

Energy from Wood Biomass

-Environmental management considerations

 Swedish benchmarks 2011

Preface

This report has been produced by Norsjö municipality as an activity under the European Union Northern Periphery Programme project RASLRES (Regional Approaches to Stimulating Local Renewable Energy Solutions – www.raslres.eu). The intention with this report is to raise awareness of potential environmental impacts and how to mitigate them when increasing the uptake of biomass in terms of forestry. It should however be pointed out that these environmental impacts should be put in perspective with the alternatives, which in many cases are fossil fuels.

The purpose of this document is to highlight potential environmental considerations and impacts associated with the increased production and use of woody biomass and those measures taken from the Swedish case that might serve to mitigate those impacts.

The Swedish case is unique in that more than 50% of the Swedish land area is actively managed, productive forest which provides an important and significant industrial resource on a national level. Sweden understood aspects of sustainability with regards to forest management relatively early on and enacted its first forestry regulations more than 100 years ago in 1903. Sweden enjoys a modern record of success in progressive management of its productive forest resource; it has increased its standing forest inventory steadily for decades while simultaneously increasing forest production.

For countries or regions working to increase the production and use of woody biomass for energy (and/or fibre, chemicals, lumber, etc), this document should serve as a reference to further understanding the related considerations and possible adverse impacts of doing so, and provides information and knowledge resources that might help to mitigate those impacts.

Information in this document has mainly been collected from Swedish authorities and international organizations working with energy related issues. The content of this report is at a very high-level, and further information can be found in the reference section at the end of each chapter. Most of the referenced sources are in English, but for others, “Google Translate” can be used for translation.

22 August 2011

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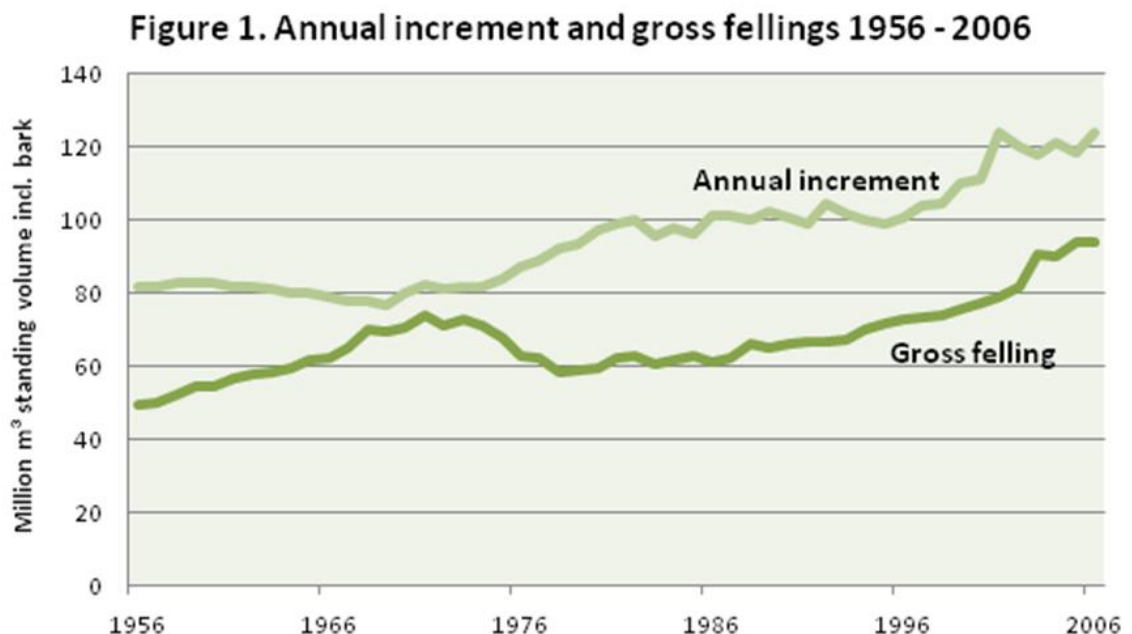
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Background

Forest covers about 70% of the total Swedish land area, mostly with Norway spruce (42%), Scots pine (39%) and Birch (12%). About 56% of the total land area is productive forest and has a significant impact on the Swedish economy. The gross output of the forestry sector was 220 billion SEK during 2007, and the total value added by forestry and the forest products industry equalled 2.7% of GDP. During 2009, there were about 97 300 employees in the forestry sector, constituting about 1% of the Swedish population.

During the 18th and 19th century, large parts of Swedish forests were overexploited for housing construction, fuel wood, charcoal for the iron industry and eventually as a source of logs for timber and pulping. Regeneration was often hindered by cattle grazing in the forests. This was an increasing problem, and eventually led to the parliament passing the first Forestry Act into law in 1903, which among other things required forest owners to replant after felling.

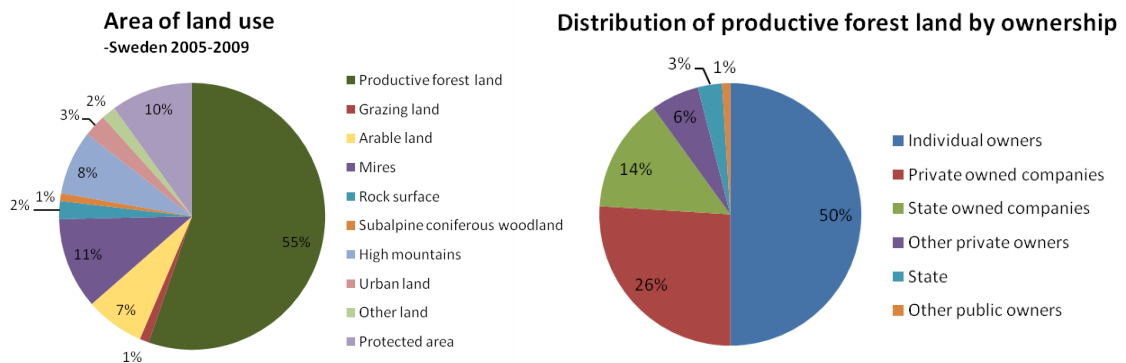
Since 1903, the forestry sector has become increasingly efficient through inventions such as the chainsaw and a variety of forest machines. Today, forestry in Sweden is highly mechanized with a total volume of felled timber in 2009 of approximately 80.1 billion cubic meters standing volume. Transportation of forest products accounts for about 25% of the total land based transportation. Demand for wood biomass has been increasing from saw mills, paper- and pulp industry and the energy sector. Despite this massive pressure on Swedish forests, the total standing volume has increased by more than 80% since the 1920s. The annual forest increment is fairly stable at levels well above the annual gross felling (figure 1).



Source: Swedish National Forest Inventory & the Swedish Forest Agency

The Forestry Act has played a major role in contributing to this increase of forest resource. It has been updated several times, most recently in 1994, and considers relevant economic, ecologic and social interests. The Forestry Act aims for sustainable development and includes two goals of equal weight; one for production and one for preserving biodiversity. Key steps of the act are as follows:

- Mandatory reforestation after final felling
- A ban on the felling of young stands
- An obligation on forest owners to carry out preventive control of insect pests
- Special management regimes for valuable hardwood forests and upland forests
- A general duty of care for objects or sites of natural, historical or heritage value in the forests



Further information

Swedish Forest Agency

-The Forest Agency is an authority working to implement the Swedish forest policy. Focus is on optimizing production while preserving biodiversity and considering the public's need for and interest in the forest for recreation and leisure.

<http://www.skogsstyrelsen.se/en/>

Swedish forestry model report:

http://www.skogsstyrelsen.se/Global/myndigheten/Skog%20och%20miljo/ENGLISH/retrieve_file.pdf

Statistical yearbook about Swedish forestry (2010):

[http://www.skogsstyrelsen.se/Global/myndigheten/Statistik/Skogsstatistik%20årsbok/01.%20Hela%20-%20Entire/Skogsstatistik%20årsbok%202010%20\(hela\).pdf](http://www.skogsstyrelsen.se/Global/myndigheten/Statistik/Skogsstatistik%20årsbok/01.%20Hela%20-%20Entire/Skogsstatistik%20årsbok%202010%20(hela).pdf)

Swedish Forestry Act (in Swedish):

<http://www.skogsstyrelsen.se/Global/PUBLIKATIONER/svl/SVL%202010.pdf>

Biodiversity

What is biodiversity?

Biodiversity is a diversity of species and a diversity of the many uniquely combined genes that each individual carries. Biodiversity is also often described as a diversity of habitats or even a diversity of ecosystems. Many plants and animals have special demands for their habitat. Demands can be for special soils or sufficient sunlight through the canopy. It can also refer to recurring events in nature, such as wildfires or variations of other species to coexist with. Basically, biodiversity is a precondition for well functioning and stable ecosystems.

Why should we preserve biodiversity?

Generally, four motives are mentioned in terms of preserving biodiversity. Firstly, biological resources are the foundation of the sustenance and much of today's and tomorrow's business. Studies of nature generate new technical inventions as well as new raw material. Genes are the ultimate "commodity" for biotechnology that is now being applied in e.g. pharmaceutical and agricultural industries. Secondly, ecosystems perform many services that are taken for granted and therefore not valued in money. Examples are the microbial release of nutrients, their degradation of pollutants in air, soil and water, insect pollination and vegetation water regulating effect. A third motive for biodiversity is that nature has always been a source of inspiration to mankind and is reflected in art as well as literature. Lastly, there are ethical and existential values in that biodiversity is the result of billions of years of evolution, and humans are part of this diversity.

Threats

Increased wood biomass production means intensified harvest, and can affect natural occurring ecosystems in the short and long run. Such discussions should however be preceded by stating that logging itself is most often the main factor in terms of affecting eco-systems, while further outtake merely increases the effect. Also, negative environmental impacts from using wood biomass should be compared to the alternative, which in many cases is fossil fuel which brings even worse impacts.

Loss of biodiversity threatens our food supplies, opportunities for recreation and tourism, sources of wood, medicines and energy. It also interferes with essential ecological functions.

Threats to biodiversity, related to forestry

Logging of high-value core areas

in old-growth forests and forests with old-growth forest structures

Increased biomass uptake

such as tips, branches and stumps

Drainage, fertilization and use of exotic tree species

with the purpose of streamlining productivity

Mechanical damage

from forest machines

Lack of natural disturbance regimes

such as flooding, which is prevented by drainage

The Swedish case

With the vast amount of forestry activities in Sweden, it is necessary to actively work for biodiversity protection. The Swedish model is mainly made out of two parts; general conservation considerations in day-to-day forest management and the designation of more strictly protected forest areas.

General conservation considerations are embodied in the Swedish forestry act, which specifies demands on the forest owner in terms of timber production and nature considerations as well as historic values and reindeer management.

Protected forest areas consist of legally protected areas and voluntary set-aside areas. Legally protected areas include national parks, nature reserves and habitat protection, whereas voluntary set-aside areas by definition are productive forest areas of at least 0.5 hectares that the forest owner without financial compensation excludes from forest production activities. These areas should contain high natural, cultural or recreational values. Voluntary set-aside areas are important for biodiversity and constitute a criterion for becoming a certified forest owner. In 2010, there were about 1.2 million hectares of voluntary set-aside areas, representing about 5 % of the productive forests in Sweden.

There are several certifying organs, of which the most common are Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC), Sustainable Forestry Initiative (SFI), The Canadian Standards Association (CSA) and Sustainable Forest Management System (SFM). In 2009, more than 11 million hectares, or about half of the productive forest in Sweden, were certified with FSC. The corresponding figures for PEFC in 2010 were more than 8 million hectares. Figures for FSC and PEFC should however not be added for the total, since many forest owners are certified with both standards.

Further information

CBM –Swedish Biodiversity Centre

-The Swedish Biodiversity Centre is a national institution with the mandate to promote, conduct and co-ordinate research, education and information on topics associated with biodiversity.

<http://www.cbm.slu.se/eng/index.php>

Swedish Forest Agency

-The Forest Agency is an authority working to implement the Swedish forest policy. Focus is on optimizing production while preserving biodiversity and considering the public's need for and interest in the forest for recreation and leisure.

<http://www.skogsstyrelsen.se/en/>

<http://www.skogsstyrelsen.se/en/AUTHORITY/Forest-and-environment/Biodiversity/>

Swedish Forest Agency report on environmental issues regarding forestry (in Swedish):

<http://www.skogsstyrelsen.se/Global/PUBLIKATIONER/Skogsskotselserien/PDF/14-Naturhansyn.pdf>

European Commission, Environment Directorate-General, Nature and Biodiversity

-The Directorate-General for the Environment is one of the more than 40 Directorates-General and services that make up the European Commission. The objective is to protect, preserve and improve the environment for present and future generations.

http://ec.europa.eu/environment/nature/index_en.htm

Convention on Biological Diversity (CBD)

-CBD entered into force in 1993, with main objectives of conserving biological diversity, using components of biological diversity sustainably and sharing benefits arising from utilization of genetic resources.

<http://www.cbd.int/>

CBD report on biodiversity:

<http://www.cbd.int/iyb/doc/prints/cbd-sustain-en.pdf>

Swedish fourth national report to CBD (2009):

<http://www.cbd.int/doc/world/se/se-nr-04-en.pdf>

European Environment Agency

-The European Environment Agency (EEA) is an agency of the European Union with the task to provide information on the environment.

<http://www.eea.europa.eu/soer/synthesis/synthesis>

Swedish Environmental Protection Agency

- The Environmental Protection Agency is a national agency for environmental protection and nature conservation as well as outdoor recreation and hunting issues.

<http://www.naturvardsverket.se/en/In-English/Menu/State-of-the-environment/Sense/Biodiversity---Why-should-we-care/>

Swedish Environmental Protection Agency report on Sweden's approach for biodiversity according to CBD (in Swedish):

<http://www.naturvardsverket.se/Documents/publikationer/978-91-620-6389-4.pdf>

Air quality

Problem

Although biomass combustion is a renewable alternative, it can contribute to emissions of various environmental and health hazardous air pollutants from exhaust gas and ash which can cause problems with respiratory and cardiovascular systems and increase the risk of cancer. Especially vulnerable are children, elderly people, asthmatics and others suffering from bronchitis and respiratory problems. Emissions from combustion facilities depend on combination of fuels and combustion/cleaning techniques.

Environmental effects from combustion facilities can be divided in categories based on whether the effects are global, regional or local. Particulate matter, carbon monoxide and hydrocarbons are predominantly affecting human health locally. Nitrogen oxides and sulphur dioxide primarily has a regional impact and contributes to acidification of lakes and woodlands. Nitrogen oxides also contribute to eutrophication of waterways. Nitrogen oxides and hydrocarbons combined with sunlight can form ambient ozone, which can have local and regional impact. Greenhouse gases (CO₂ and nitrous oxide) have a global impact as it remains in the atmosphere for a long period of time, allowing distant spread. Some persistent toxins such as dioxins also have a global impact as the emissions are spread over large areas.

Small scale combustion

Emissions from small scale combustion mainly include volatile organic compounds (VOC), fine particles from ash and soot, and polyaromatic hydrocarbons (PAH). Emissions are significantly higher for old wood boilers without or with undersized accumulator tanks. Without accumulator tanks of the proper size, the boiler will reduce the airflow to keep the water from boiling, leading to incomplete combustion and increased emissions. This will also lead to decreased energy output. As such, the best way of minimizing emissions is to keep the boiler constantly running at maximum capacity.

Large scale combustion

Larger combustion facilities have higher requirements for emission cleaning. Also, it is more economically viable to invest in emission cleaning techniques for large scale combustion as compared to small scale combustion. Because of this, large scale combustion is often relatively clean in terms of emissions.

Fluidized beds are commonly used for large scale biomass combustion. This is a technique where the fuel hovers in the combustion chamber, which consists of a hot bed of sand. The hover property occurs due to a powerful wind blowing through the bed of sand. This technique enables use of multiple fuel types, including peat, waste and different types of biomass. Combustion in fluidized beds occur in temperatures significantly lower (1 000 – 1 600 °C) than conventional combustion techniques. This allows fuel particles to mix well with the air, lowering e.g. NO_x emissions.

Emission type	Description	Counter measures
Particulate matter	Particulates from ash and soot (<0.1µm - >100 µm), found in the exhaust gas after combustion. Amount varies with fuel ash content and combustion technique. Solid fuels generally have higher ash content relative to other fuels.	The most common techniques for treatment of particulates are different types of dynamic separators, e.g. simple cyclones, multicyclones, electric filters and textile blocking filters. Exhaust gas condensers also have a cleaning effect.
Nitrogen oxides (NO_x)	Formed by the nitrogen contained in the air and/or fuel. Combustion method, facility design and nitrogen content determine the amount of NO _x emissions.	NO _x emissions can be reduced by combustion technology measures, such as operational optimization and tuning of the combustion properties. In many cases, these measures need to be reinforced by cleaning equipment, such as exhaust gas cleaning.
Sulphur dioxide	Sulphur dioxides are formed by oxidization of sulphur in the fuel. The amount of emissions depends on the sulphur content in the fuel.	Emissions can be limited through combustion optimization, exhaust gas cleaning or by changing fuel or fuel quality.
Carbon dioxide (CO₂)	All combustion of carbonaceous fuels results in CO ₂ emissions. Bio fuels are however counted as neutral in terms of CO ₂ emissions due to CO ₂ uptake.	Today, there are no commercially available methods for CO ₂ separation, but research and development for separation methods and CO ₂ storage are ongoing.
Carbon monoxide	Poisonous gas formed at combustion of carbonaceous fuels. Emission levels depend on combustion completion.	An important factor for carbon monoxide emissions are fuel preparation and fuel input. To reduce emissions, the fuel should be fed to the boiler at a constant flow and have a constant calorific value.
Hydrocarbons	Volatile Organic Compounds (VOC) are emitted at incomplete combustion	Same as for carbon monoxide (see above).
Heavy metals	Heavy metals from the fuel are emitted through bottom ash, fly ash and exhaust gas. Especially toxic are cadmium, lead and mercury.	Heavy metals are mainly separated with the particulate matter, however certain metals such as mercury are also emitted as gas, in which cases active coal can be used as a separator.
Dioxins	Dioxin is a generic term for a group of chlorinated organic compounds, formed at combustion of chlorine-containing fuels in the presence of copper, which acts as a catalyst.	Dioxin formation is avoided primarily through combustion technology by keeping high temperature for a sufficient amount of time and avoiding air deficit zones.

The Swedish case

Problem

Most of the air quality issues in Sweden are found in villages and small towns with large amounts of old household wood boilers without or with undersized accumulator tanks. District heating systems with few emission sources, often located outside the town centre are commonly found in larger towns. From a geographical standpoint, air quality issues are more common in the inland of northern Sweden due to unfavorable meteorological conditions. Low temperatures cool the ground, creating a condition called ground inversion, where temperature rises with altitude. This prevents vertical spread, and instead creates a layer of horizontally moving emissions.

Laws and regulations for small scale combustion

Laws and regulations for small scale combustion can be found in the Environmental Code, Building and Planning legislation, and in the Civil Protection Act. Also, each municipality is ultimately responsible for air quality within its own jurisdiction, and can therefore regulate small scale combustion via building permits.

On a national level, the Swedish law regulates small scale combustion rather loosely by stating in the Environmental Code that the owner of a wood biomass heating solution is responsible to take necessary precautions to avoid negatively affecting human health or the environment. In practice however, this is very hard to monitor as wood boilers are very common in Sweden. About 20 - 25% of all houses in Sweden are heated with wood as the main fuel source. The Building and Planning legislation sets requirements for safety in case of fire, protection with regard to hygiene, health and environment as well as energy efficiency. The Civil Protection Act regulates chimney sweeping and fire protection control procedures.

Further information

Swedish Environmental Protection Agency

- The Environmental Protection Agency is a national agency for environmental protection and nature conservation as well as outdoor recreation and hunting issues.

<http://www.naturvardsverket.se/en/In-English/Start/State-of-the-environment/Air-quality/>

World Health Organization –Regional Office for Europe

- WHO is the authority responsible for public health within the United Nations system. The WHO Regional Office for Europe (WHO/Europe) is one of WHO's six regional offices around the world. Following is the report "Air Quality Guidelines for Europe" produced by WHO.

http://www.euro.who.int/data/assets/pdf_file/0005/74732/E71922.pdf

European Commission, Environment Directorate-General, Air Quality

-The Directorate-General for the Environment is one of the more than 40 Directorates-General and services that make up the European Commission. The objective is to protect, preserve and improve the environment for present and future generations.

<http://ec.europa.eu/environment/air/quality/index.htm>

European Parliament

-Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF>

European Environment Agency

-The European Environment Agency (EEA) is an agency of the European Union with the task to provide information on the environment. The EEA supports implementation of a number of EU Directives linked to air emissions and air quality.

<http://www.eea.europa.eu/themes/air>

Land use

Problem

The rapid human population increase over the past century from approximately 1.6 billion (1900) to about 6.1 billion (2000) has increased demand for food, energy, housing and wood commodities. These demands all compete for land resources and this has led to an escalating land use conflict between these interests and others, such as forest for recreational purposes, biodiversity and soil qualities in terms of erosion and carbon storage. Land use conflicts will certainly continue to escalate considering the renewable energy targets for 2020 set out by the EU. Because of this, demand for biomass will increase dramatically, and the question will be how to combine and prioritize conflicting land use interests.

Possible solutions

There are several ways of attacking the land use issue, however perhaps the most important strategy is to keep a broad perspective in terms of trying several approaches simultaneously.

Streamlining production

Streamlining production means extracting more value from the same land. This can for example be achieved by new inventions and new species that brings higher biomass yield. Efficient urban planning is another example.

Combined purposes

Using land for several purposes is another way to go forward with the land use problem. This includes ecological food production, where food is produced while preserving natural conditions. It also includes forestry management where dedicated areas are set aside for biodiversity reasons. Another example is green housing, i.e. urbanization with minimized environmental impact.

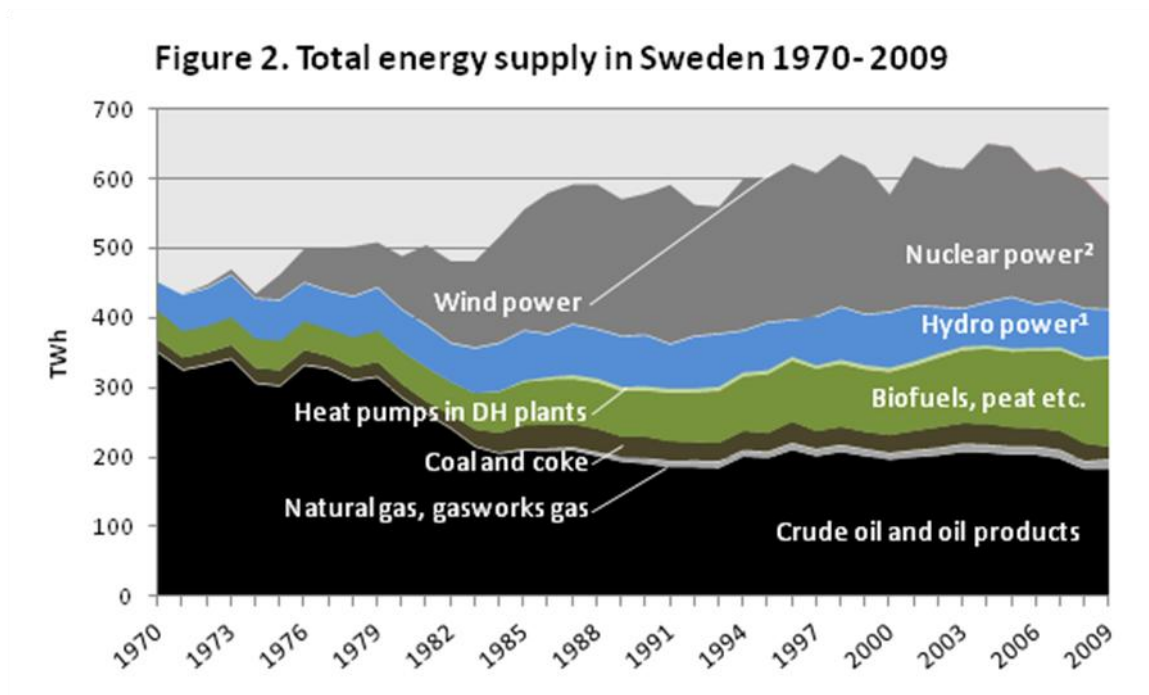
Policies

Land use issues are very different depending on location, resources, type of land etc. However, regardless of preconditions, policies can be a powerful tool in terms of regulating tradeoffs between sectorial interests such as agriculture, forestry and biodiversity.

Land use planning and management decisions are usually made at local or regional level, although the European Commission ensures that member states take environmental concerns into account in their land use development plans.

The Swedish case

Only three percent of Sweden's area is built up land. 53 percent consists of forests, 8 percent is agricultural land, 9 percent is bogs and mires without forests, 10 percent comprises heath land, high mountains and bare rocks, and 9 percent is water. As compared to the rest of Europe, Sweden is a relatively sparsely populated country with a large share of forest. Combined with the cold climate and the oil embargo in the 70s, this has contributed to a strong effort from the Swedish Government over the past 50 years to switch from fossil to renewable energy. In this work, biomass has been playing an increasingly important part (figure 2).



1: Including wind power through 1996
2: UN ECE calculation method

Source: Swedish Energy Agency

Forestry has been streamlined over the past decades with new and more efficient machines to extract more value from the forest. Also, there are several ways in which Swedish forests and biodiversity are protected. In 1990, the government ordered the Swedish Forest Agency (SFA) to inventory key habitats to enable biodiversity protection. SFA also offer other types of formal biodiversity protection such as nature conservation agreements with forest owners and nature reserves. Finally, many forest owners in Sweden voluntarily set aside parts of their productive forest for biodiversity protection.

As of today (2011), no national strategy for sustainable land use exists for Sweden. Work is however undertaken to develop such a strategy from the Swedish Government. The recommendation from an appointed parliamentary committee is to develop the strategy in two stages with main focus on forestry and agriculture.

Further information

Swedish Forest Agency

-The Forest Agency is an authority working to implement the Swedish forest policy. Focus is on optimizing production while preserving biodiversity and considering the public's need for and interest in the forest for recreation and leisure.

<http://www.skogsstyrelsen.se/en/>

Swedish Geotechnical institute

The Swedish Geotechnical Institute is a government agency dealing with geotechnical research, information and consultancy.

http://www.swedgeo.se/default_126.aspx?epslanguage=EN

European Environment Agency

-The European Environment Agency (EEA) is an agency of the European Union with the task to provide information on the environment. The EEA supports spatial requirements of EU thematic strategies on marine systems and soils, amongst others, and pays particular attention to land use changes in ecologically sensitive areas and protection of soils.

<http://www.eea.europa.eu/themes/landuse>

EEA SOER 2010 thematic assessment report on land use:

<http://www.eea.europa.eu/soer/europe/land-use>

European Commission

-European Spatial Development Perspective (ESDP). Report about balanced and sustainable development of the territory of the European Union.

http://ec.europa.eu/regional_policy/sources/docoffic/official/reports/pdf/sum_en.pdf

The Encyclopedia of Earth

-The Encyclopedia of Earth (EoE) is an electronic reference about the Earth, its natural environments, and their interaction with society. The EoE is a free, expert-reviewed collection of content contributed by scholars, professionals, educators, practitioners and other experts who collaborate and review each other's work.

http://www.eoearth.org/article/Land-use_and_land-cover_change

Groundwater and surface water impacts

Groundwater constitutes the largest reservoir of freshwater in the world. Over 97 % of all freshwater on earth comes from groundwater, and the remaining 3 % is composed mainly of surface water (lakes, rivers and wetlands) and soil moisture. Groundwater is mainly used as drinking water (e.g. 75 % of all EU residents depend on groundwater for water supply), but is also an important resource for industry (cooling water), agriculture (irrigation) and environmental values. Groundwater also plays an essential role in the hydrological cycle by maintaining wetlands and river flows, and acting as a buffer during dry periods. Deterioration of groundwater quality can also directly affect surface water and terrestrial ecosystems.

Forestry impacts on groundwater

Forestry in terms of clear cuttings can affect hydrological and chemical conditions. In clear cut areas, groundwater levels rises for two reasons; the trees no longer intercept precipitation and stops consuming water through transpiration. Since roots require oxygen to grow, there is risk for oxygen deficiency if groundwater levels rise too high. In addition to increased groundwater levels, nutrient conditions can also be affected through nitrogen leaching to the groundwater.

Forestry impacts on surface water

Different forestry measures have different surface water impacts. A measure can cause either long term or short term chemical, physical or biological impacts and impacts can be categorized as follows:

Type of forestry operation	Water chemistry can be affected by final harvest, fertilization and drainage. Also, runoff and water temperature can be affected by final harvest. Careless driving near streams and lakes as well as drainage increases export of sludge to surface waters, which has biological impacts with varying duration. Forest fertilization for example affects water chemistry for about 1-2 years whereas drainage can affect runoff patterns and the aquatic life for decades.
How operations are carried out	How forestry operations are implemented is of significant importance in terms of environmental impacts. Fertilization as well as ash spreading and driving in general should for example not be done close to surface water. This also applies for protective drainage, ditch cleaning and making new ditches, which can increase transport of sludge to nearby surface waters.
Proportion of watershed/watercourse length affected	Leaching of nutrients and other substances depends on the size of the catchment area affected by the forestry operation. This especially applies for final harvest and fertilization. Leaching increases with size of harvest/fertilization area.
Watershed size	Large catchment areas are normally less affected by forestry operations. Forestry operations therefore have greatest impact locally in the groundwater and nearby lakes. Chemical effects are diluted downstream.

Location of operations	The biggest risks for rivers and lakes are associated with outflows where groundwater flows from the ground. Wheel tracks in the outflow can lead to sludge being transported with the groundwater to the stream. Erosion in wheel tracks at high water flows can also increase sludge transportation. Fertilizer, ash and pesticides ending up in outflows close to surface water risk direct leaching.
Timing of operations	Effects on water quality are affected by when during the year the forestry operation is undertaken. Reasons for this are, among other things, that runoff and buoyancy varies over the year. Adding fertilizer or ash when runoff is high and vegetation nutrient uptake is low increases leaching. Moist and soft ground increases the risk for wheel tracks to form as compared to dry or frozen ground.
Species water composition	Water chemistry, bottom material and species present along with their ability for escape and re-colonization is relevant for how forestry affects aquatic organisms. Impacts depend on water's ability to resist interference from forestry operations.
Soil type and topography	Risk for erosion and other ground damages close to surface water is highest on grounds containing high levels of silt and fine sand. Risk for erosion and sludge transportation is higher in steep terrain.
Geographical location	Forestry impacts on water can vary with geographical location if also climate and soil fertility differs. In northern Sweden, final harvest seems to affect nitrogen leaching over a longer period of time than in southern Sweden.

The Swedish case

In Sweden, about half of the productive forest is privately owned and the other half is owned by private companies and state owned companies. Because of the “freedom under responsibility” approach of the Swedish forest policy, different forest owners have different water considerations. Large private forest companies generally have their own set of guidelines and rules for forest management based on the Forestry Act, while small private forest owners generally base management on recommendations from the Swedish Forest Agency (SFA).

The Swedish Forest Agency is the authority in charge of implementing the Forestry Act, which sets rules for how Swedish forests should be managed to optimize production while preserving biological values. Recommendations in terms of water protection from SFA include:

- Terrain transports/crossovers
 - Avoid driving in or close to watercourses
 - Avoid driving in small marshes
 - If possible, perform forestry operations on frozen soils when soils are fine-grained
- Road construction
 - Roads should not be built closer than 30 meters from aquatic environments

- Build sludge traps to avoid ditches flowing straight to watercourses
- Build bridges over watercourses
- Ditching/drainage protection
 - Avoid ditching/drainage protection by considering other regeneration methods
 - Be cautious with small marshes when making protective ditches

Further information

European Parliament

-Directive 2006/118/EC of the European Parliament and of the Council of 12 Dec 2006 on the protection of groundwater against pollution and deterioration.

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF>

Swedish Forest Agency

-The Forest Agency is an authority working to implement the Swedish forest policy. Focus is on optimizing production while preserving biodiversity and considering the public's need for and interest in the forest for recreation and leisure.

<http://www.skogsstyrelsen.se/en/>

Report on forestry, ground and water from the Swedish Forest Agency

<http://www.skogsstyrelsen.se/Global/PUBLIKATIONER/Skogsskotselserien/PDF/13-Skogsbruk%20-%20mark%20och%20vatten.pdf>

European Environment Agency

-The European Environment Agency (EEA) is an agency of the European Union with the task to provide information on the environment. On their website, the water information system for Europe (WISE) can be found, which is the European entry point for water related data.

<http://www.eea.europa.eu/themes/water>

Swedish Environmental Protection Agency

-The Environmental Protection Agency is a national agency for environmental protection and nature conservation as well as outdoor recreation and hunting issues. Following is the report "Groundwater –Environmental quality criteria"

<http://www.naturvardsverket.se/Documents/publikationer/620-6033-3.pdf>

European Commission

-Brochure about groundwater protection in Europe through the groundwater directive:

<http://ec.europa.eu/environment/water/water-framework/groundwater/brochure/en.pdf>

Waste and waste management

Background

Increased biomass consumption for energy isn't only benefiting the environment, but also creates a new waste stream in terms of ash. For example, a 3MW boiler running at capacity could produce 4-to-15 tons of ash per month, depending on wood fuel type and quality. Questions therefore arise about ash handling procedures, ash disposal etc.

Ash has historically been treated as waste, but is now more often considered a resource. It can be used for multiple purposes depending on its characteristics, e.g. as fertilizer or for road constructions. The composition depends on type of fuel (wood biomass, household waste etc.), type of boiler (fluidized bed, grate boilers etc.) and operation procedures of the boiler (full load or not). Wood combustion generally produces ash with pH levels of 9-13 with about 10-30% calcium. It also contains potassium and phosphorous. Liming qualities together with rich nutrient content makes ash suitable for forest fertilizer. It should however be noted that ash from wood combustion also can be contaminated with unburned material as well as gravel and sand.

The Swedish case

In Sweden, new heating plants and combustion facilities in sizes between 10 and 200MW are required to report to the county administration, whereas smaller boilers (down to 500kW) are managed by each municipality. This reporting procedure provides authorities an opportunity to affect the set up, including fuel choice and ash handling procedures. Follow-up reports are required annually by authorities in charge.

Since 2002, it is prohibited to discard combustible waste in landfills in Sweden. This prohibition was expanded in 2005 to include all organic waste, with a few exceptions such as well combusted ash (with less than 18 percent of organic coal (TOC)). This means that proper combustion needs to precede ash storage in landfills. Since most large CHP plants in Sweden use the fluidized bed technique where very low amounts of unburned material is left in the boiler, the ash can be placed in landfills. Despite this, search for alternative uses for ash is often undertaken, partly due to a landfill tax. The landfill tax was introduced in 2001 in Sweden as a consequence of EU directive 1999/31EC, and as of 2009 all landfills are required to meet the requirements of the directive. To further decrease use of landfills, the Swedish government raised the landfill tax by 74% between 2001 and 2010. In 2010, the tax was 435 SEK per ton.

About 1.5 million tons of ash is produced annually in Sweden, out of which about 1 million tons are utilized, mainly for covering old household landfills, but also for forest fertilization and road constructions.

Ash recycling for forest fertilization

The Swedish Forest Agency (SFA) recommends forest owners to use ash for fertilization if the wood biomass outtake, except for logs, corresponds to more than 0.5 tons of ash per hectare unless most needles have been left somewhat evenly scattered at the site.

SFA has recommendations for using ash for forest fertilization:

- No more than 3 tons of ash per hectare should be used
- The ash should contain sufficiently high levels of nutrients and low levels of heavy metals
- The ash should be processed (hardened) before spreading to neutralize the PH value
- Sensitive areas such as wetlands and key habitats should be avoided when spreading ash

Ash spreading can be done any time of the year, but preferably not during snow melting or heavy rainfalls which may flush it away. Tractors or forwarders equipped with sprinklers are normally used for ash spreading. Using helicopters is more expensive, but causes no damage to the forest and can be used for large scale operations.

Further information

Swedish Forest Agency

-The Forest Agency is an authority working to implement the Swedish forest policy. Focus is on optimizing production while preserving biodiversity and considering the public's need for and interest in the forest for recreation and leisure.

<http://www.skogsstyrelsen.se/en/>

Report on recommendations for outtake of forest residues and ash recycling (in Swedish):

<http://www.skogsstyrelsen.se/PageFiles/395/Meddelande-2-2008.pdf>

Report on wood biomass outtake to ash recycling for forest fertilization (in Swedish):

[http://www.skogsstyrelsen.se/Global/myndigheten/Projekt/RecAsh/Handb%C3%B6cker%20Handbooks/RecAsh%20handbok%20\(svenska\).pdf](http://www.skogsstyrelsen.se/Global/myndigheten/Projekt/RecAsh/Handb%C3%B6cker%20Handbooks/RecAsh%20handbok%20(svenska).pdf)

The Forestry Research Institute of Sweden

-The Forestry Research Institute of Sweden (FRI), is the central research body for the Swedish forestry sector. FRI cover research in fields such as forest technology, raw-material utilization, environmental impact and conservation, forest tree breeding, organizational structures etc.

<http://www.skogforsk.se/en/Research/Conservation/Wood-ash-recycling/>

Informational video clips about ash spreading (in Swedish):

<http://www.skogforsk.se/sv/KunskapDirekt/skogsbransle/Filmer/Askaterforing/>

<http://www.skogforsk.se/sv/KunskapDirekt/skogsbransle/Filmer/Behandling-av-aska/>

<http://www.skogforsk.se/sv/KunskapDirekt/skogsbransle/Filmer/Spridning-av-aska/>

Swedish Environmental Protection Agency

-Policy instruments for sustainable waste management:

<http://www.naturvardsverket.se/en/In-English/Start/Products-and-waste/Waste/Objectives-strategies-and-results/Policy-instruments-for-sustainable-waste-management/>

Soil

Problem

Soil is defined as the top layer of the earth's crust, and is composed of mineral particles, organic matter, water, air and living organisms. Soils are the basis for 90 % of all human food, livestock feed, fibre and fuel, as well as an important part of biodiversity, making it essential to human society in terms of socio-economic and environmental benefits. The slow rates of soil formation mean that soil must be regarded as essentially non-renewable. Nevertheless, in many parts of Europe, soil is being over-exploited, degraded and irreversibly lost due to impacts from industrial activities and land use change.

Despite this, only nine EU member states currently (2011) have specific legislation on soil protection. There are policies in place that contribute to soil protection, but those policies generally have other main aims and scopes of action. To counteract soil degradation, the European Commission adopted a Soil Thematic Strategy and a proposal for a Soil Framework Directive in 2006, with the objective to protect soils in the EU.

Soil degradation impacts related to wood biomass production

Erosion of soil due to damage caused by heavy forest machinery. Consequences are reduced resistance to storms because of exposed roots, root rot and decreased growth. This can be avoided by planning appropriate routes, crossings and drop zones ahead of time.

Contamination from more than 200 years of industrialization. The most frequently found contaminants are heavy metals and mineral oil. Heavy metals (e.g. mercury) can also be emitted from forest machinery.

Soil compaction from heavy machinery reduces capacity to store and conduct water, making it less permeable for roots.

Loss of soil fertility due to increased outtake wood biomass in terms of forest residues (tips, branches and stumps).

Loss of biodiversity through all degradation processes listed above.

The Swedish case

In 1994, the Swedish forest policy was reviewed with the result of a new forest policy being implemented the same year. The new policy was characterized by "freedom under responsibility" as opposed to the previous policy, which was heavily regulated. According to the new policy, harvests and transports should be planned ahead to minimize soil damages. The Swedish Forest Agency provides guidelines on how to minimize do this, e.g.:

- Avoid driving in low parts, where the soil is often wet with low buoyancy.
- Avoid driving along edges of streams, lakes and wetlands.
- Use an auger to determine soil buoyancy. The more fine-grained material and humus, the poorer buoyancy. Use forest residues to reinforce soil with low buoyancy in busy parts

- Make use of the experience held by the machine operators to prevent soil damages.

In addition to the guidelines, there are different types of forest protection that contributes to soil protection:

Protection method	Description
Nature reserves	To preserve biodiversity, valuable natural habitats and outdoor recreation.
Biotope protection	For smaller areas (about 2-20 ha) containing very high natural values such as key habitats. All measures harming natural values are prohibited, except hunting. The land owner gets reimbursed for reduced market value of the property.
Conservation agreements	An agreement for 1 – 50 years signed between the landowner and the state with the purpose of preserving and developing existing natural values. The agreement contains strategies for achieving this and the level of reimbursement.
Voluntary provisions	Voluntary provisions (at least 0.5 ha) for environmental reasons (without financial reimbursement) is in line with the Swedish forest policy with “freedom under responsibility”. A certified forest owner has to exclude at least 5 % of the productive property.

Finally, the Swedish Forest Agency uses GIS mapping to determine whether soil fertility is rich enough for forest residues outtake (tips, branches and stumps) and all residue harvesting is approved through the forest harvest permitting process.

Further information

Swedish Forest Agency

-The Forest Agency is an authority working to implement the Swedish forest policy. Focus is on optimizing production while preserving biodiversity and considering the public's need for and interest in the forest for recreation and leisure.

<http://www.skogsstyrelsen.se/en/>

European Environment Agency

-The European Environment Agency (EEA) is an agency of the European Union with the task to provide information on the environment. The EEA produces regular assessments on soil resources in Europe, which describe the status of soil, as well as causes and impacts of any deterioration at a continental level. The assessments provide in-depth analysis of soil deterioration: erosion, sealing, contamination and desertification, and have contributed to developing reliable knowledge in areas where policy action is needed.

<http://www.eea.europa.eu/themes/soil>

Temperate Forest Foundation

-The Temperate Forest Foundation (TFF) was founded in 1989 in Portland, Oregon. From 1989-2010, the Foundation helped people move toward the positive vision of living sustainably, with the successful integration of economic, ecological, and social needs. Since 2010, the Foundation is no longer in operation, but their website remains.

<http://www.forestinfo.org/>

<http://www.forestinfo.org/products/eco-links/05-4ForestSoil.PDF>