0.1	0.3	**9.57**	**46.7**
Level 2	1.66	8.1	2.03	10.0	0.91	4.5	0.82	4.0	-	-	**5.42**	**26.6**
Level 3	0.98	4.8	1.20	5.9	0.56	2.7	0.50	2.5	-	-	**3.24**	**15.9**
Hela Landet												
Level 1	**7.43**	**36.4**	**11.74**	**57.5**	**3.93**	**19.2**	**5.73**	**28.1**	**0.5**	**2.2**	**29.33**	**143.4**
Level 2	**5.11**	**25.0**	**6.87**	**33.8**	**2.67**	**13.1**	**2.70**	**13.2**	**-**	**-**	**17.35**	**85.1**
Level 3	**3.17**	**15.4**	**4.24**	**20.8**	**1.73**	**8.4**	**1.75**	**8.5**	**-**	**-**	**10.89**	**53.1**

It should also be noticed that about 30 % of the primary forest fuels are found among traditional roundwoods (Brunberg 2012) and mainly used for energy purposes within the industries.

In conclusion, estimates show that less than 20 % of the total annual forest fuel potential is currently utilized in Sweden, and it is dominated by logging residues from final felling (Nordfjell *et al.* 2010). In absolute figures the annual potential forest fuel harvest was estimated to 7.4–19.2 million metric oven dry tons (ODT) from final felling and 3.5–9.7 million ODT from thinnings. Estimated in TWh figures this is 39–102 and 19–51, respectively. A conclusion was also that the biofuel potential is 2.8 to 4.4 times higher on forest land than agricultural land.

12.5. ESTONIA

The allowable level of utilization of forest resources is given by the Forestry Development Programmes. In the programme for the period 2011–2020 (https://www.riigiteataja.ee/aktilisa/3180/2201/1003/Eesti_%20metsanduse_arengukava.pdf) three potential scenarios of wood supply are presented (Table 12.5.1):

- active wood supply - it is expected that the area of strictly protected forests will not change and that the restitution process in forestry is finished.
- moderate wood supply – the share of strictly protected forests will increase to 10% and the land reform continues.
- shrinking supply of timber - share of strictly protected forests will be increased to 12% and the land reform continues.

Table 12.2.1. Scenarios for wood supply according the the Forestry Development Programmes in Estonia.

Tree species	Scenario. 1 000 m³		
	Active	Moderate	Schrinking
Pine	4 379	3 151	1 958
Spruce	3 885	3 054	2 136
Birch	3 089	2 492	1 786
Aspen	1 451	1 199	806
Black alder	762	558	403
Grey alder	1 766	1 520	1 245
Total	15 332 (~34 TWh)	11 974(~27 TWh)	8 333(~19 TWh)

At the moment the *Long-term Development Programme for the Estonian Energy Sector up to year 2030+* is prepared (http://www.energiatalgud.ee/index.php?title=Eesti_pikaajaline_energiamajanduse_arengukava_2030%2B). In this programme the potential volumes of woody biomass for energy (fuelwood, harvesting residues, residues from non-forest land and wood processing residues) were estimated among other resources. The calculation was based on the moderate scenario of the Forestry Development Programme for the period 2011–2020. The results are presented in Table 12.5.2, showing a total energy potential of 12.3 million m³ yr⁻¹ (~27 TWh) and also that fuel wood and biomass from industry residues dominate.

Table 12.5.2. Results from the *Long-term Development Programme for the Estonian Energy Sector up to year 2030+*. Link: see the text above.

	Volume of biomass (1 000 m³)										
	From fellings									**From wood industry**	**Total**
	Stemwood from fellings						Felling residues	Stumps	Non-forest land		
Tree species	Logs	Small logs	Pulpwood	Fuelwood	Residues	Total					
Pine	1 447	568	431	186	519	3 151					
Spruce	772	500	761	483	538	3 054					
Birch	371	213	1 061	329	519	2 493					
Aspen	167	45	439	321	228	1 200					
Black alder	46	39		380	93	558					
Grey alder	14	41		920	173	1 148					
Other	53	23		237	58	371					
Total	**2 870**	**1 429**	**2 692**	**2 856**	**2 128**	**11 975**	**1 435**	**150**	**200**	**3 402**	
Usable for energy purposes	**0**	**0**	**0**	**2 856**	**0**	**2 856**	**718**	**150**	**200**	**2 232**	**6 156**
Energy potential											
(1 000 m³)				**5 712**			**1 436**	**300**	**400**	**4 464**	**12 312**
(TWh)				**12.7**			**3.2**	**0.7**	**0.9**	**9.9**	**27.4**

12.4. LATVIA

Estimates in Latvia reveal that the annually extractable forest biofuel is 49.5 TWh yr⁻¹ (Gruduls *et al.* 2013). Of this amount about 40 % is firewood and around 60 % small trees and residues. It should also be noticed that 31 % of the biofuel amount is only available during winter time.

13. Discussion and conclusions

This compilation for the Nordic countries Denmark, Finland, Norway and Sweden, and the Baltic countries Estonia and Latvia shows that forest land is generally a dominating land use class (Table 4.1), constituting roughly 50–70 % of the total land area. Only in Denmark are agricultural areas dominating and forest land is only 14 % of the total area. The comparably small share of forest land in Norway (38 %) is mainly explained by large areas of mountains and plateaus. If these areas are excluded the forest land share will be almost 80 %. In conclusion, the areas available for wood production are quite extensive in the region.

In section 5.6 we can see that some of the productive forest area is not available due to different kind of protections. In Finland about 92 % of the forest land area is available for wood production. The corresponding figures for Norway, Sweden, Estonia and Latvia are roughly 75, 90, 75 and 92 %, respectively. In addition, not all areas of productive forest land without restrictions are available for harvest operations because of technical difficulties. Productive forest areas with steep terrain are often not available for harvesting. Some steep areas require forest road constructions, while others are only available by cable logging. For example in Norway, 11 % of the productive forest area is classified only for cable yarding (Granhus *et al.* 2012). However, although some areas are removed from commercial forestry there are still large areas available for wood production where harvest operations are allowed and can be carried out. It should also be kept in mind that the ownership structure, which varies among the ENERWOODS countries, has important implications for how much biomass can be harvested in practice.

Increasing land areas may be available for afforestation and biomass production in the future. There is a general trend in Europe of diminishing agriculture land (Rounsevell *et al.* 2005). A political goal in Denmark is to obtain 20–25 % forest land (from 14 %), which means 250 000–470 000 ha have to be afforested. The total area of fallows and uncultivated arable land was estimated to almost 280 000 ha in Finland in 2011 (Ministry of Agriculture and Forestry in Finland 2012a). There are nearly 200 000 ha of coastal heathland and unused agriculture land in Norway (Granhus *et al.* 2012, SSB 2012a), and in Sweden estimates (e.g. Larsson *et al.* 2009) say that 300 000–500 000 ha are available for new use like woody biomass production. In Estonia almost 300 000 ha are found to be little used and thus probably available for afforestation (Landresource 2007), and in Latvia about 260 000 ha are potentially available for bioenergy production (Rural Support Service of Latvia 2012). As can be seen there exist land areas not currently used. Some of it is on comparably unfertile land but there are also large areas where forest growth would be high.

Since there is a general trend that more fertile soils are less protected than less fertile ones on forest land, a reduction of forest land area is less important for available biomass than the figures suggest. Thus, a look into availability of volumes and growth show, for example, that 97 % of total tree growth is available in Finland (Table 5.6.1). Available volumes/biomasses has been analysed in section 12 and the potential harvest levels for energy purposes has been estimated. Calculations on technical potential for Finland resulted in 16 million m^3 (36 TWh) available annually today (Helynen *et al.* 2007) from young stands and thinnings (45 %) and final fellings (55 %). Prognoses by Kärkkäinen *et al.* (2008) of the theoretical potential indicate 22–25 million tons yr^{-1} (117–132 TWh yr^{-1}) in a sustainable cutting scenario with the current climate during the forthcoming 40 years. Norwegian estimates of the current biomass potential include three levels, from all possible wood to technical and biological restrictions. The annual harvesting potential was found to be 3.8–5.1 million tons DM yr^{-1} and represents 20–27 TWh yr^{-1} for biofuel purposes. Swedish calculations for the period 2010–2019 showed a potential of 11–29 million tons DM yr^{-1}, which was calculated as roughly 55–145 TWh yr^{-1}, with three levels involved. Level 1 had no restrictions in biofuel use while level 2 had ecological restrictions and level 3 both ecological and technical/economic restrictions (Swedish Forest Agency 2008). In Estonia 8–15 million m^3 yr^{-1} (c. 19–34 TWh yr^{-1}) has been considered available depending on protection levels, of which there are three (active, moderate and shrinking available areas), and in Latvia the available forest biofuel has been estimated to almost 50 TWh yr^{-1} (Gruduls *et al.* 2013).

The figures above are estimates without considering a changing climate which will most probably increase the availability of wood. The effects of changing climate on standing volume are presented in section 7. Finnish estimates for the future, i.e. 2050, indicate a total growth increase of 29 % compared to the current growth (Kellomäki *et al.* 2008). In Sweden, the effects of a changed climate and increased standing volume were estimated to over 30 % for the whole country in the year 2100 (Swedish Forest Agency 2008). Estimates from Estonia show that forest growth has accelerated with 15 % during the period 1950–1990 (Nilson *et al.* 1999). This means that figures based on the current situation of availability and climate most probably will increase substantially in the future.

If we consider the amounts of energy wood taken care of today we can see that the recent end use of biofuels (including peat and refuse) was 41 TWh in Denmark, 105 TWh in Finland, 13 TWh in Norway, 75 TWh in Sweden, 5 TWh in Estonia and 12 TWh in Latvia (Table 10.1). Although the values are not completely comparable between scenarios and real end use, the figures indicate that we can take out substantially more biofuels than we do today. We have then not calculated with growth improvement measures like increased fertilization, increased use of improved plant material, extended cultivation areas, change of tree species and management systems etc.

As the use of renewable energy is already high in the region (e.g. Eurostat 2012), the vision of independence of fossil energy by 2050 in the Nordic countries can be approached with confidence and energy from biofuels will most likely be of great importance in the future in all ENERWOODS countries. It is a main goal of the ENERWOODS project to better evaluate the potential of using wood from the Nordic and Baltic forests for energy purposes.

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