Information on LULUCF actions by Sweden

This information on LULUCF actions by Sweden responds the request set out in article 10 of Decision [*529/*2013*/EU*] on Land-Use, Land-Use Change and Forestry.

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Ministry for the Environment

Division for Climate

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Background

This information on LULUCF actions by Sweden responds the request set out in article 10 of Decision [529/2013/EU] on Land-Use, Land-Use Change and Forestry.

The information is based on several sources, including "*Sweden's sixth national communication on climate change*", *"National Inventory Report Sweden 2014*" and *"Submission of information on forest management reference levels by Sweden"* submitted to the UNFCCC.

The work has been conducted by the Swedish Environment Protection Agency in collaboration with the Swedish Forest Agency and the Swedish Board of Agriculture.

Stakeholders have been consulted via the webpage of the Swedish Environment Protection Agency.

1. Description of past trends of emissions and removals (Article 10.2 a)

Information on past trends of emissions and removals 1990-2012 can be found in the "National Inventory Report Sweden 2014" submitted under the United Nations Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP).

The activities Afforestation Reforestation (AR) and Deforestation (D) are relatively uncommon in Sweden. In 2012 AR and D represented an accumulated area since 1990 of approximately 230 000 hectare respectively. Around 10 000 hectares are afforested each year. Also the annual deforestation area is around 10 000 hectares. The trend for AR is an increasing removal due to increasing growth and due to increase in acreage (Table 1). There is no clear trend in D. The level of D depends heavily of the amount of the harvested biomass and large internal fluctuations are likely. However, a small increase in emissions from soils and litter due to the increase in acreage can be seen for the first 20 years. The total emission from ARD in 2012 is estimated at 2.5 million tons of CO2eq.

The total size, variation and trend of the net removals in the LULUCF-sector are mainly affected by the carbon stock change in the activity Forest Management (FM), dominated by the net removals in the living biomass pool.

Sweden did not report or account for the activities Cropland Management (CM) and Grazing land Management (GM) for the first commitment period of the Kyoto Protocol. Estimation of CM and GM are estimated indirectly from reporting of Grazing Land (GL) and Crop Land (CL) under the UNFCCC. Both activities account for small areas and small emission/removals compared to FM. The carbon stock change in GM was small during the period 1990-2012. The net emissions in CM varied during the period 1990 to 2012 between 1.3 and 2.5 million tons of CO2eq. Cropland management is responsible for emissions of carbon dioxide due to emissions from drained organic.

Table 1 Trend in emissions (+) and removals (-) from the activities: Afforestation-Reforestation (AR), Deforestation (D), Forest Management (FM), Cropland Management (CM), Grazing land management (GM) for the period 1990-2012.

	Activity	Reported emissions (+) and removals (-) in Mton CO2 eq per year																						
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Article 3.3																								
	AR	-0,02	-0,04	-0,04	-0,05	-0,12	-0,14	-0,17	-0,22	-0,32	-0,35	-0,39	-0,40	-0,41	-0,47	-0,61	-0,77	-0,90	-1,18	-1,37	-1,40	-1,22	-1,34	-1,37
	D	2,05	1,86	1,37	3,93	1,85	2,38	2,47	2,92	2,71	2,92	2,89	2,28	2,06	3,03	2,67	2,13	2,12	3,07	3,13	3,20	2,66	3,77	3,89
	ARD total	**2,03**	**1,82**	**1,33**	**3,87**	**1,72**	**2,24**	**2,31**	**2,70**	**2,39**	**2,57**	**2,50**	**1,87**	**1,64**	**2,56**	**2,06**	**1,36**	**1,22**	**1,90**	**1,76**	**1,80**	**1,44**	**2,43**	**2,52**
Article 3.4																								
	FM	-44,19	-44,34	-40,80	-38,96	-39,04	-42,94	-44,47	-44,18	-45,99	-46,09	-47,41	-45,85	-46,46	-44,92	-39,52	-34,83	-38,57	-38,89	-40,04	-39,44	-39,16	-40,15	-39,60
	CM	2,23	2,20	2,02	2,09	1,86	1,96	2,21	1,72	2,31	2,34	1,53	2,52	1,94	1,95	2,04	1,80	1,36	1,71	1,66	1,74	1,98	1,32	1,82
	GM	-0,37	-0,38	-0,36	-0,32	-0,40	-0,43	-0,38	-0,31	-0,39	-0,39	-0,37	-0,35	-0,37	-0,28	-0,28	-0,25	-0,16	-0,07	-0,04	-0,06	-0,06	-0,05	-0,04

2. Projections for emissions and removals for the accounting period 2013-2020 (Article 10.2 b)

Information on projections for emissions and removals from Forest Management for the accounting period 2013-2020 hectares been submitted to UNFCCC on 16 April 2011 "Submission of information on forest management reference levels by Sweden". The projected average removal during 2013-2020 was 41.336 Mton CO2eq per year. Rough estimates of projected emissions and removals for the accounting period 2013-2020 from Afforestation-Reforestation (AR), Deforestation (D), Cropland Management (CM) and Grazing land Management (GM) are shown below (Table 2).

Table 2. Projected emissions and removals from the LULUCF activities: Afforestation-Reforestation (AR), Deforestation (D), Forest Management (FM), Cropland Management (CM), Grazing land management (GM) for the accounting period 2013-2020.

Projected Emissions (+) and Removals (-) in Mton CO2eq per year	**2013-2020**	**2015**	**2020**
Article 3.3 activities			
AR	-2,28	-1,97	-2,99
D	3,14	3,13	3,12
ARD total	**0,86**	**1,16**	**0,13**
Article 3.4 activities			
FM*	-41,336	-42,611	-38,825
CM	1,74	1,79	1,59
GM	-0,10	-0,09	-0,13

*Projection for FM is based on the submission to UNFCCC on 16 April 2011 *"Submission of information on forest management reference levels by Sweden".*

3. Information on potential to reduce emissions, appropriate measures, existing and planned policies in Agricultural land (Article 10.2 c-f)

AGRICULTURAL LAND

Potentials

The Swedish Board of Agriculture has estimated the potential to reduce the greenhouse gas emissions from Swedish agriculture to 2050, as a part of the government position to develop a road map towards an emissions-neutral Sweden 2050[1]. In this context also carbon dioxide fluxes from soils

[1] Swedish Board of Agriculture (2012a) A climate friendly agriculture in 2050. Report 2012:35 (In Swedish).

and vegetation were included. Measures in order to decrease carbon dioxide emissions from cultivated mineral soils and organic soils used for agriculture and to increase the carbon storage in grasslands were analyzed. The potentials presented below originate from these calculations.

Carbon dioxide emissions from cultivated mineral soils

Intensive use of agricultural land reduces the amount of soil carbon and, at present, cultivated mineral soils in Sweden are on average net sources of carbon dioxide. Different measures can be taken in order to reverse the current trend with decreasing soil carbon content, e.g. addition to soils of organic materials as animal manure, residue from biogas production or straw. The potentials to reduce carbon dioxide emissions from cultivated mineral soils were estimated assuming that the soil carbon stock in a national perspective could be in balance by 2050.

Carbon dioxide emissions from organic soils

Several measures have been discussed in order to decrease emissions of carbon dioxide from cultivated organic soils. Based on present knowledge, the most promising measure seems to be rewetting of soils and thereby returning the agricultural land into wetland. The potential to 2050 was calculated assuming that the total area of organic soils in fallow as well as organic soils used for lay production would be rewetted, which resulted in a reduction of the emissions from cultivated organic soils by around 1 Mton CO2eq . When emissions from the constructed wetlands were subtracted, the net reduction became 0.52 Mton CO2eq .

Carbon dioxide fluxes from grassland

In the Swedish National Inventory Report, grasslands are defined as unfertilized pasture land[2]. Such grasslands in Sweden are on average net sinks of carbon dioxide. The major part of the carbon storage is in trees, and the soils only constitute a small sink. The carbon storage in soils may increase if measures are taken that increases the biomass production. However, such measures (i.e. nitrogen fertilization) may also affect biological values negatively. However, the carbon storage in trees could be increased. The potential was calculated by assuming that the standing volume could be increased by on average 25 m^3sk per hectare to 2050. This would result in additional carbon storage of 1.49 Mton CO2eq per year during a period of 40 years.

Appropriate measures

Carbon dioxide emissions from cultivated mineral soils

Which measures that are suitable to increase soil carbon content differ among farmers, and no specific measure was promoted. As increased soil carbon content also increases the fertility of soils, investments aiming at increasing the amount of carbon pay off in the long term[3]. However, in the short term the economic viability of the farms will not increase with measures. The Swedish Board of Agriculture concluded that information and knowledge transfer would be suitable policy instruments, but that the incentive could be further increased by for example an investment support[4].

[2] Swedish Environmental Agency (2014) National Inventory Report Sweden
[3] Hedlund K. (ed.) (2012) SOILSERVICE. www.lu.se/soil-ecology-group/research/soilservice
[4] Swedish Board of Agriculture (2012a)

Carbon dioxide emissions from organic soils

In the Rural Development Program 2007–2013 there was a support for rewetting of agricultural soils and support could also be given for management of wetlands. It was suggested that establishment of wetlands to a larger extent should be allocated to organic soils.

Carbon dioxide fluxes from grassland

The number of trees on agricultural land is limited by EU rules and agricultural land with trees is not permitted payment under the single payment scheme. Further, the European Commission has provided guidelines for the maximum number of trees allowed in unfertilized pasture land.

Even if some trees (at maximum 60 stems per hectare) are allowed on unfertilized pasture land the large potential is probably in an increased number of trees on from a biodiversity perspective less valuable pasture land. The incentives for more extensively management of such pasture land, increasing the standing tree volume, will be low as long as payment under the single payment scheme for the land will not be approved.

Ongoing activities

Carbon dioxide emissions from cultivated mineral soils

There is a cross-compliance requirement concerning soil carbon content. To receive a payment under the Single Payment Scheme Swedish farmers are not allowed to burn stubble.

The Swedish Board of Agriculture works with information and knowledge transfer to farmers. Within the Rural Development Program financed counselling “Focus on Nutrients” there is one module dealing with crop rotation and soil fertility. In this module soil carbon and the effect of different management practices are included and farmers get advice on how the carbon content of soils can be increased. Focus on Nutrients will be prioritized in the new Rural Development Program (2014–2020) as well.

Within the Rural Development Program 2007–2013 there was an agri-environmental payment for lay, and as lay production may increase soil carbon content this support has a potential to increase carbon storage in soils. A similar support will also be available in the new program.

It is difficult to estimate the potentials of the ongoing activities in terms of increased carbon storage in mineral soils.

Carbon dioxide emissions from organic soils

Support for establishment and management of wetlands has also been proposed to be available in the new program, 2014–2020[5]. The main purpose of the support is to promote biodiversity and reduce nutrient leakage and, consequently, the wetlands can be established on mineral soils as well as organic soils. However, organic soils could be prioritized if the Country Administrative Boards should so desire.

[5] Swedish Board of Agriculture (2012b) Technical ground Rural development program 2014–2020. Report 2012:15 (In Swedish)

The Swedish Board of Agriculture has, together with the Swedish Environmental Protection Agency, the Swedish Forest Agency, the Federation of Swedish Farmers and researchers studying greenhouse gas emissions from organic soils, developed recommendations on how Swedish drained organic soils should be managed from a greenhouse gas perspective. The recommendations includes the types of drained organic soils that could be prioritized for measures and also how wetlands on organic soils could be established and managed in order to decrease greenhouse gas emissions. Recommendations are being discussed at present.

4. Information on potential to reduce emissions, appropriate measures, existing and planned policies in Forest land (Article 10.2 c-f)

FOREST LAND

Analysis of the potential to limit or reduce emissions and to maintain or increase removals

Replace fossil fuels with bioenergy

Background

The general carbon tax that was introduced in 1991 (cf below) has effectively helped to reduce fossil fuel use in the heat sector. In this sector, bioenergy has been the main replacer because of low prices relative other alternatives. Installation of heat pumps has also contributed. Most of the biomass for heating has been used in district heating, but also as wood and pellets for furnaces in single homes. Today, 70 percent of all fuels in district heating are wood fuels, biogenic waste, or waste heat from forest industries.

Electricity produced with biomass (biopower) has also increased considerably in recent years. From 2003, the green certificate system (see below) made it favorable to switch fuels, from fossil fuels to biomass, in existing combined heat and power plants (CHP:s) and in forest industries producing their own power. As a result, biopower today is produced in 180 units producing 12 TWh yearly, 7 percent of Sweden's electricity production, whereof half in connection to pulp production.

In the transport sector, the conversion to bioenergy has been slower, due to higher costs for liquid and gaseous biofuels than for solid fuels. The technical barriers are also higher. Ethanol has been used for buses since around 1990, but a broad introduction of biofuels didn't happen until 2001, when the first large-scale production of ethanol started, and flexi fuel cars were launched on the Swedish market. E85 was introduced as fuel, and pumps were installed all over the country. Today biofuels account for almost 13 percent of the transport fuel market, including, beside ethanol, biodiesel from rape, tall oil based hydrated vegetable oil plants (HVO) and biogas.

Altogether, the use of bioenergy has doubled from 1990 to 2012, from 15 percent to over 30 percent of total energy consumption in Sweden.

The increased use of bioenergy has been derived from a more efficient use of residues from the forestry (branches, tops, low-quality wood), from forest industries (bark, sawdust, pieces of wood,

lignin in black liquors), from refinement industries and from society (waste)[6] and energy crops from agriculture. The increased demand of biomass for energy production mainly concerns thinning of low-quality wood – an operation which improves dimension growth and timber qualities of the remaining trees in the forest. This development has been parallel to a slow decrease in the demand for and production of newspaper type paper, a trend that is expected to continue.

Mostly what is needed to secure the present achievements and to bring about fossil fuel replacement is therefore stronger suppression on fossil fuel use. Thus demand for further forest biomass would likely follow and again more harvesting residues (branches and tops) would be recovered and thinning would be maintained or increased.

The higher replacement potential is within the transport sector. Oil-based gasoline and diesel could be blended or replaced with bio-based ethanol, biodiesel (fatty acid methyl ester (FAME), HVO), dimethyl ether (DME), methane, etc., partly based on forest biomass. Some replacement potential is also within the steel industry, in which fossil-based coal could be replaced with bio-based alternatives. Many new production possibilities have been tried at industrial and semi-large scale or at laboratories for many years now.

Estimation of potential to replace further fossil fuels

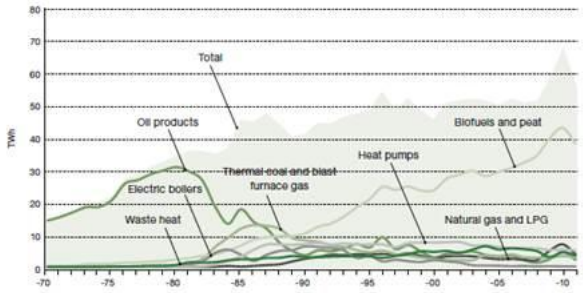
In 2012, Sweden domestically used approximately 76 TWh fossil fuels for transports, 30 TWh for industrial use and 20 TWh for heating and services.

Most of the remaining fossil fuel use within industry and heating and services sector could be replaced if fossil CO_2 emissions would be somewhat higher priced. Also a replacement of the coal used within the steel industry (7 TWh) with wood-based material is not far away if price relations would change.

The potential to reach a sustainable and fossil-independent transport sector is huge, and as outlined in the Official Report of the Swedish Government "*Fossilfrihet på väg, SOU 2013:84"*, Sweden has the potential to reduce the usage of fossil fuels in the transport sector with 80 percent until 2030. However this demands powerful measures in the following areas; development of society and transports, energy efficiency, change towards more use of electricity and biofuels.

[6] Parallel to this development, a refinement of set-off demands within the forest sector has been pursued, to ensure that a sufficient area of natural ecosystems and availability of important micro-environments are preserved/recreated to hold viable populations of all naturally occurring forest-dependent species (cf Forest Act §1). There is also work going on to reach a sufficient level of ash recycling to offset underbalanced alkalinity and nutrient balances caused by whole-tree harvesting in forest soils.

Figure 19 Input energy used in the production of district heating 1970–2011, TWh



Source: Annual energy balance sheets. EN20. Swedish Energy Agency.

As the figure shows there is a constantly growing use of biofuels and at the same time reduction of fossil fuels. To produce another 25-35 TWh of energy and transport fuel from domestic biomass is fully doable. Part of the biomass can be taken from the heat sector as improved insulation and solar heating are gradually being applied in houses[7]. Additional biomass can be derived from further and more efficient use of residues from forest, industry and society, from further thinning and from new energy plantations on abandoned and unused agricultural land.

If biofuels are produced within so called bio-refineries (in co-production with other products) a high production efficiency can be gained. With high production efficiency, less than 7 Mton dry weight (3.5 Mton C) woody biomass/year is required to produce 30 TWh fuels, which is less than the actual available non-used wood production in Swedish forests[8]. Concerning effect on C stock – see below.

Replace GHG-intensive materials with forest biomass

Potential discussion

The greatest potential to replace GHG-intensive material with forest-based materials in terms of size would be to increase the use of wooden structure when building new multistory house, bridges and certain other constructions at the expense of metal-reinforced concrete. In Sweden, concrete production gives rise to approximately 0.8 Mton CO_2-C. A review study have shown that for each ton of wood-C, ca 2 tons of CO_2-C from alternative material production can be avoided[9].

However, the choice of construction material for such uses depends on a range of considerations related to strength, durability, appearance, etc. Negative incentives on CO_2 emissions would have to be considerably higher to make an economic impact on the material choice. To some extent, however, the material choice depend on tradition and lack of knowledge about wood as a material for larger constructions and such factors could be affected through certain campaigns. A law stopping houses higher than two floors from having wooden frames was lifted in the 1990's, as it is no longer motivated by fire prevention considerations.

Adapt forestry to reduce risks for damage from fire, insects, pathogens and wind-felling

In Sweden, a relatively thorough knowledge review on the need for climate adaptation in Swedish forestry was performed in 2007, as a part of the governmental 'Climate and vulnerability

[7] Provided stronger incentives for the heat sector will be back in place.
[8] Applying relatively high standards for sustainability.
[9] Sathre R & O'Connor J. 2010. Meta-analysis of greenhouse gas displacement factors of wood product substitution. Environmental Science & Policy 13: 104-114.

investigation'[10]. It was concluded that certain changes relative 'business-as-usual' was desirable to reducing sensitivity to climate-induces risks for damage from insect, pathogens, drought, wind-felling, fire and reduced soil bearing capacity at winter. A difficulty is, however, that forest plants of many species are browsed by various deer species (cervids), thereby reducing the level of freedom to increase the species variety of the forest. Better hunting strategies are therefore crucial to reach improved resistance towards climate change. Improved planning is the major tool against soil and small-stream damage from forestry vehicles.

All in all, there is no way to completely reduce the additional risks derived from climate change.

There are examples of adaptation taking place. The largest forest owner association in southern Sweden (Södra) has implemented a strategy to lower rotation periods, and also area extension to some degree, of Norway spruce stands, the dominating tree species of this region. Norway spruce is more susceptible to wind-felling, drought and some common plagues (such as butt rot and spruce beetle) than for example the Scots pine.

Increase the amount of wood in the product stock

Estimation of potential

According to an inventory of the product stock conducted by Bergh et al (2003)[11], the total content of carbon in forest-based products and material storage in Sweden was approximately 26 Mton C, whereof approximately 17 Mton C in buildings. Average annual increase between 1990 and 2000 was estimated to below 0.1 Mton C/ year , varying between positive and negative values depending on the balance between new building (booms) and demolition of buildings taken out of use. A substantial change in material choices in favor of wood also for multistory houses could three-double this figure. Also important for the climate impact of the building sector will be the accumulated consumption of heat (and cooling) during the lifetime of the building and CO_2 emissions and energy consumption at building material production.

In addition to the domestic potential, there is a large potential in an increase in exports of wooden materials to other countries, keeping in mind that most of the production of sawn wood (currently approximately 16 million m3 annually) is exported for use abroad while the stored carbon is accounted for within the Swedish inventory.

Increased biomass in forest and use of measures and techniques that result in increased carbon stock in soils

Indicative measures

Measures to stop drainage and stimulate restoration of wetland

Approximately 1.5 million hectares have been drained in Sweden to increase agriculture or forest production. At drained sites CH_4 emission decrease somewhat whereas CO_2 and N_2O emissions increase, normally resulting in a negative net impact on climate. N_2O emissions increase significantly

[10] Eriksson H. (Ed.). 2007. Svenskt skogsbruk möter klimatförändringar. Skogsstyrelsen Rapport 2007: 8.
[11] Bergh S., Englund F., Jarnehammar A, Johansson R & Lindholm E.-L. 2003. Kollagring i den skogsindustriella sektorn i Sverige. Trätek (nu SP), Stockholm.

only at more fertile sites. With time, as the aerated peat is being consumed, the impact is again reduced. The main present effect is estimated to come from areas which have extra deep ditches or have been drained or redrained during the last 50 years (cf above) (less than 500 000 hectares). Of these, it is the more fertile quarter which emits most per hectare and totally approximately 0.3-0.5 Mton CO_2-C equivalents per year[12], roughly about five times more than the increased production of harvestable biomass per year, and thus, even rougher, the substitution potential.

Measures connected to forestry practices

Increasing carbon stocks through changes in forestry practices

As forestry is a profitable activity in Sweden, and has largely been so over the last century, forest owners undertake a range of actions to maintain or enhance the production of valuable wood beyond what is required in the forest law. Such actions include e.g. better regeneration, pre-commercial thinning, early thinning, control of deer populations, etc. Therefore, there is an on-going stock increase in stem-wood taking place (3-7 Mton C/ year). There could have been a certain increase in soil C as well, had it not been for losses of C (and N_2O) from drained soils[13]. Society contributes mainly with effective fire prevention and with information and advice.

Carbon stocks of Swedish forests of the 19th century were a function of natural death causes (e.g. insects, pathogens, fire), slash-and-burn practices, forest grazing, wood use for housing and heating and exploitive cutting for charcoal production and for the fast-growing sawmill industry.

It has been estimated that the stock increase that takes place because of more ambitious forestry will level off during this century as the steady-state stock levels are nearly reached (averages over rotation periods for managed forests and equilibrium stocks for off-set forests[14]. The effects of some forestry measures on sequestration of carbon are presented as part of the background analysis commissioned by the Government for its 'roadmap towards a Sweden with no net climate emissions by 2050'[15].

There are several alternative forest management practices that potentially could reduce emissions from forest soil and increase carbon stocks further per hectare over the coming century, such as restricted use of clear-cutting, increased length of rotation periods and reduced use of site preparation. However, such measures may reduce delivery of biomass and thereby substitution potential[16]. More knowledge on alternative forest management practices are needed to evaluate their possible benefit to the climate.

Implementation of already established silvicultural practices such as fertilization with precaution could increase growth and carbon sequestration.

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[12] Klemedtsson L., von Arnold K., Weslien P. & Gundersen P. (2005) Soil CN ratio as a scalar parameter to predict nitrous oxide emissions. Global Change Biology 11: 1142–1147.

[13] Hagberg L., Karlsson P.-E., Stripple H., Ek M., Zetterberg T & Zetterberg L. 2008. Svenska skogsindustrins emissioner och upptag av växthusgaser. IVL Rapport B1774, Stockholm.

[14] Claesson, S. et al. 2008. Skogliga konsekvensanalyser 2008. SKA-VB 08. [Forest Impact Analysis 2008]. Skogsstyrelsen rapport 2008/25.

[15] Swedish Environmental Protection Agency (2012). *Underlag till en färdplan för ett Sverige utan klimatutsläpp 2050.* Stockholm: Naturvårdsverket. Report 6537. ISBN 978-91-620-6537-9.

[16] Poudel B.C (2014) Carbon balance implications of forest biomass production potential. PhD-thesis

Increasing biomass growth by measures related to forestry activities

There is a substantial theoretical potential to increase biomass (tree) growth in the future by means of e.g. tree breeding, fertilization, intensified reforestation and the use of exotics tree species. Concerning most of these measures there is a time lag to when the more significant effects become apparent in about 30+ years. The exception is fertilization of middle aged or old growth production forests in which effects are noticeable within the first decade.

In a scientific study[17] on intensive forestry practices, requested by the government and published in 2008, some of these measures were scrutinized and put into a fictive action plan. The conclusion was that national level accumulated growth over the next century could be increased by some 15 percent by applying these methods selectively on 3.5 million hectares throughout the country. However, to avoid negative effects on other values in the forest, the available land area is most probably substantially smaller than 3.5 million hectares. The main reason is that most of the efficient measures have negative effects on at least some aspects of sustainable development.

The Swedish Forest Agency, however, see some possibilities to enhance growths with little or no negative side effects. These may be improvements in the implementation of already established silvicultural practices. For example, higher ambitions in reforestation could generate something in the range of 2-3 percent increase in accumulated, national level growth over the next century[18]. Another currently feasible measure is tree breeding which could generate about 3 percent increase in national level growth over the next century[19]. As in the example above, the resulting growth effect becomes apparent several decades from now.

These measures also have potential to increase sequestration of carbon in biomass and harvested wood products. It should be noted that all measures described in this section constitutes investments in forestry. This means that the forest owner rationally would want to capitalize on his or her investment in the future. It is thus fair to say that any increased growth stemming from such measures is earmarked for harvest in the future.

Preventing deforestation

The land use situation in Sweden is very stable as shown in Table 3. A reforestation obligation has been in force in Sweden since the first national forestry Acts in 1903.

Currently small areas of forest are lost annually to settlements and infrastructure. Forest area is gained from farmland. Emission from deforestation could potentially decrease somewhat with new policies on planning of future infrastructure and settlements, e.g. avoiding building roads on land with high carbon content.

Table 3 Land Use Categories 1990, 2012 and gross and net land use transfers 1990-2012. Source: *National Inventory Report, Sweden 2014 - Greenhouse Gas Emission Inventories 1990-2012* -

[17] Larsson S. et al. 2008. Möjligheter till intensivodling av skog [Possibilities of intensive management of forests]. SLU, Slutrapport regeringsuppdrag Jo 2008/1885

[18] Gustafsson, K. (ed.) 2000. Skogliga konsekvensanalyser 1999 [Forest Impact Analysis 1999]. Skogsstyrelsen rapport 2/2000.

[19] Claesson, S. et al. 2008. Skogliga konsekvensanalyser 2008. SKA-VB 08. [Forest Impact Analysis 2008]. Skogsstyrelsen rapport 2008/25

Area [1000	"From" Year 1990	"To" Year 2012 Forest Land	Crop-Land	Grass-Land	Wet-Land	Settle-ments	Other Land
Forest land	27399	27035	9	55	56	202	40
Cropland	3165	122	2898	75	0	70	0
Grassland	503	84	34	366	0	19	0
Wetlands	7973	223	0	7	7646	14	83
Settlements	1710	66	29	2	20	1588	5
Other land	4518	23	0	0	77	6	4412
Sum after transfers		27554	2970	505	7799	1900	4540

List of appropriate measures in order to pursue the mitigation potential[20]

Policy measures that will contribute to reduce emissions and maintain or increase removals include:

1. Replacing greenhouse gas intensive materials with forest raw materials.
2. Replacing fossil energy with bioenergy, including from harvesting residues.
3. Increasing biomass growth through forestry methods such as improved propagating material, intensified reforestation practices, fertilisation with precaution[21] and continued afforestation, as well as enhancing the carbon stock in forest soils by methods such as changes in silvi-cultural systems and setting aside of land in reserves and the like.
4. Avoiding forestry methods which increase greenhouse gas emissions from forest soils, such as drainage, and in other respects adapting forestry to reduce the risk of future emissions as the climate changes.
5. Increasing the amount of carbon stored in harvested wood products.

The last three measures are LULUCF actions that will primarily influence carbon sequestration in the LULUCF sector, while the first two measures are LULUCF actions that will reduce emissions in other sectors.

Policies and measures to implement measures to pursue the mitigation potential

Forest policy

Swedish forest policy has two overarching, coequal objectives, relating to production and the environment. The environmental objective is as follows: The natural productive capacity of forest land should be preserved. Biodiversity and genetic variation in forests should be secured. Forests should be managed in a manner that enables plant and animal species occurring there naturally to

[20] Most of these measures described in Sweden's Sixth National Communication on Climate Change Under the United Nations Framework Convention on Climate Change, Ds 2014:11, Ministry of the Environment, Sweden
[21] Fertilization with precaution is an established silvi-cultural practice in Sweden. Environment should be safeguarded.

survive in natural conditions and in viable populations. Threatened species and habitats should be protected. The cultural heritage assets of forests and their aesthetic and social values should be safeguarded. The production objective is: Forests and forest lands should be used effectively and responsibly so that they produce high, sustainable yields. The direction of forestry production should be towards giving a free hand with regard to what forests produce. Emphasis is placed in forest policy on the significance of forests for climate, including the need for increased forest growth.

Government initiatives

As part of the 'Forest Kingdom' initiative, central government advice to the forestry sector has been stepped up, with a view to promoting effective and functional consideration for the environment and improved forest management. The Swedish Forest Agency provides guidance in five targeted areas, including regeneration, cleaning/stand treatment and game damages. To implement this initiative, funding is being increased by 10 MSEK per year over the period 2012–2015. The Swedish Forest Agency has mounted information campaigns on forestry and climate change with support from the Rural Development Programme (RDP): "Forestry in a changed climate" and "Forest owners and climate". In addition, it is running a forest bioenergy project, also funded by the RDP. This project aims to provide forest owners and professionals with knowledge that will enable greater use to be made of forests for bioenergy purposes.

Another strand to the Forest Kingdom initiative is a three-year programme to help achieve its goal of creating conditions for more jobs in the Swedish countryside. The programme seeks to support the development of sustainable forestry methods that will increase production, based on a systematic, iterative approach of active learning. These methods are to be developed in combination with effective and functional consideration for the environment. Examples of measures that may be analysed are tree species selection, use of improved planting material and genetic variation, thinning regimes, shortened rotation times, silvi-cultural systems other than even-aged management, and fertilisation based on actual needs. In developing methods, the social values of forests are to be taken into account. To implement the programme, funding will be increased by a total of 60 MSEK over the period 2013–2015.

Legislation

The methods used in forestry are mainly regulated by provisions in the Forestry Act and the Environmental Code. Existing provisions influence carbon dioxide removals and emissions in various ways, in particular:

Provisions on forest management are described in the Forestry Act. Examples include requirement to establish new forest after felling and requirement to afforest abandoned farmland no later than the third year after it is taken out of production. These requirements are designed to ensure full use of the timber-producing capacity of land, which is beneficial for climate change mitigation as it promotes the uptake of carbon dioxide by forest biomass and sustains high production of biomass, enabling the substitution of fossil fuels and greenhouse gas intensive materials for forest biomass.

Provisions on land drainage are described in the Environmental Code. In central parts of the southern Swedish highlands and north of the *limes norrlandicus* (the Biogeographical Boundary of Northern Sweden), land drainage – defined as drainage with the aim of permanently increasing the suitability

of a property for a certain purpose – may only be undertaken with a permit. In the rest of the country and on sites specially protected under the RAMSAR Convention, such schemes are prohibited. Permit applications are considered by county administrative boards. Land drainage has declined since the early 1990s and now occurs on a very small scale. Drainage of wetland may induce increased emission of carbon dioxide and nitrous oxide while emissions of methane normally decrease, and increased forest production on drained land increase removals of carbon dioxide in forest biomass and enable the substitution of fossil fuels and greenhouse gas intensive materials for forest biomass.

Conservation work (site protection, nature conservation agreements and voluntary set-aside of land) not only preserve biodiversity, but also have an impact on carbon stocks in forest biomass, and soil carbon are maintained or continue to increase. The ordinary forests are used primarily for timber – timber production forests – and have a relatively low average age and therefore a large capacity to store carbon, even long after a conservation measure has been implemented. The Swedish forest hereby contributes to climate mitigation reduction since a sustainable production of timber and biomass can substitute for other less climate friendly materials and products. In addition, there are proposals to set aside further areas of forest, further described below. There are also targets for the conservation and protection of areas containing both wetlands and forest land. Since such areas are usually excluded from felling, their stocks of carbon in biomass and soil will in most cases be larger than those of production forests.

Carbon dioxide tax and energy tax are regulatory instruments that influence the demand for forest raw materials for energy supply and construction purposes, and indirectly impact forestry's fluxes of greenhouse gases. The carbon dioxide tax is currently 1080 SEK/tCO2 and is levied on fuels' fossil carbon content. Thus, biofuels are not taxed. There are exemptions and reductions for several sectors, e.g. for industries included in EU ETS, combined heat and power production, heat generation, energy-intensive industries, agriculture and forestry. Limiting carbon dioxide tax to fossil carbon and exempting biofuels from energy tax for certain end uses have increased the profitability of biomass fuels from forests and been a major factor behind the emission reductions achieved, for example in the district heating and residential and commercial/institutional sector.

Other notable regulatory instruments that contribute to reducing the impact on the climate include market-based support schemes such as the electricity certificates system and quota obligation on renewable transport fuels. In the energy sector, electricity certificates support the expansion of electricity production from renewable resources and peat. Renewable electricity generators are granted certificates and electricity users are required to purchase a certain share. The scheme will continue to increase renewable electricity generation, and increase demand for forest biofuels for electricity generation.

The Government has previously emphasised the importance of analysing the scope for regulatory and other policy instruments that could be considered to further enhancing the contribution of forestry to the cost-effective achievement of Swedish climate policy objectives. Such analysis should include studies of possible incentives to increase sequestration of carbon in sinks, where appropriate, and to minimise greenhouse gas emissions from land, while avoiding negative effects on the production and environmental objectives of Swedish forestry. The Government is currently considering how this analysis should be undertaken.

Sectorial responsibility

Since the early 1990s, forest policy is built on landowners having considerable freedom to make their own decisions about the aims of their forestry and the operations they wish to undertake, at the same time as they have an important part to play in achieving forest policy objectives in the framework of their sectorial responsibility. One component of this sectorial responsibility is the voluntary third-party certification schemes which most of Sweden's forest owners have joined. There are two such schemes, that of the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). Both are based on landowners undertaking to follow guidelines on sustainable forestry in managing their land. Swedish legislation sets a common standard for all productive forest land regarding consideration for the environment. Certification requirements are designed to raise the bar even higher as regards the ecological, economic and social aspects of forestry, and include provisions for the voluntary set-aside of forest land. Since many forest managers have signed up to certification schemes, the areas being set aside have also increased. As a rule, this land is set aside from any form of management, or managed with the primary purpose of promoting biodiversity. As a result, more than 1 million ha of land has been set aside voluntarily by the forestry sector – without compensation from the state. These set-aside areas may also represent a contribution to increasing uptake of carbon dioxide.

Swedish Environmental Quality Objectives[22]

A Governmental Bill on Biological Diversity and Ecosystem Service was presented in March 2014. The bill established five additional environmental interim targets for already established environmental quality objectives in the area of protection of biodiversity. These five additional environmental interim targets include environmental consideration in forest management and conservation work.

They include a goal that at least 20 percent of land, fresh water and 10 percent of marine areas should contribute to attain objectives for biological diversity. Protected areas should increase by at least 1 142 000 hectares between the years 2012 and 2020, including the additional protection of 150 000 hectares of forest land through set aside from any form of management, or managed with the primary purpose of promoting biodiversity. It also includes an expected additional 200 000 hectares forest land to be set aside voluntarily by the forestry sector without compensation from the state.

To reach the objectives of the environmental and forest policy voluntary efforts by the landowners are crucial. Advice to the forestry sector from the central government to promote effective and functional consideration for the environment and improved forest management play a fundamental role. The potential effect on the emissions and removals of greenhouse gases due to these measures has been described above.

Indicative timetables for policy measures

The appropriate measures in order to pursue the mitigation potential will be implemented through interconnected strategies for different ecosystem services and a diverse set of policy instruments as described above. Strategies and policy instruments have various focuses but may also influence how

[22] http://www.miljomal.se/sv/Environmental-Objectives-Portal/Undre-meny/About-the-Environmental-Objectives/

the forestry sector can contribute to mitigating climate change. Below is the indicative timetable for existing or planned policies, initiatives and proposals:

Increased central government advice funded by the Governments Forest Kingdom initiative is provided during the period 2012-2015.

The three-year programme within the Forest Kingdom to support the development of sustainable forestry methods that will increase production, based on a systematic, iterative approach of active learning, will be funded over the period 2013-2015.

The shares of electricity certificates electricity users are required to purchase is gradually being increased year by year up to 2020.

The final report from the All Party Committee on Environmental Objectives was presented in June 2014.

The Government's Bill on Biological Diversity and Ecosystem Services includes increasing the protected area by at least 1 142 000 hectares between the years 2012 and 2020, including 350 000 hectares forest land.