IEA Bioenergy

Task 25

Greenhouse Gas Balances of Bioenergy Systems

Proceedings of the Workshop

Between COP3 and COP4: The Role of Bioenergy in Achieving the Targets Stipulated in the Kyoto Protocol

Including a joint session with IEA Bioenergy Task 18

8–11 September, 1998

Nokia, Finland

R. Madlener and K. Pingoud (eds.)

November 1998

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http://www.joanneum.ac.at/iea-bioenergy-task25

ISBN: 3-9500847-1-1
IEA Bioenergy: T25: 1998: 04

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Cover photograph:

Small-scale heating entrepreneurship: wood chips production for a primary school
in Huittinen, Finland (courtesy of Reinhard Madlener)

Cover design:

Reinhard Madlener & Anton Stachl, JOANNEUM RESEARCH Forschungsgesellschaft mbH,
Steyrergasse 17, A-8010 Graz, Austria.

Production:

MEDIENFABRIK GRAZ, Steiermärkische Landesdruckerei GmbH,
Hofgasse 15, A-8010 Graz, Austria.

ISBN: 3-9500847-1-1

IEA Bioenergy: T25: 1998: 04

Printed in Austria.

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Foreword by the Editors

IEA Bioenergy is an international collaborative agreement under the auspices of the International Energy Agency (IEA), aiming at the use of biomass as an environmentally sound, cost-competitive, and sustainable energy source to provide a substantial contribution to meeting future energy demands. It was set up in 1978 in order to improve the international co-operation and exchange between national research, development and demonstration (RD&D) projects on bioenergy.

IEA Bioenergy Task 25 (Greenhouse Gas Balances of Bioenergy Systems), which succeeds Task XV (1995-1997), has the aim to investigate, on a full fuel-cycle basis, all processes involved in the use of bioenergy systems, in order to establish overall greenhouse gas balances. Its duration is from 1 January 1998 to 31 December 2000. The Task 25 workshop in Nokia, Finland, is part of a series of workshops within Task 25, and the predecessing Task XV, taking place every 6 to 12 months. The next workshop of the Task is scheduled for autumn 1999 in Oak Ridge, Tennessee. For more details on the Task and its history, visit the Task 25 website at http://www.joanneum.ac.at/iea-bioenergy-task25, or order a free copy of the recently published Task 25 folder from Ms Monika Samek, Joanneum Research, Elisabethstrasse 5, A-8010 Graz, Austria; phone +43-316-876-1332, fax +43-316-876-1320, ief@joanneum.ac.at .

The proceedings contain most of the presentations that were given at the workshop, and we would like to take this opportunity to express our gratitude to all authors who managed to submit their manuscripts in the short time provided, and also to those who at least submitted an extended abstract. Although, of course, each and every participant in the workshop contributed to the success of the event, particular thanks go to those who actively provided valuable feedback to the speakers, either during the sessions, or in the course of the breaks and/or social events.

For the first time in the history of the Task, there has been a joint session with another Task of IEA Bioenergy (Task 18, Conventional Forestry Systems for Bioenergy) on "Carbon Balances and Sequestration in Conventional Forestry Systems". The three objectives of this session were:

- Review research findings from key ecosystems on the effects of land-use change and conventional forestry on (i) soil carbon sequestration/balances; (ii) above- and below-ground partitioning of carbon.
- Review "common analytical frameworks" for the assessment of GHG balances in forestry, and identify opportunities for research collaboration in modelling ecosystem carbon balances resulting from land-use change and alternative forest management.
- Evaluate the role of conventional forestry biomass production systems for positive contributions to reducing net GHG emissions or enhancing GHG sinks.

We would like to thank Jim Richardson, Tat Smith and Pentti Hakkila for making this joint event possible, which turned out to be very successful and is likely to lead to further future collaboration between the two Tasks.

Two full-day excursions, organized by Task 18, were part of the workshop: Excursion I, which took place on 8 September 1998, covered the topics (i) recovery of logging residue from spruce dominated clearcut; (ii) effects of residue removal on forest regeneration; (iii) visit of the wood-fired Forssa CHP plant; (iv) combustion of wet sawmill residues at the Humppila sawmill; (v) demonstration of small-scale heating entrepreneurship, including a visit to a chip-fired heating unit at the Huittinen primary school. Excursion II, which took place on 11 September 1998, covered the topics: (i) spreading of wood ash and pulpmill sludge in forests (host: Ossi Sippola, Metsä-Serla Oy, Tampere) and (ii) centralized handling and chipping of logging residue on a peat harvesting area (host: Tero Vesisenaho, Vapo Oy, Jyväskylä). We gratefully acknowledge the opportunity provided by Task 18 to participate in these two highly interesting field tours, as well as the efforts undertaken by all organisations and individuals involved in putting them together (special thanks to Pentti Hakkila).

The workshop also contained presentations and very fruitful discussions of draft versions of two important new Task 25 documents. The first is a position paper on "The Role of Bioenergy in Greenhouse Gas Mitigation", prepared on behalf of IEA Bioenergy for the Fourth Conference of the Parties (COP4) to the United Nations Framework Convention on Climate Change (UNFCCC) in Buenos Aires, Argentina, 2-13 November 1998. Some 1600 copies of this position paper (which is contained in the proceedings, and can also be downloaded as a .pdf file from the Task 25 website) were distributed at COP4. The second is a Task paper on the issue of "baselines". Baselines, both in terms of reference land uses and reference energy systems, are needed as a benchmark to derive net carbon benefits of forestry, bioenergy, or other land-use related projects. Both the COP4 position paper (final 4-pages colour version) and the baselines paper (Final Draft, short version) are contained in these proceedings. An extended version of the baselines paper, that will also contain several case studies, is scheduled for completion by early 1999. It will also be made available on the Task 25 website as a .pdf file.

Finally, we would like to thank the local organizers, Kim Pingoud and Ilkka Savolainen of VTT Energy, without whom this workshop would not have been such a success, and both Bernhard Schlamadinger (Task Leader of Task 25) and Josef Spitzer (who represents the Operating Agent of Task 25, the Republic of Austria) for their continued support of the workshop organisation. From an editorial aspect, we are very grateful to Michael Waupotitsch for his efficient formatting of this document and to Anton Stachl for his help with the design of the cover pages.

Reinhard Madlener and Kim Pingoud

November 1998

Using biomass to improve site quality and carbon sequestration

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ABSTRACT

The future demands on forest lands are a concern because of reduced productivity, especially on inherently poor sites, sites with long-depleted soils, or those soils that bear repeated, intensive short rotations. Forest are also an important carbon sink, and when well managed, can make even more significant contributions to sequestration and to reduction of green house gases. This paper looks at the use of forest biomass as a carbon sink and as a source of nutrients for enhancing or restoring site productivity. An hypothesis that wood incorporated into the soil will store carbon for an unknown length of time and an example analysis using logging residues is presented. An overview of a field study conducted to evaluate the use of mulching and tilling as a site preparation tool for incorporating biomass into the soil is also presented.

Keywords: carbon, nutrients, site preparation, biomass

INTRODUCTION

Much of the US's and particularly the South's forest soils are in degraded condition due to past land use practices or are inherently carbon and nutrient poor. Enhancing and restoring degraded and poor soils can lead to increased productivity and carbon sequestration. An effective means of increasing and stabilizing soil organic matter is through the application of organic soil amendments, and forest biomass in the form of logging residues is usually a readily available source. Coupled with the need for site preparation treatments that include stump and slash clearing or displacement from the planting row, logging slash mulching (comminution into small particles) and incorporation into the soil has appeal as a means to accomplish all these objectives.

This paper explores the use of mulching/tilling to prepare harvested sites for planting, improve and restore short- and long-term site productivity, and sequester carbon. Our hypotheses are:

- comminution of slash and stumps provides good site preparation,
- incorporation of woody biomass and humus improves nutrient retention and carbon pools,
- incorporation slows wood decomposition, reduces CO_2 flux, and lengthens carbon storage (short term benefit),
- incorporation makes carbon more readily available for nutrient cycling and captures more carbon through soil biotic processes that lead to reduced CO_2 flux, and
- incorporation improves soil physical properties that enhance both short- and long-term productivity, i.e. providing for carbon storage in both vigorously growing above-ground biomass and below-ground root mass that can be used to perpetuate the carbon storage and nutrient retention cycle.

The first section of this paper addresses the use of woody biomass for enhancing soil carbon storage capacity. An hypothetical example is given for increases in carbon pools when using conventional logging residues and when a significant portion of merchantable volumes are diverted to improving soil. Secondly, the paper presents the methodology of a field study that was only recently installed to explore using woody biomass incorporation to enhance soil carbon and nutrient storage capacity.

LITERATURE REVIEW

Much is known about nutrient cycling and mineralization in forest soils, and the important role the carbon cycle in soil productivity. The above-ground processes of decomposition of biomass, humification, the release of emissions, and the return of organics to the soil is fairly well understood. Less is known about below-ground carbon processes, and the role of organic amendments in nutrient and carbon cycling. Very little research has addressed decomposition of wood incorporated into the soil.

Nutrient turnover rates are generally more relevant to forest productivity than total soil carbon (Cole and Rapp, 1981; Edmonds and Hsiang, 1987; Binkley and Hart, 1989). Increasing organic matter in soil is an important key to long-term productivity. Besides regulating forest productivity, organic matter dynamics are critical to carbon sequestration. Although the consequences of carbon sequestering in forest soils are not well understood, evidence suggests that there may be a negative feedback between organic carbon levels and carbon allocation to plant root systems that limit carbon storage in the soil (Ruark and Blake, 1991). Significant increases in the recalcitrant soil organic matter fractions may suggest the potential for carbon sequestration. Since this fraction has been linked to the soil's physical properties (Elliot, 1986; Beare et al., 1994), fluxes in the size or chemical identity of this fraction may result in significant long-term changes in the soil.

Accurate knowledge of carbon dynamics at the landscape and stand scale is needed to predict and manage forests. Presently, models that evaluate the potential effects of climate change on forest sustainability include a limited amount of information on carbon dynamics. Improving our understanding of carbon processes relative to common soil variables, such as texture, will contribute to the accuracy of such models.

Several models describing soil organic matter dynamics have been presented in the literature (Van Veen et al., 1985; Jenkinson, 1990; Verberne et al., 1990; Hassink and Whitmore, 1997). A common theme among these models has been the importance of clay, especially in warmer climates (McDaniel and Munn, 1985; Amelung et al., 1997). However, the capacity of a soil to preserve organic matter is limited by the soil's protective capacity (Hassink, 1995; Hassink and Whitmore, 1997). The protective capacity of a soil is the maximum amount of carbon that can be associated with the clay and silt fractions. Once this capacity is reached then no additional soil organic matter can be stored (Hassink, 1995). Hassink and Whitmore (1997) recognize that a significant portion of the soil protective capacity cannot be accounted for by clay content. They estimate this portion to between one- third to one-half of the total protection. It is possible that part of this is correlated to the soil micropore density. Organic matter incorporation into micropores and microaggregates is a recognized mode of physical protection for the soil organic matter and forest management strategies that alter soil micropore and microaggregate density may significantly affect the ability of the soil to sequester carbon.

Incorporating the mulched material by tilling the soil can enhance soil structure and loosen the soil permitting improved air and water infiltration. However, the soil will be exposed and initial oxidation of soil organic matter may be more rapid than on sites where the mulch is on the surface. Another consideration is that many mulched plant materials have a high C:N ratio and will tie up large amounts of nitrogen during decomposition, thus reducing nutrient availability for the new vegetation, while the woody biomass can provide little direct nutrients except for essential micronutrients. Incorporating the biomass into the soil simultaneously incorporates the carbon and nutrients into the soil minimizing the loss of nitrogen, in particular, to the atmosphere. The increased carbon capital on the site will improve soil physical properties and enhance the nutrient retention capacity of the site over the longer term.

The use of woody biomass as a soil amendment could be expected to have an impact on carbon mineralization and sequestration. Carbon mineralization and CO_2 evolution accompanies elevations in pH and has been attributed to changes in soil microbial populations. The carbon dynamics may be further influenced by the altered chemistry of soil organic matter and specific clay types at elevated pH levels. At elevated soil pH levels, the association between soil organic matter and clays will be primarily through cationic bridges. At low soil pH, protons can displace the cations and change the soil organic matter - clay interaction from a cationic bridge to a hydrogen bond. A consequence of this activity may be that the soil organic matter will not be as strongly associated with the clay, thus making the soil organic matter susceptible to decomposition. Further investigations are necessary to quantify carbon mineralization and sequestration reactions in soil amended with woody biomass to determine the extent of its influence and utility.

AN EXAMPLE OF BELOW-GROUND CARBON STORAGE

A conceptual model of the hypothesized system is shown in Fig. 1. The two standard pathways for standing biomass are: (1) for harvested tree and stand components to be removed from the site and enter a product stream, e.g. biofuels, paper, or solid wood products and (2) for litter accumulated over the rotation and logging residues to be left on the soil surface following harvest. In this conceptual model, leaving the litter and logging residue on the soil surface would lead to essentially the same growth rate for the next rotation, all other things being equal. Another possibility is shown by the shorter pathway associated with incorporating the litter and logging residues into the soil which, by improving the physical properties and the nutrient retention and cycling properties of the soil, would increase the productivity of the site and lead to increased growth rates. Additional options presented in Fig. 1. are: (1) the incorporation of some portion of the material that would normally be harvested and enter the product stream and (2) the incorporation of all of the standing biomass. This might be an appropriate option on those sites where the existing standing biomass has no product value, but if incorporated into the soil, may have significant value for increasing the carbon and nutrient capital (and long-term productivity) of the site.

The analysis of the potential carbon available to return to the site by comminuting and incorporating the residual biomass was done using two hypothetical loblolly pine (*Pinus taeda* L) stands grown in the southeastern United States. One stand represents a poor site (Site Index_{25} = 15 m) and a good site (Site Index_{25} = 21 m). Stand yields for determining the amount of carbon in the stand were taken from Clutter, et. al. (1984). The methods for determining the amount of carbon in the stand were taken from Birdsey (1992). Three harvest options were used in the analysis: (1) removing all the merchantable volume, (2) removing all of the merchantable volume to a 5 cm top, and (3) removing all the merchantable volume to a 5 cm top in stems greater than 15 cm diameter at breast height (Dbh). The analysis considers the top 30 cm of soil would be directly impacted by the mulching and tilling. Residual biomass and logging slash was assumed to be comminuted and incorporated into the soil.

The carbon removed from the site under the various options is shown in Table 1. The impact of the various options on the amount of carbon in the soil after incorporation is given in Table 2. The base amount of carbon in the top 30 cm of soil is approximately 79,000 Kg/ha (Brady, 1974). The results presented in Table 2 show that potentially significant gains in the amount of soil carbon can be attained by incorporating biomass into the soil. Significant unknowns are the fate, forms, and amount of carbon that could be added to the carbon capital of a site or stored as slowing decomposing organics over the long term.

Figure 1. Conceptual model of stand components and potential growth rates following harvest and incorporation of biomass.

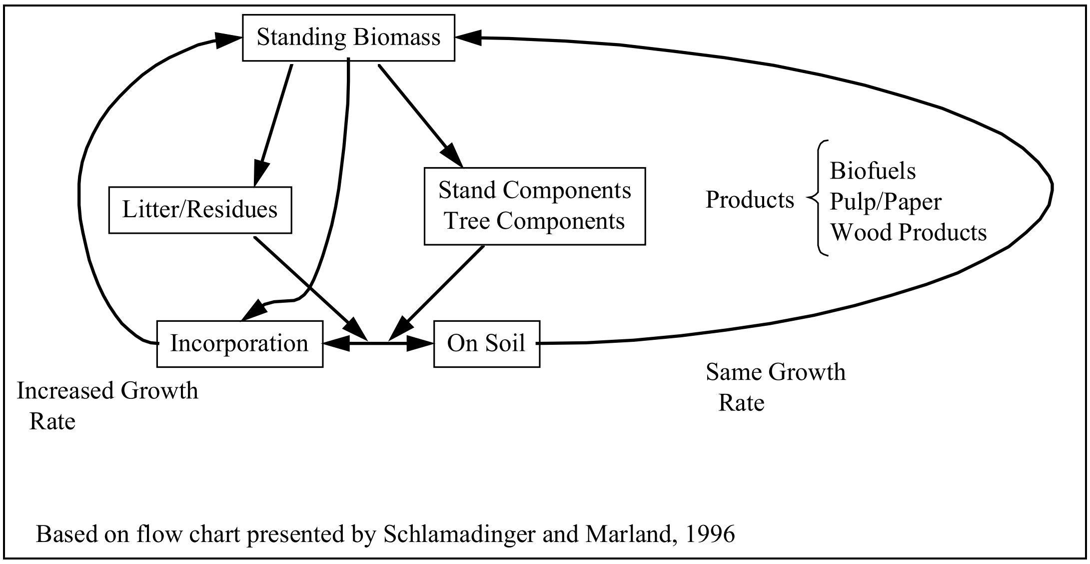

Table 1. Carbon removed from the site and returned to the soil for a range of harvest options for loblolly pine (*Pinus taeda* L.).

	Site Index (base age 25 years)			
	15 m		21 m	
Harvest Option	C removed (kg/ha)	C returned (kg/ha)	C removed (kg/ha)	C returned (kg/ha)
total merch. vol.	44,535	40,534 (trees) 4,454 (forest floor) 44,988	85,737	78,012 (trees) 8,574 (forest floor) 86,595
merch. vol. (to 5 cm top)	44,121	40,948 (trees) 4,454 (forest floor) 45,402	85,192	78,566 (trees) 8,574 (forest floor) 87,140
merch. vol. (to 5cm top, stems > 30 cm)	36,623	48,446 (trees) 4,454 (forest floor) 52,900	78,438	85,320 (trees) 8,574 (forest floor) 93,894

Table 2. Potential soil carbon in top 30 cm of soil from incorporation of different levels of stand biomass. The table entries include the base carbon available in the soil, an average of approximately 79,353 kg/ha (2.08%) in the top 30 cm of soil.

	Site Index (base age 25 years)			
	15 m		21 m	
Harvest Option	Total soil C (kg/ha)	%	Total soil C (kg/ha)	%
total merch. vol.	124,341	3.27	131,997	3.47
merch. vol. (to 5 cm top)	124,755	3.28	166,493	4.38
merch. vol. (to 5 cm top, stems > 15 cm)	132,253	3.48	173,247	4.60

FIELD STUDY

A preliminary study was installed in the fall of 1997 to compare mulching/tilling with conventional site preparation techniques. The study is a joint effort with Weyerhaeuser Company, Virginia Tech University, and Rayco Manufacturing Company. Goals of the study are to compare soil physical and chemical properties between shearing/bedding and mulching/tilling.

The sites are located on Lower Coastal Plain soils in eastern North Carolina. The stands were typical loblolly pine (*Pinus taeda* L.) plantations that had been clearcut and are to be replanted with the same species. Two soils were selected, a highly organic and a highly mineral, in order to isolate the effect of adding additional woody organics to the soil. Also, mulching the slash and stumps as a treatment was compared to mulching and tilling into the soil as another treatment. Finally, a comparison was made between mulching strips (similar to the conventional operation) and broadcast mulching.

A Rayco[1] Model FM726 Forestry Mower/Mulcher was used to install the study. The machine has a 2.4 m horizontal rotating drum with 36 attached swing hammers that: (1) mulches logging slash, stumps, and humus layer, (2) tills the soil approximately 20 cm deep, and (3) mixes these woody biomass into the soil. The machine was powered by a 205 kw engine and was mounted on tracks. The conventional operation included one pass of a dozer with a KG V-blade to shear stumps and roll logging debris to the sides to clear the strip for bedding. Another dozer was used on the second pass to apply fertilizer and to bed with a disk bedding plow.

Treatments

The treatments differed by soil type. On the organic site, the treatments were:

- Control: no mulching, no v-shearing, no bedding, no fertilizer, no weed control
- Conventional: v-shearing, bedding, fertilizer, weed control
- Strip mulch: bedding, fertilizer, weed control
- Strip mulch/till: bedding, fertilizer, weed control

On the mineral site, the treatments were:

- Control: no v-shearing, no bedding, no fertilizer, no weed control
- Conventional: v-shearing, bedding, fertilizer, weed control
- Strip mulch: bedding, fertilizer, weed control
- Strip mulch/till: bedding, fertilizer, weed control
- Broadcast mulch: bedding, fertilizer, weed control
- Broadcast mulch: no bedding, fertilizer, weed control

The plots were 40 x 40 m, 0.16 ha. The area was blocked based on logging traffic and micro-elevation and had 4 blocks per treatment in close proximity to ensure uniformity of residual slash, stump size and distribution, and soil.

Measurements

An effort was made to quantify the levels of above ground logging slash and the size and distribution of stumps. This information was also used to help locate the plots for uniformity. Soil cores were taken to quantify the soil horizons. Water wells were installed to measure water tables and for access to water chemistry samples. Volumetric soil samples were taken before and after the installation of the treatments. Later, tree growth measurements will be made to assess plot productivity.

Water chemical samples are being taking from the wells for dissolved O, C, and P. Lysimeters are being used to understand the soil water flux. These samples will be analyzed for dissolved organic carbon, NH_4- N, NO_3-N, total nitrogen, total P, pH, and conductivity.

Soil samples were collected near each well from each soil horizon to a depth of 50 cm. These samples will be analyzed for organic matter, texture, pH, nitrogen, and P. Additionally one

[1]The use of brands and trade names is for the convenience of the readers and does not imply an endorsement by the USDA Forest Service, Weyerhaeuser Company, or Virginia Tech.

standard two-inch soil core was collected from each horizon to evaluate bulk density, porosity, hydraulic conductivity, and air permeability.
Soil moisture will be evaluated using a time domain reflectometer (TDR) near each well point at depths of 15, 30, and 60 cm. Sampling rods were permanently installed at each soil depth. These stations are measured monthly in conjunction with the wells and lysimeters. A rusty rod was inserted near each well so that average reducing conditions can be evaluated. At the same locations and depths as the TDR measurements, soil temperature and soil oxygen levels are measured.

Soil CO_2 evolution is measured monthly at five locations within each measurement plot. One sampling point was centrally placed within the measurement plot and the remaining four sampling points were placed near the four corners of the measurement plot. Bulk soil CO_2 evolution will include root activity and microbial activity. All CO_2 measurements will be done in the field using a portable CO_2 chamber system.

At the CO_2 sampling points, soil cores were collected from the upper 15 cm of the mineral soil. The soil cores will be collected on a half-year basis and will be used to quantify the labile and recalcitrant organic matter fractions. Portions of the soil cores were extracted to remove the labile organic matter fraction using the method of Sanchez and Ruark (1995). The remaining portions of the soil cores will be analyzed by particle size and density fractionation by the method of Meijboom et al. (1995). Soil aggregate stability measurements were also made from the soil samples.

Outcomes

An assessment of the soil, water, vegetation, and gasses will provide a basis for constructing the carbon balance of the site, and better understand treatment effects on soil quality. Quantifying the labile and recalcitrant organic pools will give an estimate of carbon sequestered in the soil. Chemical characterization of these pools will provide insight on their inherent resistance to microbial decomposition. Carbon sequestered in vegetation will be determined from the biomass measurements. Monitoring the soil water movement and composition will give estimates of carbon and nutrient loss from the plots. CO_2 measurements will give estimates of carbon loss to the atmosphere. This information along with soil moisture, temperature, and other data will help parameterize future carbon and nutrient dynamics models.

The study will also provide information on the benefits derived from ameliorating soil physical characteristics. Measurements on bulk density, soil porosity, hydraulic conductivity, and air permeability will aid in determining the physical factors impacting site productivity and CO_2 efflux.

The site quality and carbon budget information will be valuable for understanding the relationships as well as establishing the effectiveness of the treatments. This understanding will become more important as land managers are given more responsibility in managing both productivity and carbon, which translates into managing biomass effectively.

FUTURE QUESTIONS

Mulching and tilling may be an effective way to regenerate sites, but may also be cost prohibitive unless value is given to increasing site productivity and sequestering carbon. Certainly, there are significant questions as to how well the activity does perform these functions. Our hypotheses are only hypotheses that still have to be proven or disproved. Our preliminary tests will not be able to answer all, if any of the major questions on below-ground decomposition and the gas fluxes. Much work is still needed to determine if carbon can be stored short- or long-term and/or if incorporation enhances mineralization and the capture of carbon in the biotic processes. Other studies are already being planned to better address these issues, particularly deep tilling and decomposition rates of various forms of woody biomass. We plan to evaluate the incorporation of the woody biomass at depths greater than 45 cm.

The analysis, although based on many assumptions, shows the potential to increase soil carbon through the use of residual biomass. Increases in the nutrient pools and resulting site productivity may also be derived from above-ground biomass. If biomass can be used for such values as site enhancements and carbon storage, the question becomes the „appropriate“ use of logging residues, or any component of the stand or tree that has multiple values - and not purely monetary. In the long run, which is best: to reduce the use of fossil fuels with renewable energy, or to offset emissions by sequestering more carbon in a biological system? We need to know.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr. Michael Aust, Virginia Tech, for assistance developing and installing the field study, Weyerhaeuser Co. for installing and protecting the study, and Rayco for supplying the mulching machine.

REFERENCES CITED

AMELUNG, W., FLACH, K.W., ZECH, W. 1997. Climatic effects on soil organic matter composition in the Great Plains. *Soil Sci. Soc. Am. J.* 61:115-123.

BEARE, M.H., HENDRIX, P.F., COLEMAN, D.C. 1994. Water stable aggregates and organic matter fractions in conventional and no-tillage soils. *Soil Sci. Soc. Am. J.* 58: 777-786.

BINKLEY, D., HART, S.C. 1989. The components of nitrogen availability assessments in forest soils. *Adv. Soil Sci*. 10: 57-112.

BIRDSEY, R.A. 1992. Carbon storage in trees and forests. p. 23-40. In: SAMPSON, R. N., HAIR, D., (eds.). *Forests and Global Change, Volume 1: Opportunities for Increasing Forest Cover*, American Forests. Washington, DC.

BRADY, N.C., 1974. *The Nature and Properties of Soils. 8th Ed.* MacMillan Publishing Co., Inc., New York. 639 p.

CLUTTER, J.L., PIENAAR, L.V., SHIVER, B.D., HARMS, W.R. 1984. Stand structure and yield of site-prepared loblolly pine plantations in the lower Coastal Plain of the Carolinas, Georgia, and north Florida. USDA Forest Service, Southeastern Forest Experiment Station, GTR-SE-27. Asheville, NC. 173 p.

COLE, D.W., RAPP, M. 1981. Elemental Cycling. p. 341-409. In: RIECHLE, D.E. (ed.), *Dynamic Properties of Forest Ecosystems*, Cambridge Univ. Press, Cambridge, U.K.

EDMONDS, R.L., HSIANG, T. 1987. Forest floor and soil influences on response of Douglas fir to urea. *Soil Sci. Soc. Am.* 51: 1332-1337.

ELLIOT, E.T. 1986. Aggregate structure and carbon, nitrogen and phosphorus in native and cultivated soils. *Soil Sci. Soc. Am. J.* 50: 627-633.

HASSINK, J. 1995. Organic matter dynamics and N mineralization in grassland soils. *Ph.D. diss.* Wageningen Agric. Univ., Wageningen.

HASSINK J., WHITMORE, A.P. 1997. A model of the physical protection of organic matter in soils. *Soil Sci. Soc. Am. J.* 61: 131-139.

JENKINSON, D.S. 1990. The turnover of organic carbon and nitrogen in soil. *Phil. Trans. R. Soc. Lond.* B. 329: 361-368.

MCDANIEL, P.A., MUNN, L.C. 1985. Effect of temperature on organic carbon-texture relationships in Mollisols and Aridisols. *Soil Sci. Soc. Am. J.* 49: 1486-1489.

MEIJBOOM, F.W., HASSINK, J., VAN NOORDWIJK, M. 1995. Density fractionation of soil macroorganic matter using silica suspensions. *Soil Biol. Biochem.*27: 1109-1111.

RUARK, G.A., BLAKE, J.I. 1991. Conceptual stand model of plant carbon allocation with a feedback linkage to soil organic matter maintenance. pp. 187-198. In: DYCK, W.J., MEES, C.A. (eds.) *Long-term Field Trails to Assess Environmental Impacts of Harvesting*. Forest Research Institute, Rotorua, New Zealand, FRI Bull. No. 161.

SANCHEZ, F.G., RUARK, G.A. 1995. Fractionation of soil organic matter with supercritical freon. p. 33-41. In: MCFEE, W.W., KELLY, J. M. (eds.) *Carbon Forms and Functions in Forest soils.* SSSA, Madison, WI.

SCHLAMADINGER, B., MARLAND, G. 1996. The role of forest and bioenergy strategies in the global carbon cycle. *Biomass and Bioenergy* 10: 275-300.

VAN VEEN, J.A., LADD, J.N., AMATO, M. 1985. Turnover of carbon and nitrogen through the microbial biomass in a sandy loam and a clay soil incubated with [^{14}C (U)] glucose and [^{15}N] $(NH_4)_2SO_4$ under different moisture regimes. *Soil Biol. Biochem.* 17: 257-274.

VERBERNE, E.L.J., HASSINK, J., WILLIGEN, P.D.E., GROOT, J.J.R., VAN VEEN, J.A. 1990. Modelling organic matter dynamics in different soils. *Neth. J. Agri. Sci.* 38: 221-238.

Framework for assessing the contribution of soil carbon to New Zealand CO_2 emissions.

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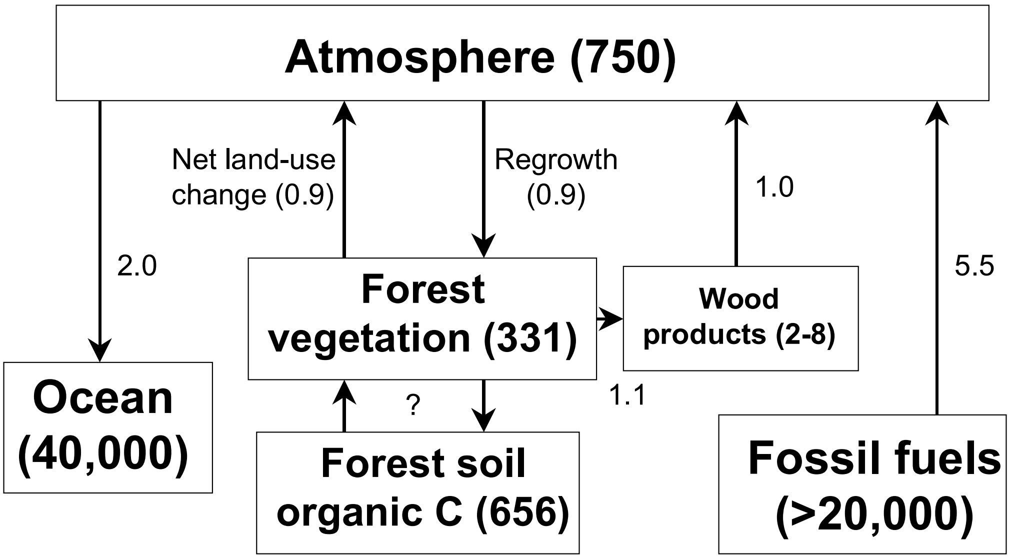
ABSTRACT

Soils contain the largest amount of carbon (C) in the terrestrial biosphere, so changes in soil C resulting from land management must be considered in estimating national C balances. New Zealand has developed a framework for estimating the 1990 soil C baseline for three soil depths (0-0.1 m, 0.1-0.3 m, 0.3-1.0 m) and future changes in soil C based on the premise that (1) IPCC soil groups, (2) climate groupings based on USDA Soil Taxonomy soil moisture and soil temperature regimes, and (3) land use are the major factors determining the C content of New Zealand soils. These three factors were the basis for deriving 166 cells from a matrix of the key 18 Soil/Climate Groups and 11 Land Use Classes, minus cells that were not found in New Zealand, which were condensed down to 39 "key" cells, which contribute significantly to the soil C content of New Zealand. The soil programme is linked to efforts to determine C in indigenous forests and scrub. For each of three soil depths, each cell is currently represented by varying numbers of sample points, based on historical data and new field samples. Current data in the system being developed provides an estimate of baseline soil C for New Zealand, some preliminary information on the amount of soil C under different land-uses, and provides us with an opportunity to conduct a preliminary assessment of methodologies for periodically updating New Zealand national soil C levels, and their propensity to change. We believe that a system for periodically updating national soil C should consider: use of 'modal soil pedon' to increase the efficiency of field sampling to estimate soil C contents of specific combinations of soil-climate-land use; number and classification of key soil groups essential to efficiently and precisely estimate national soil C contents; accuracy of 'coefficients of change' estimated from sample points lacking experimental control between land uses; gaps and linkages in estimates of below- and above-ground components of total ecosystem C; number of benchmark, long-term ecological study sites required for a national network representative of key soil-climate-land use categories; and information system requirements of a national soil C monitoring system.

ACKNOWLEDGMENTS

Ministry for the Environment
Foundation for Research Science and Technology

Major pools and fluxes of global C with relevance to forestry (Gt C/yr)



from Kirschbaum, 1998

Implications of global C estimates

Forestry significantly affects global C

- Maintain forest cover
- Establish new forests
  -- limited scope
- Bioenergy substitution for fossil fuels
- Wood products substitute for other materials with higher CO_2 emissions

from Kirschbaum, 1998 and IUFRO, Melbourne, August 1998

Implications of global C estimates

Soil storage and flux important

What assumptions commonly made?

- IPCC assumes loss of soil C with forest clearing
- Often assume above-ground biomass correlated with below-ground C storage
  -- forest has greater soil C than grasslands

Has this been adequately tested?
What are key drivers of soil C in New Zealand?

Objectives

Discuss the framework New Zealand has developed for

- establishing 1990 baseline soil C
- monitoring future changes in soil C

Describe

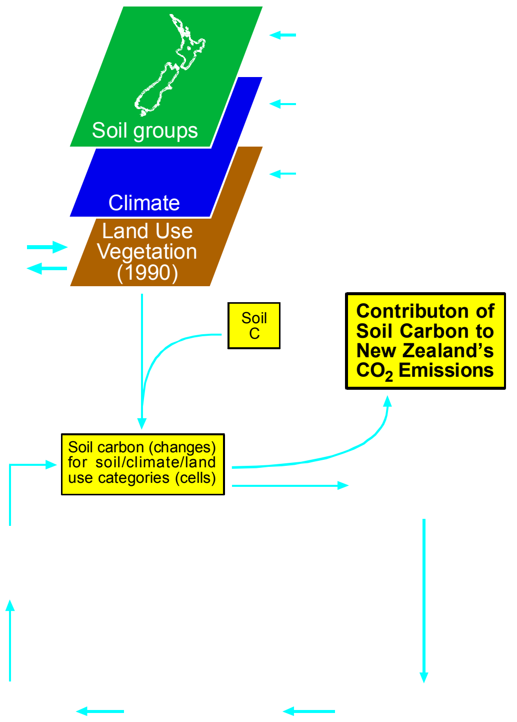
- framework of monitoring system
- current estimates of soil C to I metre depth
- initial estimates of land-use effects on soil C

Discuss key strategic scientific issues

Framework of monitoring system

Development of data layers

Spatial stratification based on 3 factors assumed to be major drivers of soil C content
- Soil type
- Climate
- Land use



Framework of monitoring system

Soil categories

Reclassification of New Zealand soil series to 7 IPCC categories based on soil OM stability

• soils with high clay activity (HCA)	high
• soils with low clay activity (LCA)	low
• sandy soils	low
• volcanic-derived soils	high
• aquic soils	high
• organic soils	high
• podzols (not IPCC category)	high

Framework of monitoring system

Climate categories

Climate surfaces fitted to monthly temperature, precipitation and potential evapotranspiration

- 5 USDA soil moisture regimes

- 3 USDA soil temperature regimes

Framework of monitoring system

Land use categories

Land use (cover) categories based on

- Vegetative Cover Map of New Zealand (Newsome 1987)

Framework of monitoring system

Spatial stratification of NZ by 3 data layers gives

- total of 166 soil/climate/land use 'cells'
- minor combinations (<1000 km^2) condensed to 39 'key' soil/climate/land use cells

  based on AOV indicating soil type effect on soil C greater than climate effect

Revised 1990 soil C baseline

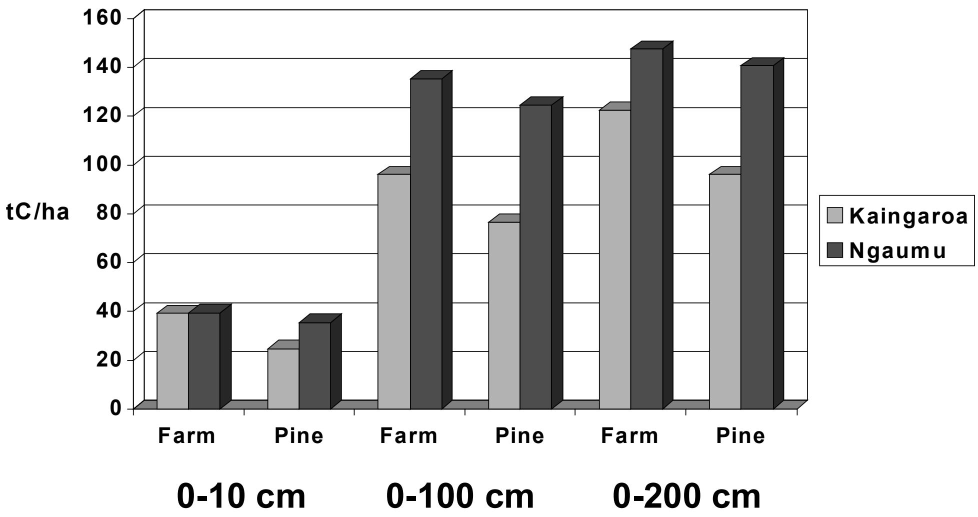
Estimated for three soil depths at 504 points
- 0-0.1 m, 0.1-0.3 m, 0.3-1.0 m

Criteria for inclusion in national database
- grid reference
- land use (cover)
- depth of horizon sampled
- soil C concentration
- dry bulk density
- stone content

Revised 1990 soil C baseline

Estimated total soil C content for New Zealand
- 0-0.1 m 1208 ± 66 Mt
- 0.1-0.3 m 1532 ± 107 Mt
- 0.3-1.0 m 1944 ± 278 Mt

Soil carbon under pasture and pine



Total soil C at different depths

Tonnes C/ha	0-10cm		0-100cm		0-200cm	
	Mean	SD	Mean	SD	Mean	SD
Kaingaroa						
Pine	24.7	9.3	76.4	30.0	96.0	34.3
Pasture	39.1	3.8	95.9	12.2	122.4	16.5
Ngaumu						
Pine	35.4	5.5	124.5	29.0	140.6	29.5
Pasture	39.3	2.0	135.2	27.0	147.3	26.4

<2 mm soil C at different depths

Tonnes C/ha	0-10cm		0-100cm		0-200cm	
	Mean	SD	Mean	SD	Mean	SD
Kaingaroa						
Pine	22.6	8.7	62.4	26.7	78.2	27.8
Pasture	37.8	3.6	91.4	12.8	115.2	16.9
Ngaumu						
Pine	31.6	3.9	119.3	28.2	134.6	28.7
Pasture	38.6	2.0	134.0	27.0	146.1	26.4

Conclusions

Pasture-pine comparisons

Effects of land use on soil C
- significant at 0-10 cm depth
- insignificant with greater soil thickness
  0-100 cm and 0-200 cm
- consider ecosystem reorganisation

Effects of site on soil C
- significant for 0-100 cm and 0-200 cm

Conclusions

Factors affecting accuracy and precision

Lack of data for
- Unimproved pasture (native grasslands)
- Indigenous forests

Soil type ‘key’ factor at national scale

Soil C in 0-0.1 m depth most sensitive to land use

Conclusions

Issues to be addressed in future research

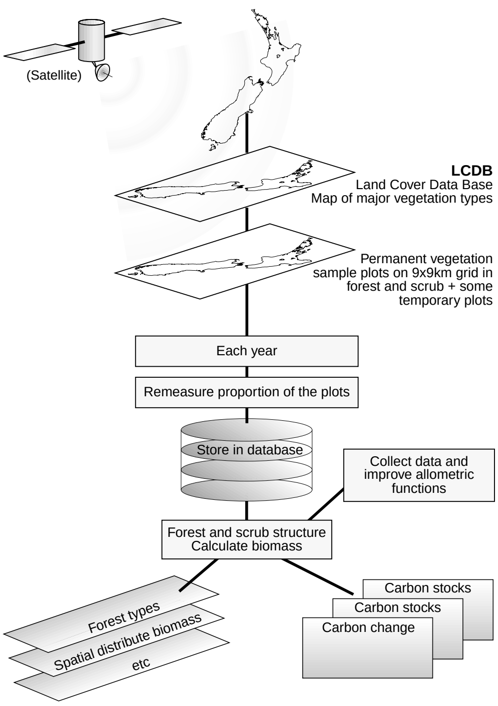
- Use ‘modal soil pedon’ to increase sampling efficiency
- Number and classification of ‘key’ soil groups
- Accuracy of methods for estimating change in soil C following land use change
- Gaps and linkages between below- and above-ground
- Number and location of ‘benchmark’ sites
- Information system requirements of national soil C monitoring system

Future updating of New Zealand soil C

Based on flexible system incorporating key framework elements

- Periodic updates of land use
  - -- assumed to be 'key' variable data layer
  - -- adjusts area in soil/climate/land use 'cells'
- Predict new soil C content following land use change
  - -- consider application of models, validated by experimental results from benchmark sites
- Update national spatial data base and soil C content

Forest and Scrub Monitoring



Towards future European forest carbon budget (LTEEF-II project)

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EXTENDED ABSTRACT

Forests are vulnerable to climate change, due to the longevity of trees and the expected climate change within their lifespan. Through its impact on forest growth and decomposition of organic matter in the soil, climate change will affect both long-term wood supply and carbon sequestration in trees, forest soils and wood products.

The central objective of a newly started EU-funded project “Long-term regional effects of climate change on European forests: impact assessment and consequences for carbon budgets” - shortly LTEEF-II - is to assess climate change impacts on European forests with respect to water and carbon fluxes, regional differences, long-term effects, and the overall carbon budget for forests in Europe. The effects of environmental changes on physiological processes and the seasonal pattern of growth rates will be quantified and integrated at the forest level as well as at the regional level over long time periods.

Regional differences in climate change

The impacts of climate change are likely to differ between regions. By comparing effects for characteristic forest types in Europe it will be possible to assess the large-scale consequences of climate change on forest resources, carbon sequestration and the feedback resulting from vegetation-atmosphere interactions. Boreal, temperate and Mediterranean regions will be characterised individually, as there are regional differences in climate change over Europe that can be quantified using the current generation of global circulation models, and because the growth of the various forest types differs due to climatic factors such as temperature in Northern Europe and water availability in Southern Europe. For each region, a limited number of forest types will be characterised by main tree species and the most important climatic

factors affecting forest growth. Selected process-based models for each region will be used for the evaluation of forest growth and responses to climate change.

Carbon storage capacity of the European forests assessed

Upscaling from the regional to the European scale will be carried out to provide a dynamic overall carbon budget for European forests and in order to quantify the current and potential carbon storage. The upscaling will be based on national forest inventory data and results from process-based models in a large scale forestry model, as well as on remote sensing data which will be used as input data in models capable of estimating gross primary productivity, net primary productivity and net ecosystem gas exchange.

This project will provide new information on the role of European forests in the global carbon balance. Information on the future carbon sequestration capacity of European forests will be valuable also in terms of the commitments made in Kyoto in December 1997 on reducing greenhouse gas emissions.

The LTEEF-II project is coordinated by Dr. Frits Mohren, from the Institute for Forestry and Nature Research (IBN-DLO), Wageningen, the Netherlands. There are altogether 14 partners from 9 countries in the project, which started in January 1998 and will last until June 2000. The project has also links to other European projects such as ECOCRAFT and EUROFLUX.

Project participants

The 14 participating institutes in the LTEEF-II project (ENV4-CT97-0577) out of nine EU countries are:

Institute for Forestry and Nature Research (IBN-DLO), Wageningen, the Netherlands
Dept. di Prod. Vegetale, Univ. Basilicata (DPV-UNIBAS), Potenza, Italy
Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany
Institute of Terrestrial Ecology (NERC-ITE), Penicuick, United Kingdom
Institute of Ecology and Resource Management (UEDIN), Edinburgh, United Kingdom
Centre de Recerca Ecològica i Aplicacions Forestals (CREAF), Barcelona, Spain
Faculty of Forestry, University of Joensuu (JOY), Finland
Department of Forest Ecology, Helsinki University (UHE), Finland
Bayreuth Inst. For Terrestial Ecosystem Research (BITÖK), Bayreuth, Germany
Dept. Of Forest Production Ecology (SLU), Uppsala, Sweden
Institut National de la Recherche Agronomique (INRA), Bordeaux, France
European Forest Institute (EFI), Joensuu, Finland
Univ. della Tuscia (UNITUS), Viterbo, Italy
Flemish Institute for Technological Research (VITO), Mol, Belgium

Long-term effects of whole-tree harvesting on carbon pools in coniferous forest soils

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ABSTRACT

Results from Swedish field experiments and ecosystem modeling on the effects of whole-tree harvesting on soil carbon pools are presented and discussed. Soil inventories on 8 field experiments where whole-tree harvesting were made at clear-felling or at thinnings give no support to the hypothesis that whole-tree harvesting leads to reductions in soil carbon pools. Nor is there strong support from field experiments for the hypothesis that whole-tree harvesting reduces the litter production from the next forest generation or ground vegetation. A model of a spruce forest ecosystem predicted that harvesting of logging residues is likely to have a relatively small impact on soil carbon pools. Some research needs were identified.
Key-words: clear-felling, logging residues, Q-model, Sweden, thinnings.

INTRODUCTION

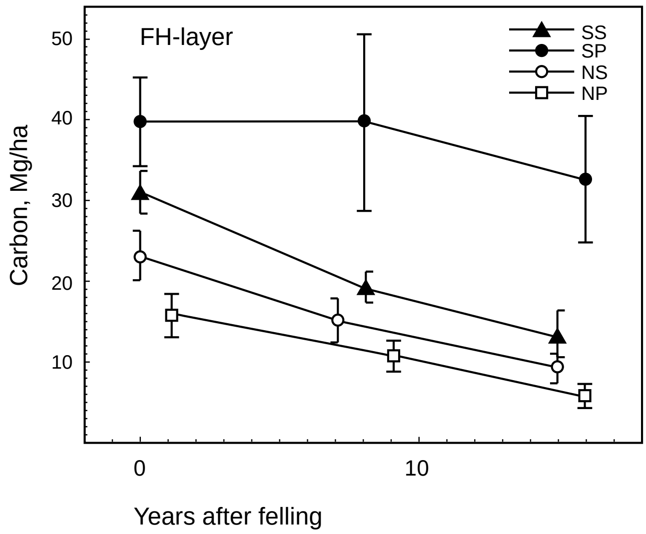
The aim of this paper is to present results from Swedish field experiments and ecosystem modeling on the effects of whole-tree harvesting on soil carbon pools. A second aim is to identify research needs and opportunities for making a closer connection between field studies and modeling.

FINDINGS FROM SWEDISH LONG-TERM FIELD EXPERIMENTS

A retrospective study comparing the effects of whole-tree and conventional harvesting at clear-fellings was made on four sites in Sweden with Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.), representing different climates and site fertility levels (Olsson et al. 1996). Three treatments were applied on all sites in a randomized block design (n=4): (i) conventional stem-only harvesting, with all slash left, (ii) stems and branches harvested, with needles allowed to fall off before branches were removed, and (iii) whole-tree harvesting, with no above-ground tree biomass left on site.

No significant effect of harvesting intensity was detected on soil carbon pools 15 to 16 years after felling; however, there was an overall decrease across treatments in carbon content in the organic soil horizon, caused by the clear-felling (Fig. 1). On the other hand, the carbon content of the mineral soil (0-20 cm) had increased since harvesting on three sites, but this change was of lower magnitude than the carbon loss in the organic horizon. Thus, a net decrease in soil carbon stores of the investigated horizons was detected. One possible source of error is that only scattered parts of the woody debris in the forest floor were included in the soil sampling; thus, it is possible that differences in soil carbon pools between treatments were missed. We estimated that a difference on the order of 20% was necessary to detect a difference between means ($P < 0.05$).

Figure 1. Changes in amounts of carbon (Mg ha^{-1}) in the humus (FH) layer over the 15-16 year period after harvesting in four experiments on whole-tree harvesting in Sweden. Mean values and standard deviation are given for each site across all three treatments (n=12). SS, southern Norway spruce; SP, southern Scots pine; NS, northern Norway spruce; NP, northern Scots pine. From Olsson et al. 1996, Forest Ecology and Management, Elsevier Science B.V.



Other Swedish field studies have been established to compare the effects of whole-tree and conventional harvesting at thinnings. Bengtsson, Lundkvist and Olsson (unpubl.) found no effects of slash harvesting on a 30-year-old productive Norway spruce site in southwestern Sweden, where the harvesting treatments were made at clear-felling and on three thinnings. On two Scots pine sites in the boreal zone, no significant reduction in soil carbon amounts was found 10 years after single-slash harvesting at thinning. On one fertile Norway spruce site in southern Sweden, no effects of whole-tree thinnings repeated three times over 12 years have been detected. Thus, soil inventories on Swedish field experiments give no support to the hypothesis that whole-tree harvesting leads to reductions in soil carbon pools (Olsson and Lundkvist unpubl.).

Litter production in field experiments

Harvesting of logging residues can affect soil carbon pools in several ways. Apart from the direct removal of carbon with the harvested biomass, dynamic effects can be expected to occur from the lowered litter fall caused by reductions in site productivity. The role of the ground vegetation for litter production is indicated by its above-ground biomass. Olsson and Staaf (1995) studied the ground vegetation of the four sites investigated by Olsson et al. (1996), and although logging residues had an influence on the species abundance of the ground vegetation community approximately 8 and 16 years after clear-felling, there were no effects on above-ground biomass.

Needle litter fall has been monitored on stands aged 16 years on one Norway spruce site with whole-tree and conventional harvesting in southwestern Sweden (Olsson and Lundkvist unpubl.). Annual litter fall has increased from approximately 100 to 150 g C m^{-2} over 7 years, but no statistically significant difference in accumulated litter fall between treatments has been detected. However, on average, litter fall appears to be approximately 10% higher in treatments with all slash or only needles left on site, and this trend corresponds to differences in stem increment between treatments (Egnell and Leijon in press). Thus, there is no strong support from field experiments for the hypothesis that harvesting of logging residues leads to reductions in the litter production from the next forest generation.

MODEL PREDICTIONS

Bengtsson and Wikström (1993) used the Q-model, based on the theories of Ågren and Bosatta (1996), to estimate the influence of harvesting intensity on soil carbon pools in two Norway spruce stands of differing productivity. They analyzed three management regimes: (i) conventional stem-only harvesting at clear-felling and thinnings, (ii) whole-tree harvesting (above-ground) at clear-felling and thinnings, and (iii) clear-felling without harvesting. The model predicted that total soil carbon pools would instantly increase after clear-felling for all harvesting regimes. This peak resulted from considering the below-ground biomass and other tree parts as dead organic matter after felling. The soil carbon pools declined thereafter but at different rates. In the management regime where no biomass was extracted, total soil carbon pools declined markedly less rapidly than in stem-only or whole-tree harvesting. In the long run, whole-tree harvesting resulted in carbon pools in soils being 5% to 10% less than they were with stem-only harvesting, whereas in the no-harvest regime, carbon pools were about twice those from conventional harvesting. The overall trend over 200 years and 1-2 rotations was an increased soil carbon content with the no-harvest regime but decreased carbon pools where stems or all above-ground biomass were harvested. Thus, retention of stem biomass would have the most profound influence on the long-term carbon pools. This conclusion was also drawn by Ågren and Bosatta (1987) from theoretical analyses of decomposition. Since the links between carbon and nitrogen in the model are strong, it can express long-term dynamic effects caused by changes in nutrient availability. However, the model did not consider potential indirect effects (such as mulching effects of slash). Furthermore, the model was restricted to nitrogen-limited growth of trees, and carbon allocation in trees was expressed in a relatively insensitive way.

These restrictions of the model may not, however, be very important for its ability to accurately depict long-term consequences of whole-tree harvesting. A central question is how the theories of the model describing plant growth (the nitrogen productivity concept) and decomposition (the continuous-quality theory) fit the empirical data. The greatest problem is probably predicting long-term decomposition from short-term data (the litter-bag technique). In the model used by Bengtsson and Wikström (1993), litter decomposition eventually leads to complete mineralization of carbon; however, in coniferous forests soils, there is a stabilized carbon fraction that mineralizes extremely slowly or not at all. This property of the model probably leads to over-estimation of carbon losses from the soil, including the “old soil”, which was created by the model prior to modeling the effects of various management regimes.

The problems connected with predicting long-term soil carbon storage from short-term information was analyzed by Hyvönen et al. (1998). The idea was that small errors in the extrapolation from short-term information could propagate and become very large in the long run, assuming a continuous input of litter to the soil. The processes that had to be quantified most accurately were those regulating the interaction between soil organic matter and soil texture and those regulating the change in the quality of the soil organic matter during decomposition.

In another study, Hyvönen, Olsson, Lundkvist and Staaf (unpubl.) analyzed decomposition of logging residues and the release of nitrogen and phosphorous. The study was based on decomposition data on green needles, twigs, and branches from Scots pine and Norway spruce incubated on clear-fellings. Compared with the decomposition equations used in the model by Bengtsson and Wikström (1993), mass loss rates in advanced stages of decomposition are more retarded. According to our analysis, harvesting of needles will have very small direct effects on soil carbon pools, especially since this fraction decomposes rapidly. The branch and twig material of the slash make up 60% to 70% of the logging residues, and since it decomposes more slowly than the needles, its long-term impact is greater. On the Norway spruce site, 2% to 5% of the initial carbon content in the logging residues was predicted to remain after 100 years. This amount corresponds to approximately 1% of the total carbon storage found in the soil (humus and mineral soil from 0 to 20 cm) at clear-felling. Compared with the model results of Bengtsson and Wikström (1993), the reduction in total soil carbon pools due to slash harvesting would be lower in relative terms. This suggests that dynamic effects (that is, changes in site productivity) were a major component in the difference between whole-tree and conventional harvesting found by Bengtsson and Wikström (1993). Thus, if this alternative parameter setting of the decomposition equations is implemented in the model, the predicted effects of slash harvesting on soil carbon pools will probably be different. In addition, the model will also generate different responses with different external nitrogen inputs.

INTERACTIONS BETWEEN MODELING AND EMPIRICAL STUDIES

Validation of predictions from ecosystem models over the long term is, at best, difficult and is mostly impossible. Owing to the simple and mechanistic structure of the Q-model, it is best used as a tool for analyzing the dynamic behavior of ecosystems. In future applications of the model, it will be necessary to identify how differences in soil carbon pools are created from different management regimes. Those properties of the model could possibly be distinguished even in existing field experiments (0-30 years). For example, if dynamic effects are most important, they may be observed as changes in litter fall, tree growth, or the amount of nitrogen in the foliage. Fine root turnover and decomposition of root litter may also be important.

The role of various addition rates of the limiting nutrient (here, nitrogen) is also of great interest since the model is built to create strong links between carbon and nitrogen. Incorporating nitrogen addition rates is also a highly relevant way to relate the model to ecosystems with various rates of nitrogen deposition.

Finally, no thorough field studies have been conducted in Sweden on the physical effects of logging residues on the soil. An influence of logging residues on the soil temperature and moisture regimes would potentially have an effect on the mineralization of soil organic matter.

CONCLUSIONS - RESEARCH NEEDS

New field experiments should be established to investigate the indirect, physical effects of logging residues on the soil temperature and on moisture regimes.

In existing field experiments comparing harvesting regimes, soil carbon inventories should include all dead organic matter in the forest floor and should include deeper soil horizons than have been previously investigated. Investigations of the forest generation in existing field studies should include litter fall, biomass, and nutrient content in order to make it possible to compare empirical data with results from the model. Measurements of below-ground biomass decomposition and turnover should be made.

It is important to identify the mechanisms in the Q-model that tend to produce large effects of harvesting logging residues on the soil carbon storage.

ACKNOWLEDGEMENTS

The National Swedish Board for Industrial and Technical Development (NUTEK) provided financial support.

REFERENCES

ÅGREN, G. and BOSATTA, E. 1987. Theoretical analysis of the long-term dynamics of carbon and nitrogen in soils. *Ecology*, 68:1181-1189.

ÅGREN, G. and BOSATTA, E. 1996. Theoretical Ecosystem Ecology. Cambridge University Press, Cambridge, 234 pp. ISBN 0 521 58022 6.

BENGTSSON, J., and WIKSTRÖM, F. 1993. Effects of whole-tree harvesting on the amount of soil carbon: model results. *New Zealand Journal of Forestry Science*, 23:380-389.

HYVÖNEN, R., ÅGREN, G.I. and BOSATTA, E. 1998. Predicting long-term soil carbon storage from short-term information. *Soil Science Society of America Journal*, 62:xx-xx.

OLSSON, B.A. and STAAF, H. 1995. Influence of harvesting logging residues on ground vegetation in coniferous forests. *Journal of Applied Ecology*, 32: 640-654.

OLSSON, B.A., STAAF, H., LUNDKVIST, H., BENGTSSON, J. and ROSÉN, K. 1996. Carbon and nitrogen in coniferous forest soils after clear-felling and harvests of different intensity. *Forest Ecology and Management*, 82: 19-32.

Whole-tree harvesting - effects on the N budget of forest soils in Sweden

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EXTENDED ABSTRACT

N accumulation in Swedish forest soils

At present, C and N pools in Swedish forest soils are probably increasing. An early comparison between the first and second run of the National Soil and Vegetation Inventory indicated that an average increase in the order of a hundred kg N ha^{-1} yr^{-1} (large uncertainty) has occurred over the last decade (Eriksson, 1996). The antropogenic N deposition is likely a major explanation for this increase, since addition of N increases litterfall production rates as well as reduces decomposition rates. Other contributing factors may be various changes in land-use practices over the last century, such as improved forest fire prevention, decreased shifting cultivation, decreased forest grazing, etc.

Ecological effects of Nitrogen deposition

In Sweden, present nitrogen (N) deposition rates varies from c. 25 kg N ha^{-1} yr^{-1} in the south-west to 3 kg N ha^{-1} yr^{-1} in the north (Lövblad et al., 1992). A positive effect of the deposition is that in N limited ecosystems, i. e. most boreal forests on non-peaty soils, forest production increases in relation to the increased availability of N for the trees. There are strong indicies of a general increase in site productivity in Sweden. For example, the second generation of spruce produced significantly more than the first generation, which was planted on a former Calluna heath in SW Sweden (Eriksson and Johansson, 1993).

However, several negative effects for the environment are caused or enhanced by N deposition of antropogenic origin. An increased availability of N in N limited forest ecosystems changes the species composition of field vegetation. In SW Sweden, large-scale changes that can be partly or totally explained by increased N availability have occurred; nitrophilic grasses have become more frequent at the expense of Vaccinium species since the 70’s (Rosén et al., 1992). Normally, there are little nitrate leaching from sites with growing forest. However, after fertilization, increased losses of N through leaching were apparant after clear-cutting (Nohrstedt et al., 1994; Berdén et al., 1997). These results showed that the degree of N mineralisation after clear-cutting is dependent on the amount of N added to the site. Moreover, in areas receiving the highest rates of N deposition (c. 25-30 kg N ha^{-1} yr^{-1}), also forested sites have been found to loose nitrogen through leaching, one site at about the same rates as the deposition (Nohrstedt et al., 1996). Increased leaching of nitrate enhances the consumption of buffer capacity in the soil, i. e. acidifies the soil, and eutrophy recipient seawaters.

The turnover and leaching of nitrogen is normally reduced at a clearcut site when harvest residues have been extracted (cf Lundborg, 1997). The removal of nitrogen is two to three times higher at whole-tree harvest than at stemwood harvest (Rosén, 1991b). Piles of residues have been shown to create beneficial environments for decomposition, and thus nitrification (Rosén and Lundmark-Thelin, 1986). Staaf and Olsson (1994) showed increased nitrate and potassium losses after residues were left compared to where they were removed.

Critical load of N

The critical load of an element or a substance is normally defined as the maximum deposition level at which undesired environmental effects can be avoided also in a long-term perspective (Rosén et al., 1992). For Swedish conditions, it has been suggested the critical load is exceeded either when annual leaching exceed an average concentration of 0.3 mg N dm^{-3} in runoff waters or the soil pool build-up is higher than 0.5 kg N ha^{-1} yr^{-1}, which is considered as an upper limit for long-term immobilization (Rosén et al. 1991). The N amount used to reach a certain average N concentration in the runoff water depends on the general water balance of the site. Denitrification and N fixation are considered insignificant in typic Swedish forest soils (Rosén and Lindberg, 1980; Rosén et al, 1991). Thus, the critical load of N deposition at a specific site depends on the water balance and the amounts of N removed at harvesting.

Effects of whole-tree harvesting on the N budget

A basic prerequsite for the concept of using intensified harvest as a N load reducing measure is that NO_x-N emissions are lower than the amount of N removed from the forest. In case the biomass is combusted in a furnace with modern cleaning equipment attached to it, the NO_x emissions will amount to about 10 % of the N content of the fuel (Burström and Johansson, 1995). Such cleaning equipment is attached to the furnaces which combust a major part of the residues extracted in Sweden.

The effects of whole-tree harvesting on the N budget were thoroughly discussed by Lundborg (1997). These effects were related to the N load situation at three sites in different regions of Sweden. She concluded, the value of the critical load becomes much higher if harvest residues are removed in comparison with when they are left at site.

Vinterbäck et al. (1998) used a growth model for whole-tree production (BIOSIMS) and improved knowledge about variation of N contents in stems, branches and canopy to quantify the potential N harvest for the whole forest area of Sweden. A function for calculation of the N content in the biomass removed at harvesting was included in the model, which then was applied to c. 27 000 plots of the data base of the National Forest Inventory. Data from a geographical data base on water balance was used for calculating critical loads at various harvest intensities for all sites. An N deposition data base from the Swedish Environmental Research Institute was used to compare the deposition levels with the critical loads achieved for each county. The results showed that for a site with average site productivity for the region, the N budget would overbalance in the southern half of Sweden and underbalance in the northern half of Sweden if whole-tree harvesting is used in all thinnings and at clear-cutting. The higher the site productivity level is, the higher is the potential critical loadIf stemwood harvesting is used, N deposition exceeds the critical load at over 90 % of the forest area of Sweden. In case an adapted harvest intensity is applied, a balanced N budget could be reached on about 50 % of the forest area.

REFERENCES

BERDÉN, M., NILSSON, S. I., and NYMAN, P. 1997. Ion leaching before and after clear-cutting in a Norway spruce stand - Effects of long-term application of ammonium nitrate and superphosphate. *Water, Air and Soil Poll. 93*:1-26.

BURSTRÖM, F. and JOHANSSON, J. 1995. Skogsbränsle minskar kvävebelastningen - Beräkningar av kväveflöden (The nitrogen load is reduced by forest fuels - Calculations of nitrogen fluxes), Report from Vattenfall Utvecling No 1995/3, Project Bioenergy, Vattenfall, Stockholm. ISSN 1100-5130.

ERIKSSON, H. M. 1996. Skogsbruket och växthusgaserna (Forestry and the greenhouse gases). In: ”Skogen i kretsloppen - nya steg mot en hållbar utveckling”, Report from the Forest Conference, Uppsala 5-6 dec 1995, Fakta Skog Konferens Nr 2:48-54, SLU Kontakt, Uppsala. ISSN 1101-8305.

ERIKSSON, H. and JOHANSSON, U. 1993. Yields of Norway spruce (Picea abies (L.) Karst.) in two consecutive rotations in southwestern Sweden. *Plant and Soil 154*:239-247.

LÖVBLAD, G., AMANN, M., ANDERSEN, B., HOVMAND, M., JOFFRE, S., and PEDERSEN, U. 1992. Deposition of sulfur and nitrogen in the Nordic countries: Present and future. *AMBIO 21*:339-347.

LUNDBORG, A. 1997. Reducing the nitrogen load: whole tree harvesting. A literature review. *AMBIO 26(6)*:387-393.

NOHRSTEDT, H.-Ö., RING, E., KLEMEDTSSON, L., and NILSSON, Å. 1994. Nitrogen losses and soil water acidity after clear-felling of fertilized experimental plots in a Pinus sylvestris stand. *For. Ecol. and Manage. 66*:69-86.

NOHRSTEDT, H.-Ö., SIKSTRÖM, U., RING, E., NÄSHOLM, T., HÖGBERG, P., and PERSSON, T. 1996. Nitrate in soil water in three Norway spruce stands in southwest Sweden as related to N-deposition and soil, stand, and foliage properties. *Can. J. For. Res. 26*:836-848.

ROSÉN, K. 1991a. Kritiska belastningsgränser för kväve i skogsmark (Critical load for nitrogen in forests). Skogsfakta nr. 17, 1991. Sveriges lantbruksuniversitet, Uppsala.

ROSÉN, K. 1991b. Skörd av skogsbränslen i slutavverkning och gallring - ekologiska effekter. (Residue harvest at clear-cutting and thinning - ecological effects). Skogsstyrelsen Meddelande nr. 5 - 1991.

ROSÉN, K. and LINDBERG, T. 1980. Biological nitrogen fixation in coniferous forest watershed areas in Central Sweden. *Holarctic Ecology 3*:137-140.

ROSÉN, K. and LUNDMARK-THELIN, A. 1987. Increased nitrogen leaching under piles of slash - a consequence of modern forest harvesting techniques. *Scand. J. For. Res.2*:21-29.

ROSÉN, K., GUNDERSEN, P., TEGNHAMMAR, L., JOHANSSON, M., and FROGNER, T. 1992. Nitrogen enrichment of nordic forest ecosystems - The concept of critical loads. *Ambio 21*:364-368.

STAAF, H. and OLSSON, B. A. 1994. Effects of slash removal and stump harvesting on soil water chemistry in a clear-cutting in SW Sweden. *Scand. J. For. Res. 9*:305-310.

VINTERBÄCK, J., PARIKKA, M., HEKTOR, B., and ERIKSSON, H. 1998. Kväveavlastning genom uttag av trädbränslen - en kvantitativ analys (Reducing the nitrogen load by extration of forest fuels - A quantitative analyses). Vattenfall Rapport 1998/2. ISSN 1100-5130.

Forestry, climate change and carbon in soils

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EXTENDED ABSTRACT

The soil of forests contains much more carbon than the vegetation (Post et al., 1982). For this reason, even relatively small changes in the soil C storage affect the C balance of forests significantly.

The C balance of soil depends on the rates litter production and decomposition (Fig. 1). These processes determine respectively C input to soil and output from soil. Forest management actions, such as harvesting, soil preparation, regeneration and fertilization, affect both these processes and may thus either increase or decrease the soil C storage (Johnson, 1992). Similarly, climatic changes affect both litter production and decomposition (Kirschbaum, 1996). The consequent change in the soil C storage depends on how these processes change relative to each other.

The changes in the soil C storage in response to forest management and climatic changes are not reliably known especially due to difficulties in measuring soil C. The changes in the soil C storage during years and decades are expected to be proportionally small, maybe some ten percent (Olsson et al., 1996, Liski et al., 1998a) (Fig. 2). On the other hand, the spatial variation in the amount of soil C is large at any forest site; the amount commonly varies 3-5 fold even within a few meters (Liski, 1995) (Fig. 3). It is thus very difficult, if not impossible, to detect the proportionally small temporal changes in the soil C storage by repeated measurements (Fig. 4).

In models, soil C is divided for several pools having different dynamic properties (see, e.g., Powlson et al., 1996). This division determines how the models predict the dynamics of soil C. These pools cannot, however, be measured separately (Christensen, 1996). This adds uncertainty in the model predictions. Furthermore, the response to environmental changes is only known for the pools changing most quickly which represent only a few percent of the whole soil C storage (Liski et al., 1998b). It is common to assume that this response is similar for the rest of the soil C storage too, although this is not necessarily the case. Recent studies suggest that the decomposition of old soil organic matter is far less temperature sensitive than the decomposition of young litter and rather regulated by soil properties other than temperature (Trumbore et al., 1996, Liski et al., 1998).

It seems that our knowledge on the changes in the soil C storage would be most efficiently improved by developing soil C measurements and collecting more comprehensive data on soil C. Still, it seems necessary to develop and commonly accept other means for detecting changes

in the soil C storage than direct measurements in order to account for soil like vegetation in the considerations of the C balance of forests.

FIGURES

Figure 1. The cycling of C between atmosphere, vegetation, soil. The arrows represent C flows and the valve symbolizes the processes regulating the flows.

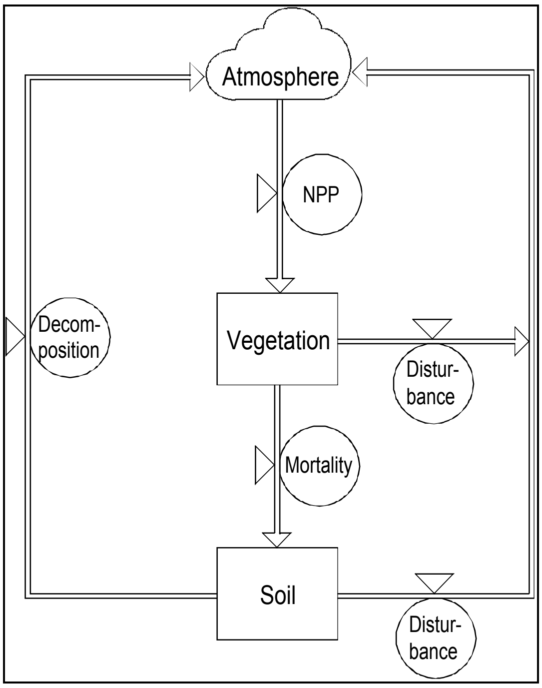


Figure 2. The simulated effect of forest harvesting on the amount of soil C at a Scots pine stand in southern Finland (Liski et al. 1998). The lines show the development of the amount of soil C in the different age classes as written above each line.

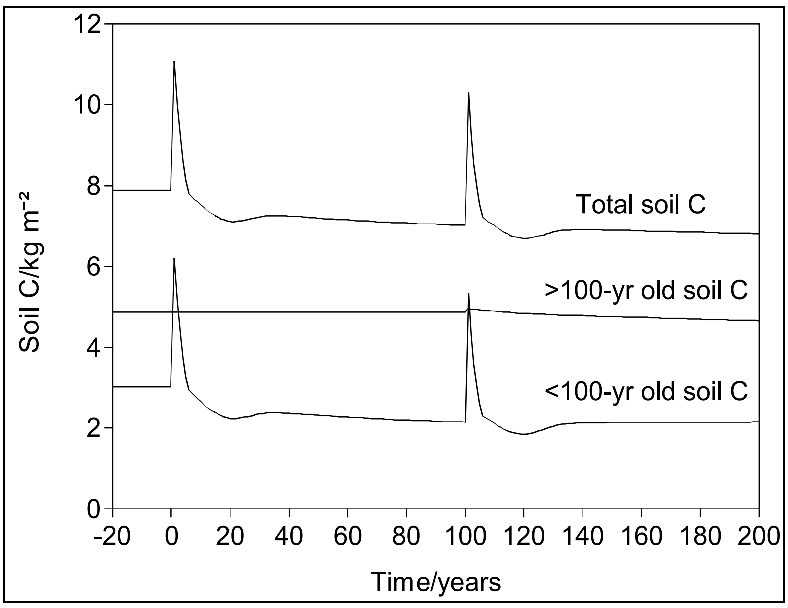
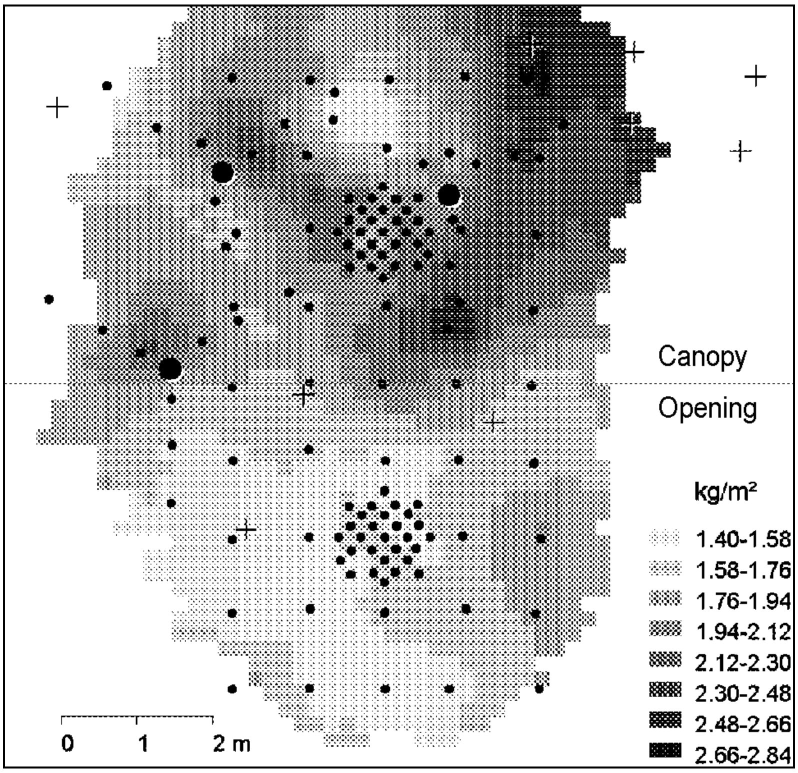


Figure 3. Spatial variation in the C density (kg m^{-2}) of the organic F/H soil layer at a mature Scots pine site in southern Finland (Liski, 1995). a) An interpolated map of the C density with soil samples indicated by the small dots, trees by the large dots and stumps by the crosses. b) Frequency distribution of the C density of the samples (n=127).



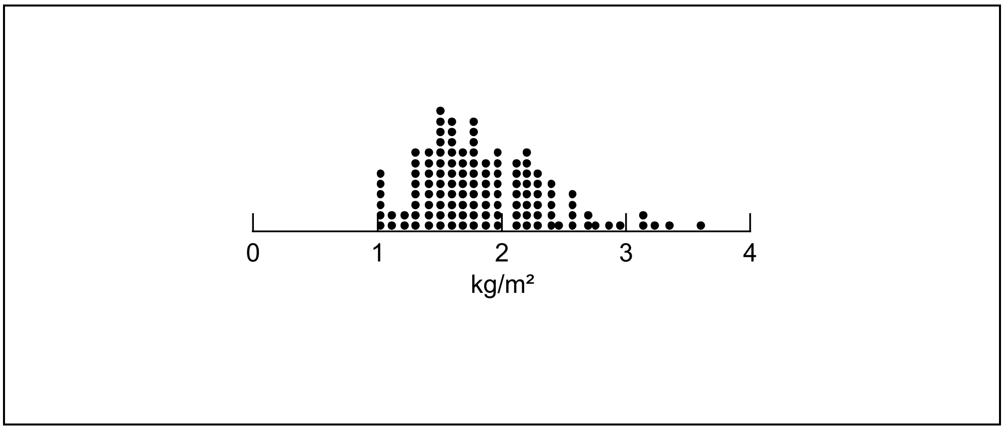
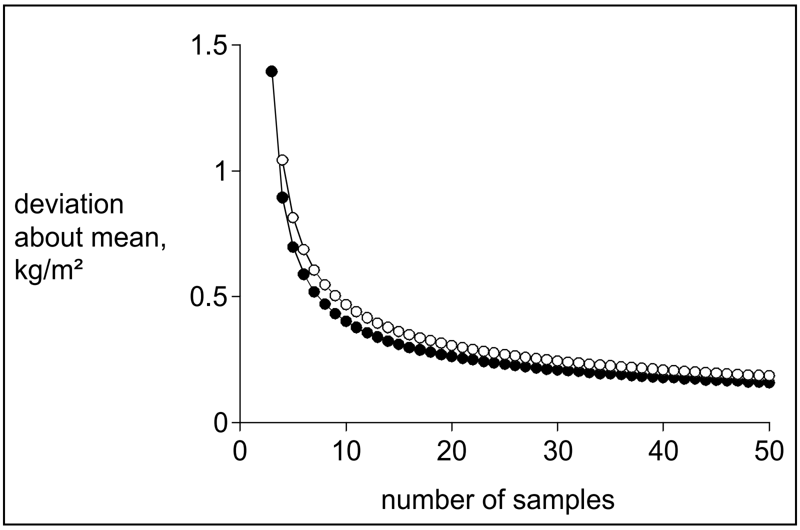


Figure 4. The 95% confidence limits for the mean estimate of the C density in the organic F/H layer (sample mean 1.86 kg m^{-2}) and 0-40 cm mineral soil layer (sample mean 2.64 kg m^{-2}) as a function of the number of samples at the same Scots pine site as in Fig. 3.



REFERENCES

CHRISTENSEN, B. T. 1996. Matching measurable soil organic matter fractions with conceptual pools in simulation models of carbon turnover: Revision of model structure. In: *Evaluation of Soil Organic Matter Models using Existing Long-term Datasets* (eds POWLSON, D.S., SMITH, P., SMITH, J.U.), Springer-Verlag, Berlin. pp. 143-159.

JOHNSON, D. W.1992. Effects of forest management on soil carbon storage. *Water Air and Soil Pollution 64:* 83-120.

KIRSCHBAUM, M. U. F. 1996. Ecophysiological, ecological, and soil processes in terrestrial ecosystems: a promer on general concepts and relationships. In: *Climate Change 1995, Impacts, Adaptations and Mitigation of Climate Change: Scientific-technical Analyses* (eds WATSON, R.T., ZINYOWERA, M.C., MOSS, R.H., DOKKEN, D.J.), Cambridge University Press. pp. 57-74.

LISKI, J. 1995. Variation in soil organic carbon and thickness of soil horizons within boreal forest stand - effect of trees and implications for sampling. *Silva Fennica* 29(4): 255-266.

LISKI, J., ILVESNIEMI, H., MÄKELÄ, A., and STARR, M. 1998a. Model analysis of the effects of soil age, fires and harvesting on the carbon storage of boreal forest soils. *European Journal of Soil Science 49(3):* 407-416.

LISKI, J., ILVESNIEMI, H., MÄKELÄ, A., and WESTMAN, C. J. 1998b. CO2 emissions from soil in response to climatic warming are overestimated - the decomposition of old soil organic matter is tolerant of temperature. *Ambio* (accepted for publication).

OLSSON, B. A., STAAF, H., LUNDKVIST, H., BENGTSSON, J., and ROSEN, K. 1995. Carbon and nitrogen in coniferous forest soils after clear-felling and harvests of different intensity. *Forest Ecology and Management 82:* 19-32.

POST, W. M., EMANUEL, W. R., ZINKE, P. J., and STANGENBERGER, A. G. 1982. Soil carbon pools and world life zones. *Nature 298:* 156-159.

POWLSON, D. S., SMITH, P., and SMITH, J. U. (eds) 1996. *Evaluation of Soil Organic Matter Models using Existing Long-term Datasets*, Springer-Verlag, Berlin.

TRUMBORE, S. E., CHADWICK, O. A., and AMUNDSON, R. 1996. Rapid exchange between soil carbon and atmosphere driven by temperature change. *Science 272:* 393-396.

Role of forestry and biomass production for energy in reducing the net GHG emissions in Finland. Assessment concerning the history and future

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EXTENDED ABSTRACT

The carbon storage of the trees and surface vegetation of the Finnish forest ecosystem is about 700 Tg C (700 billion tons of C). This is about 140 Mg (tons) C per capita of the Finnish population. The carbon storage of the products in use manufactured from the woody raw material from the Finnish forests is estimated to be about 5 % of the carbon storage of the tree biomass. More than half of this carbon storage in the products is outside of Finland, in the countries where the products of the Finnish forest industry are exported (Pingoud et al., 1996).

Currently the growth of the managed forests in Finland is greater than the cuttings, causing a carbon sink, i.e. a net accumulation of carbon in the forest ecosystem. The carbon sink in the forest ecosystem peaked around 1990 and has declined somewhat since that mainly due to increasing cuttings, but in 1995 it was still considerable, about 14 million tons of CO_2. The future sink will depend on the behavior of cuttings and growth. The considerable carbon sink in the managed forests is not, however, accounted for by the Kyoto Protocol, as it limits the consideration to afforestation and reforestation only, and not to the increase of the amount of carbon on a fixed area of managed forests.

The use of bioenergy has always been important in Finland. In fact the absolute amount of bioenergy used in Finland has been roughly constant over at least 60 years. During this time period, however, the total use of energy has grown about six-fold. Presently the share of bioenergy of total primary energy consumption is about 17 %. This consists of the use of pulping liquors, industrial wood and waste, and firewood. In the 1990s the industrial components of bioenergy use have increased.

When the greenhouse gas emission control possibilities before 2010 are considered, increased use of bioenergy and energy conservation are likely to be the main options. The real development will probably consist of many other factors, like a strong increase of the use of natural gas, overall improvement of the efficiency of energy production and to some minor extent of increased use of wind energy (Lehtilä et al., 1998).

The forest ecosystems can be utilized for many purposes: as a source of raw material for industry, as a source of bioenergy, and as a carbon sink in combating climate change. Furthermore, it serves many other purposes like recreation, and can be considered to have an intrinsic value. In certain cases one of the alternative uses of the forest ecosystem can overlap others to some extent, but easily an increase in one alternative cuts down other alternatives.

Figure 1. Estimated carbon stocks (Tg C) and flows (Tg C /a) of the Finnish forest sector in 1990 (Pingoud et al., 1996, updated numbers; Mineral soil: Liski and Westman, 1996).

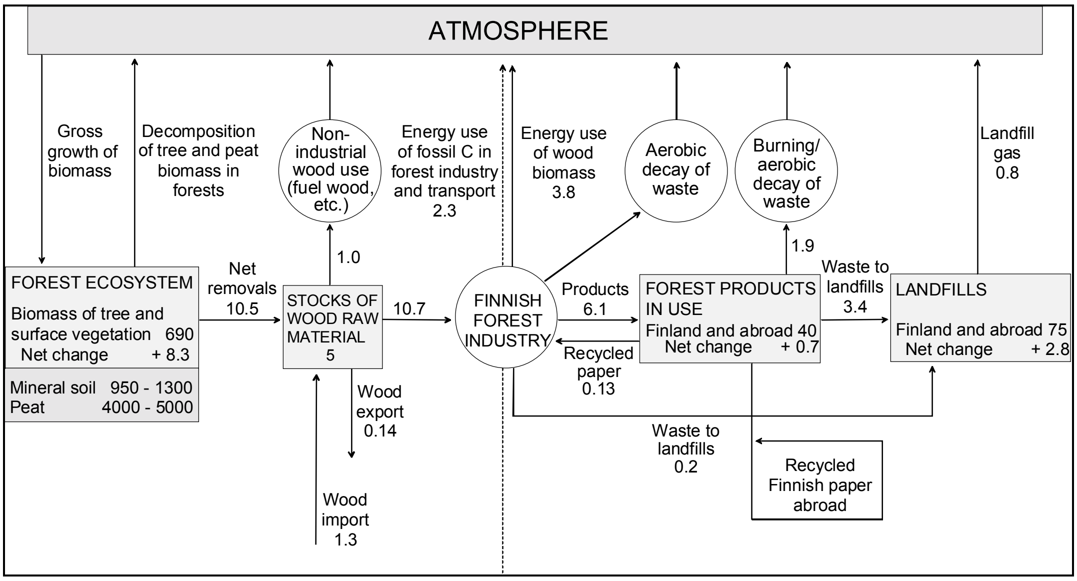


Figure 2. Estimated development of the carbon stocks in the Finnish forest sector from 1920 (Pingoud, 1997). Left vertical axis: forest stock, right vertical axis: other stocks

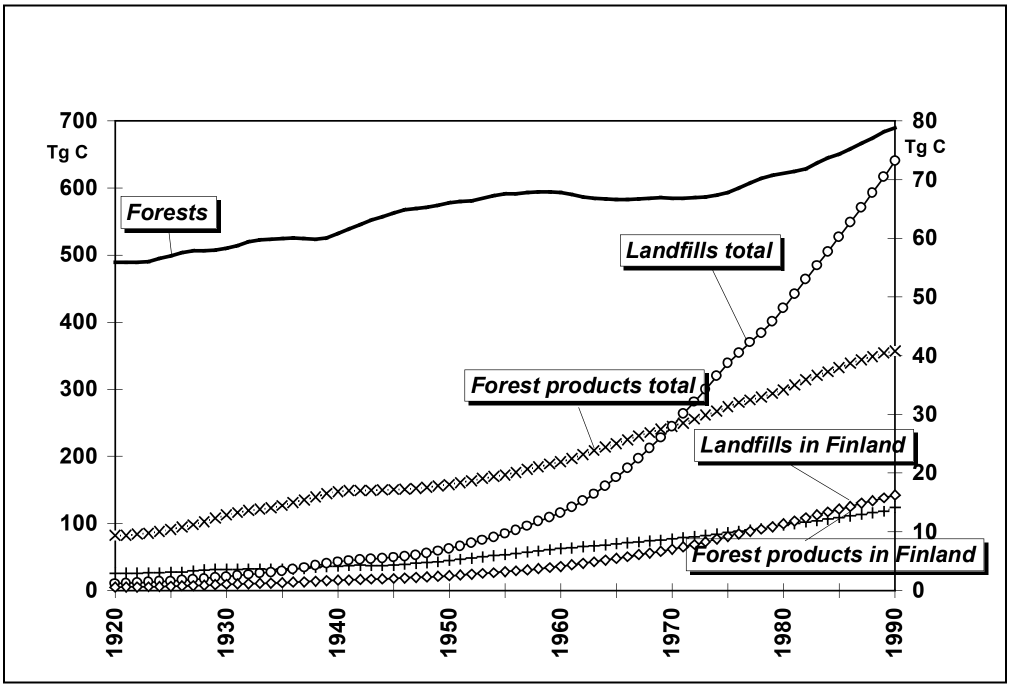


Table 1. Carbon stocks (1990) of the forest product sector and their average net change rates per year (1980-1990) (Pingoud, 1998, unpublished data).

	Carbon stock Tg C	Net change of stock Tg C /a
Roundwood stocks of the forest industry		
Stocks of felled roundwood of the forest industries	4.7	
Forest products in use and in landfills		
FINLAND		
Forest products in use		
Wood products (timber, panels etc.)		
In buildings	**10.7**	**0.20** *
In other structures	2	0.04
Short term use	0	0.00
Subtotal	*13*	*0.24*
Pulp, paper and paperboard	0.35	0.01
SUBTOTAL (forest products in Finland)	***13***	***0.25***
Forest products and wood waste in landfills		
Wood and pulp waste from forest industries	4	0.13
Wood waste from consumption		
From house building	4.7	0.15
From other structures & short term use	4.3	0.12
Paper- and paperboard waste from consumption	2.9	0.09
SUBTOTAL (landfills in Finland)	***16***	***0.5***
EXPORT MARKETS		
Forest products in use		
Wood products (timber, panels etc.)	23	0.4
Pulp, paper and paperboard	3.7	0.09
SUBTOTAL (forest products in the export markets)	***26***	***0.5***
Forest products and wood waste in landfills		
Wood waste from consumption	15	0.3
Paper- and paperboard waste from consumption	42	1.7
SUBTOTAL (landfills in the export markets)	***57***	***2.0***
TOTAL, forest products in use	***39***	***0.8***
TOTAL, forest products and wood waste in landfills	***73***	***2.5***
TOTAL, forest products/waste in use and in landfills	***110***	***3.2***

*estimate based on direct stock inventory

Figure 3. The history of the primary energy consumption in Finland (Energy Statistics, Statistics Finland).

Peatlands in Finland

Original area	10.4 Mha
• Natural peatlands	4.4 Mha
• Drained for forestry	5.3 Mha
• Drained for agriculture	0.7 Mha

Recent results concerning their global warming impacts (Laine et al. 1998)**:**

Emissions (Gg/a)	CO_2	CH_4	Total CO_2-eqv (500 a)*
Natural peatlands	- 4000	700	+0
Drained peatlands	-15000	150	-14000

* GWP (CH_4, 500 a) = 6.5

Drainage has decreased the CH_4 emissions by about 800 Gg CH_4 /a = 5000 Gg CO_2 -eqv /a = 5 Mt CO_2-eqv /a

Figure 4. The history of the primary energy consumption in Finland (Energy Statistics, Statistics Finland).

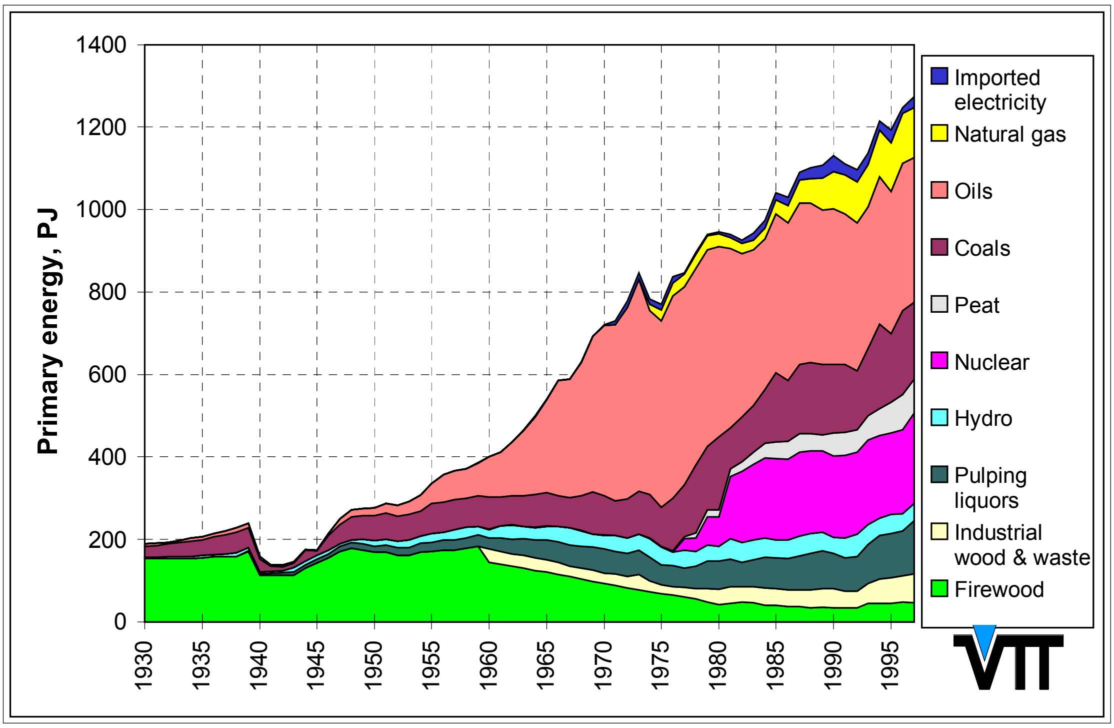


Figure 5. Share of renewable energy sources of total primary energy consumption in selected countries (Lehtilä et al., 1997).

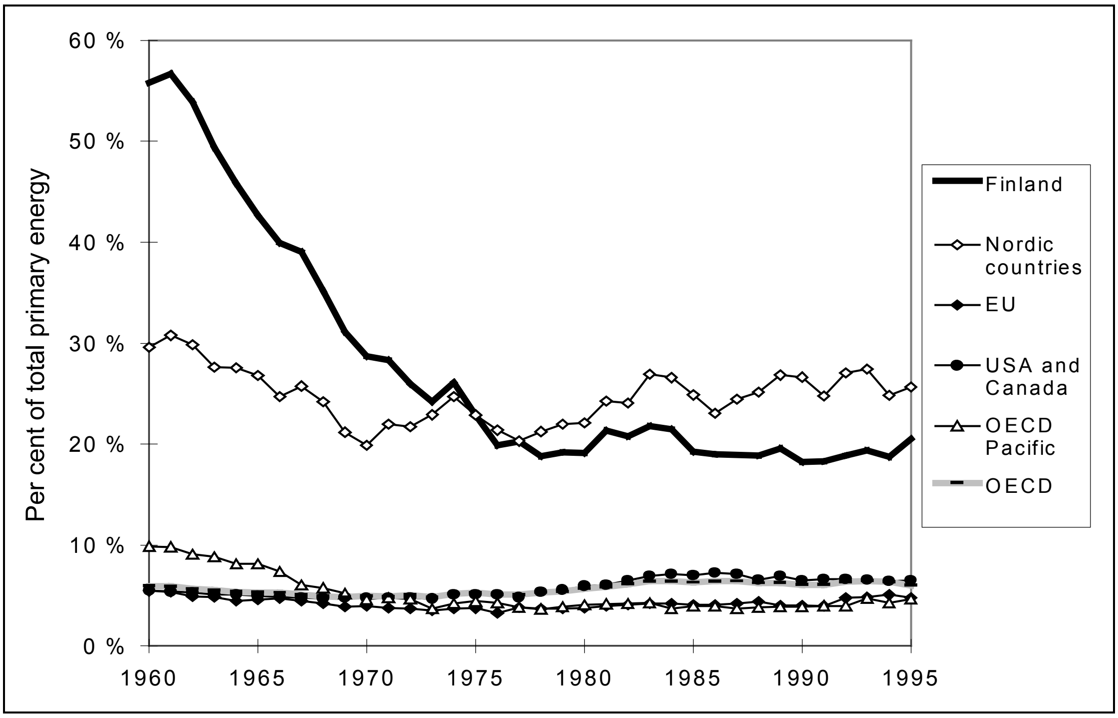


Figure 6. Share of bioenergy of total primary energy and of electricity generation in selected countries in the year 1995 (IEA, 1997).

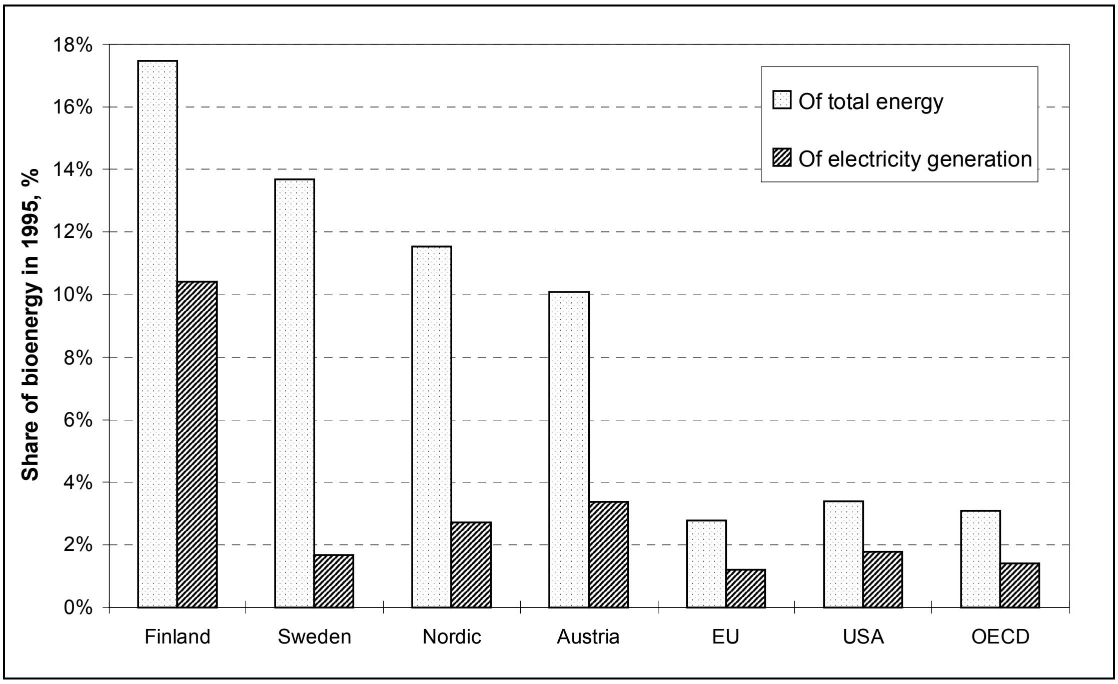
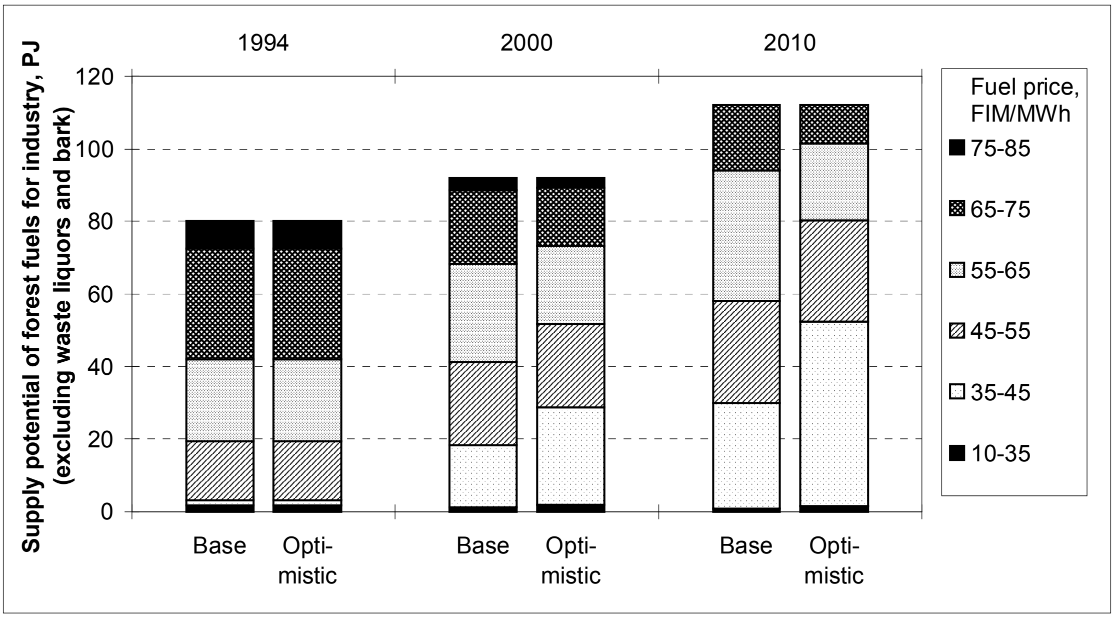


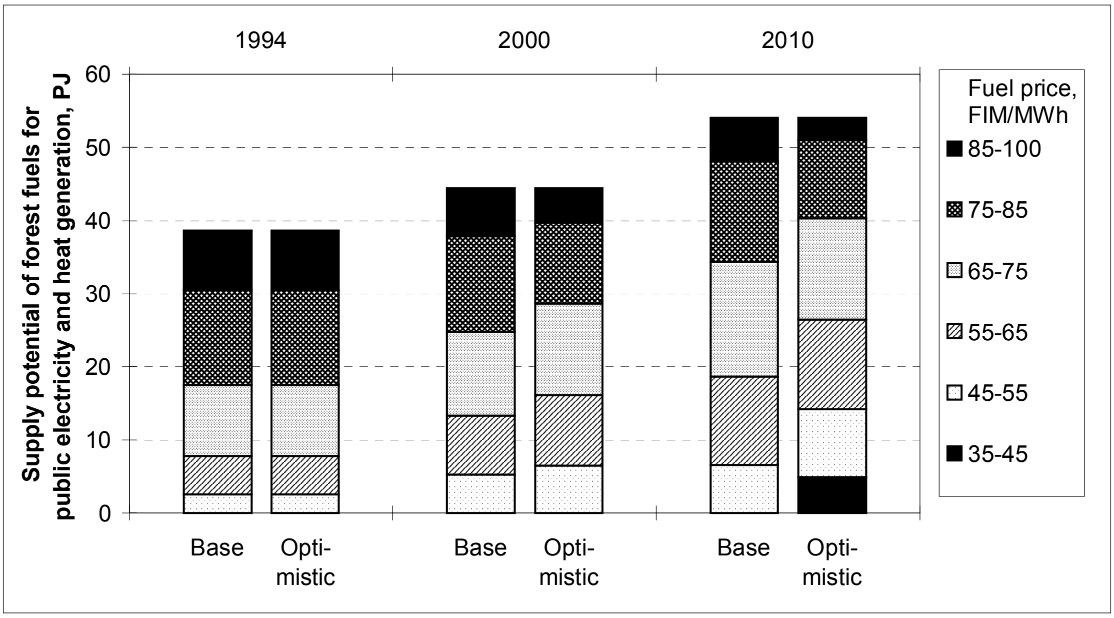
Table 2. Production potential of biomass in Finland (Pingoud and Lehtilä, 1997).

	Resources	Consumption in 1994		Technical potential in 2010
	(Sustainable) PJ/a	Energy use PJ/a	Non-energy PJ/a	Energy use PJ/a
WOOD BIOMASS				
Traditional firewood		34		34
Harvested wood	550	0	220	90
Harvesting residues	410	1		30
Byproduct wood from wood industries		43		55
Waste liquors from pulping		104		135
Total wood biomass	**960**	**182**	**220**	**345**
AGRICULTURAL BIOMASS				
Agricultural crops	30	0		18
Coppices (SRC)	15	0		5
Straw	15	0		7
Total crops	**60**	**0**		**30**
MUNICIPAL REFUSE, CONSTRUCTION & DEMOLITION WASTE				
Municipal solid waste	40	0.8		18
Construction waste	8	1.8		4
Biogas	3	0.3		2
Total refuse	**50**	**3**		**24**
BIOMASS TOTAL	**1070**	**185**		**400**

Figure 7. Supply potential and cost distribution of forest fuels (Lehtilä, 1998; unpublished estimates).



Projections for the supply potential and cost distribution of forest fuels for industrial heat and power generation in Finland (price level 1994).



Projections for the supply potential and cost distribution of forest fuels for district heating and public electricity generation in Finland (price level 1994).

Figure 8. Main energy and material flows and sectors in the calculation model (EFOM-ENV) (Lehtilä et al., 1998).

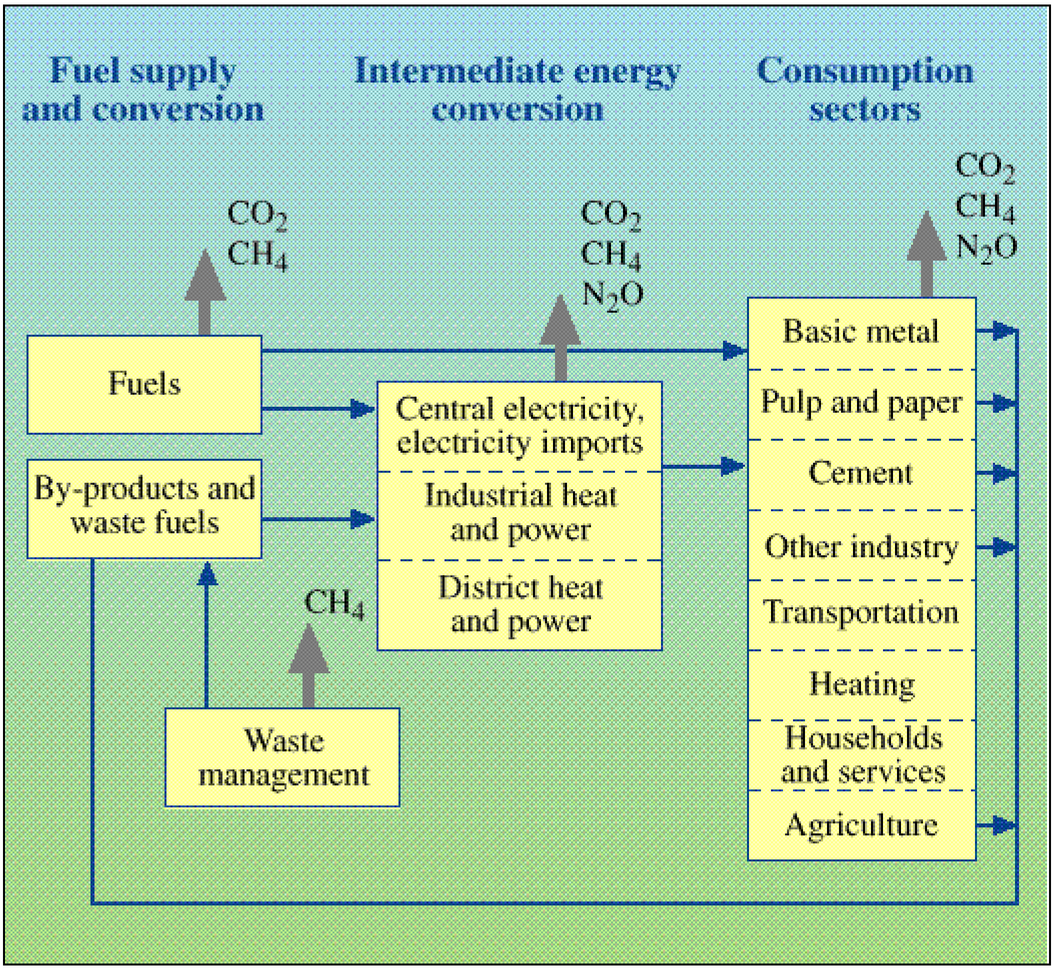


Figure 9. Cost-effective emission reduction scenarios for (a) CO_2, (b) CH_4 and (c) N_2O (Lehtilä et al., 1998):
1) Reference = baseline scenario,
2) Reduction of CO_2 only to the 1990 level by 2008-2012,
3) Reduction of the gas basket (CO_2, CH_4, N_2O) GWP to the 1990 level by 2008-2012.

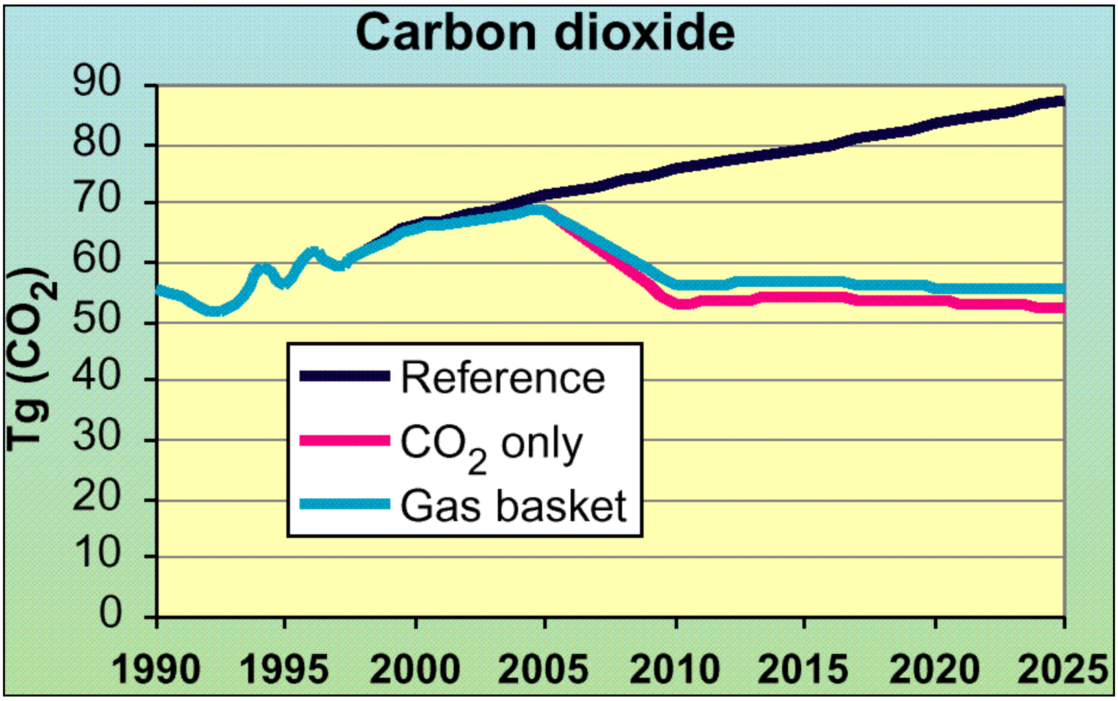


Figure 9a.

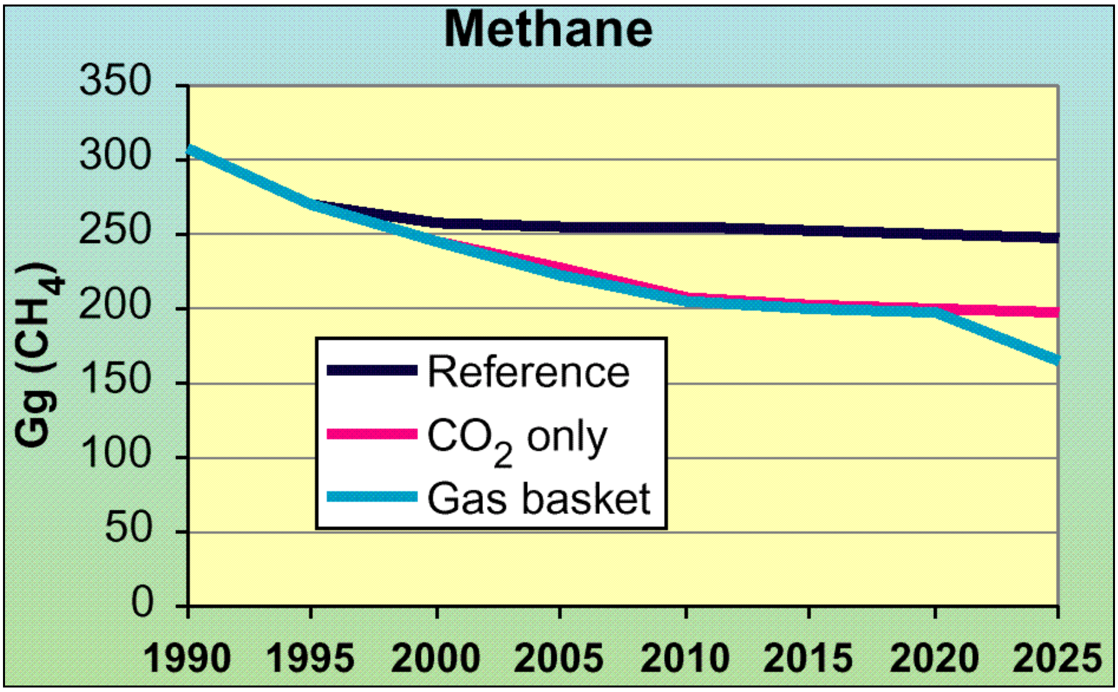


Figure 9b.

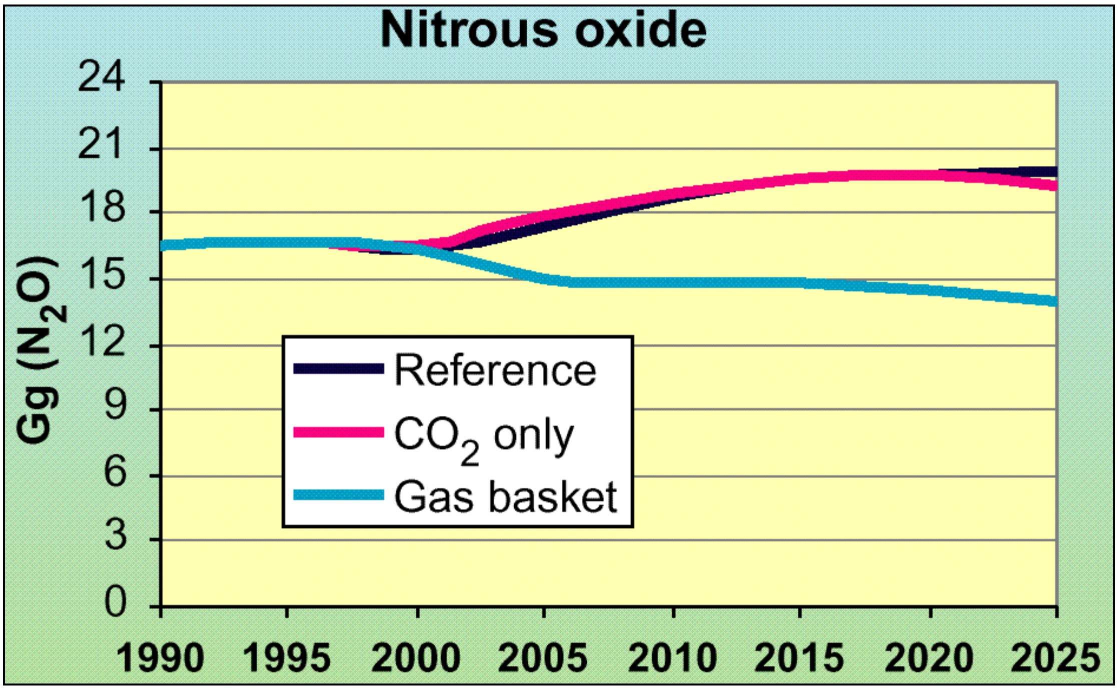


Figure 9c.

Figure 10. Annual reduction costs of the CO_2 and gas basket scenarios (Lehtilä et al., 1998).

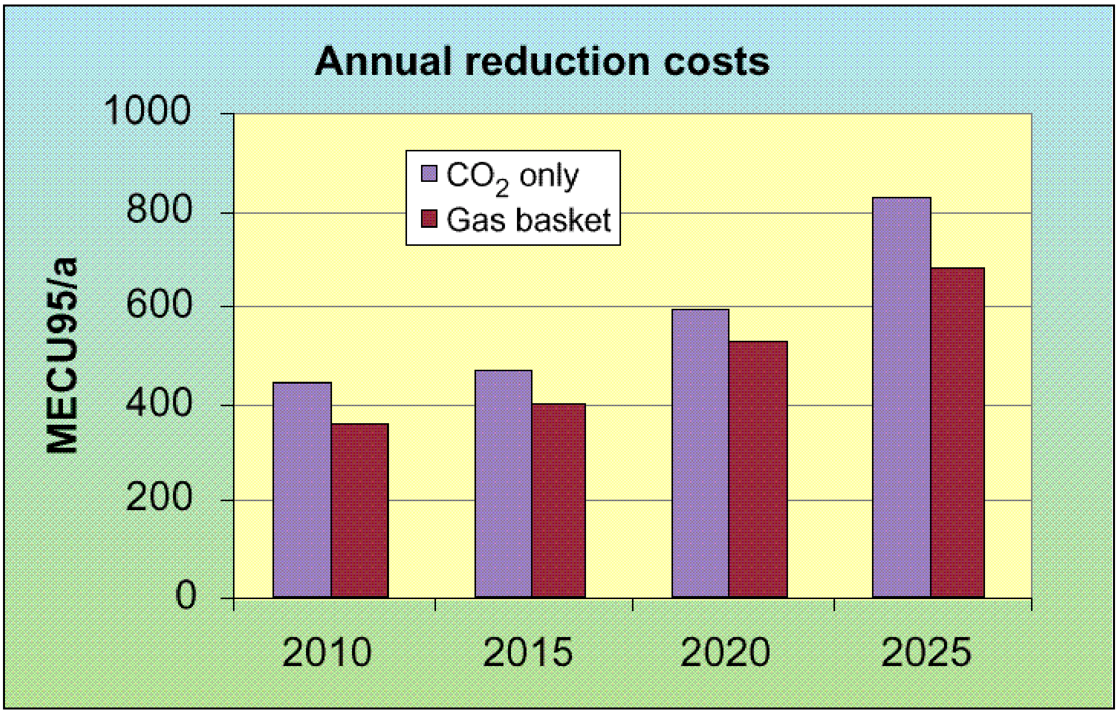
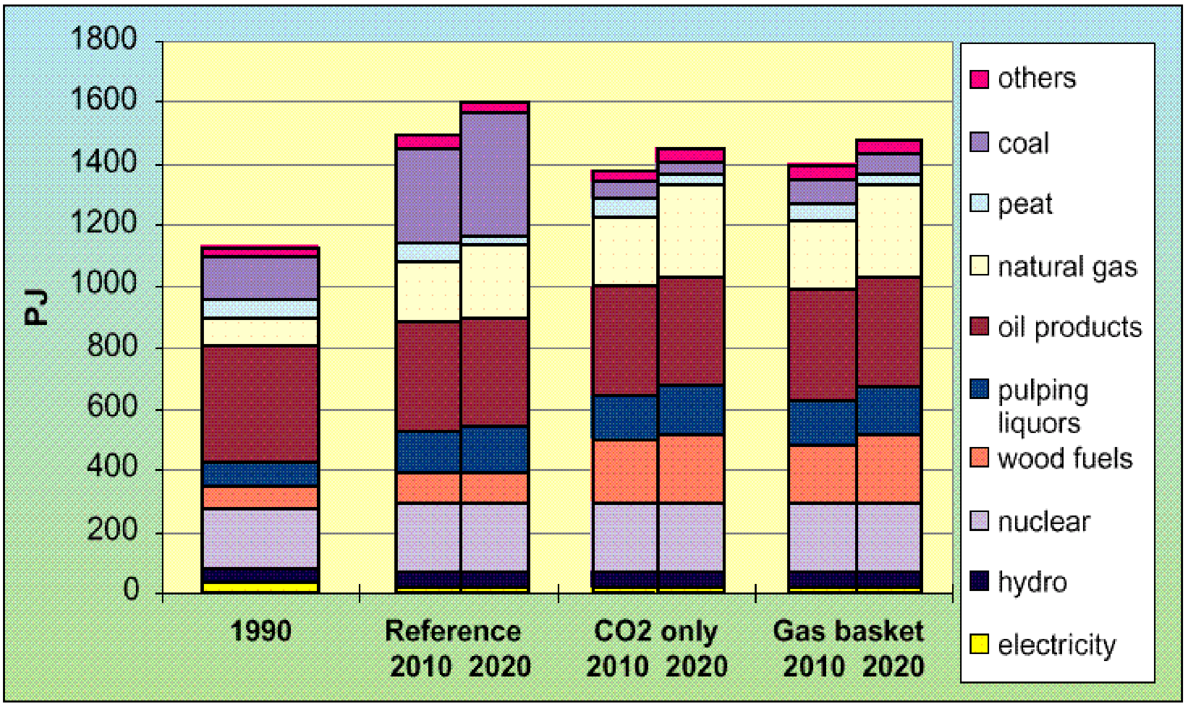


Figure 11. Impact of the scenarios on the primary energy supply in Finland (Lehtilä et al., 1998).



REFERENCES

IEA (1997). Electricity Information 1996. Paris: International Energy Agency, OECD. 688 p.

LAINE, J.K., SELIN, P. and NYRÖNEN, T. 1998. The role of peat and peat utilization in carbon balance, Peat memorandum 12.5.1998

LEHTILÄ. A., SAVOLAINEN, I. and TUHKANEN, S. 1997. Indicators of CO_2 emissions and energy efficiency. Comparison of Finland with other countries. Espoo 1997, Technical Research Centre of Finland, VTT Publications 328. 80 p. + app. 31 p.

LEHTILÄ, A., TUHKANEN, S. and SAVOLAINEN, I. 1998. Cost-effective reduction of CO_2, CH_4 and N_2O emissions in Finland. 4th International Conference on Greenhouse Gas Control Technologies, Interlaken, Switzerland, 30th August – 2nd September 1998.

LISKI J. and WESTMAN, C.-J. 1996. Carbon storage in forest soil of Finland, 2. Size and regional patterns. *Biogeochemistry* 36(3), pp. 261-274.

PINGOUD, K. 1997. The carbon balance of the Finnish forest sector and its greenhouse impact. History, present situation and future scenarios (in Finnish). In: Climate Policy and Finland (eds. Savolainen, I., Haaparanta, P. and Järvelä). Taloustieto 1997. pp. 35-57.

PINGOUD, K. and Lehtilä 1997. A. Role of forest products and bioenergy in limiting the carbon emissions of Finland. *Biomass and Bioenergy,* Vol. 13, No.6, pp. 413 - 420, 1997.

PINGOUD, K., Savolainen, I. and Seppälä H. 1996. Greenhouse impact of the Finnish forest sector including forest products and waste management. *Ambio*, Vol.25, No. 5, pp 318 - 326, August 1996.

Greenhouse gases emissions and possibilities for eeduction using biomass for energy in Croatia

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ABSTRACT

Combustion of fossil fuels is the main cause for the build-up of the CO_2 in the earth's atmosphere. Additional emissions come from changes in land use, mainly deforestation.
This paper deals with evaluation of bioenergy systems contribution in fulfilling obligations from Kyoto for Croatia. Emissions are calculated for various biomass energy scenarios in Croatia to the year 2030. These results are a part of analysis carried out within BIOEN Program activities and work on recently published document "The Energy Strategy of the Republic of Croatia".

The given results indicate that bioenergy systems have significant, so far not fully exploited, yet limited possibilities to reduce GHG emissions and help achieving Kyoto targets.

Key words: Biomass, Energy, Greenhouse gases, Kyoto

INTRODUCTION

The Republic of Croatia signed Framework Convention on Climate Change as well as Annex 1, committed itself to reduce emissions of GHG gases for 5% in comparison with base year (UNFCCC, 1992). According to Article 3 Kyoto Protocol, Croatia has, as a country in transition, opportunity to chose a base year between year 1985 and 1990 or an average of this period (UNFCCC, 1997).

Greenhouse gases emission in Croatia is relatively low if compared with other European countries. In 1990, energy sector has a share in GHG emission of 55% (according to CORINAIR methodology). For very low emission and expected development, Croatia might have difficulties in fulfilling obligations from Kyoto protocol. Energy production from biomass offers opportunities to mitigate the rise of CO_2 emission.

This paper deals with contribution of bioenergy systems in achieving Kyoto targets for Croatia according to recently published document “The Energy Strategy of the Republic of Croatia” (Graniæ, 1998). Under completion is The First National Communication for UNFCCC convention, in which a more detailed survey of the biomass use will be given in even more details.

ENERGY BALANCE AND EMISSIONS

Total primary energy supply in Croatia in 1996 increased sharply by 10.8 per cent. The consumption of almost all forms of energy increased, and a decrease was recorded only in the use of coal and import of electricity (Table 1). Bioenergy contributes with 4,6 per cent in 1996 in total energy supply. Fuelwood and wood waste from wood industry are the most important biomass resources (Vuk, 1997). It may be noted the difference in fuelwood and primary energy consumption Croatia and some other European countries is given (Table 2 – Dessus, 1998).

Biomass is being used by the rural population in a large scale for heating and cooking in all Croatian regions. In sawmills, pulp mills and all wood processing industries, residues are being made and then used for energy purposes. Other sector with significant biomass utilisation is agriculture, especially in grain dryer. There are only two small CHP plants with electricity generation from biomass and a few very small biogas fired heating plant.

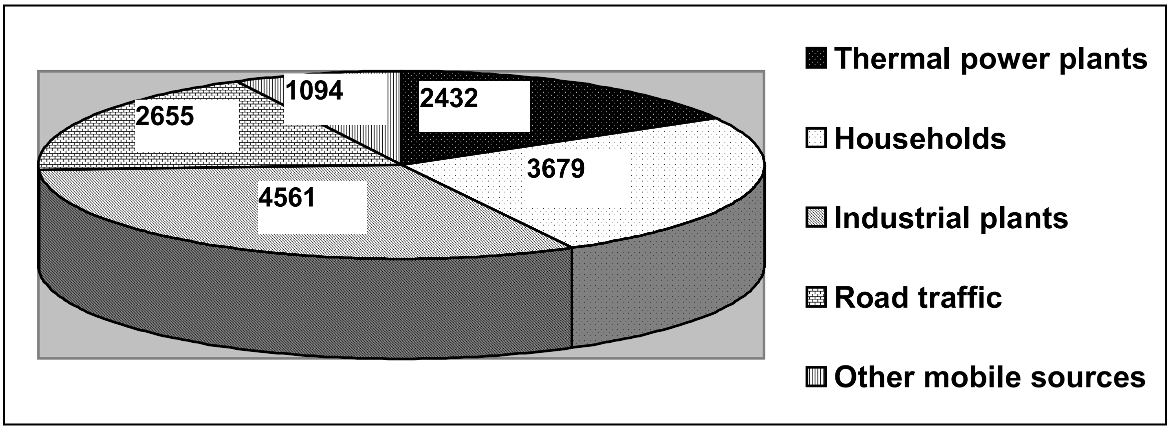
Table 1. Total primary energy supply in Croatia in PJ (1994-1996)

	1994	1995	1996
Coal	9,26	7,42	6,19
Biomass	13,06	13,52	16,14
Liquid Fuels	132,53	146,03	153,92
Natural Gas	93,27	86,93	97,60
Hydro Power	49,12	51,75	70,33
Electricity	12,83	12,59	8,39
TOTAL	310,08	318,23	352,56

Table 2. Comparison between fuelwood use in Croatia and some other countries

Country	Primary energy consumption in TWh and per capita	Fuelwood consumption in TWh and per capita
Austria	321 / 39,86	30 / 3,73
Croatia	98 / 21,85	5 / 1,12
Finland	359 / 70,41	24 / 4,71
France	2782 / 49,14	107 / 1,89
Portugal	210 / 21,23	18 / 1,82
Sweden	610 / 69,20	40 / 4,53

Figure 1. Total CO_2 emission in Gg/yr. in Croatia and the share of the energy sector in 1996



The full implementation of the Ordinance on emission registar, which require the detailed emission report for all power plants with output greater than 100 kW, as well as the structure of fuel consumption in installations with output up to 100 kW. Total CO_2 emissions in Croatia as well as the share of the energy sector in the emissions are given in Figure 1. The energy sector accounts for 90,8% of CO_2 emissions. The emissions of CO_2 from Croatian power plants are relatively low if compared with other countries due to significant utilisation of hydro and nuclear power in electricity generation. The share of thermal power plants in electricity generation ranged between 18 and 38 % in the period 1990-1996. Structure of GHG emitted from energy sector in Croatia is given in Figure 1. In 1996 CO_2 emission per capita was 3,7 Mg/year which is almost the lowest in Europe.

The inventory of emitted air pollutants has been carried out in Croatia since 1990. The emissions are calculated according to the methodology defined by the international European project CORINAIR (Co-Ordinated Information System Air Pollutants). That means that emission from biofuels is also being taken into account, which is different from IPCC methodology. Emission calculation according to the IPCC methodology, which include emission sources and sinks, is under completion. Presuming that the emission caused by the biomass use equals zero, (according to the IPCC methodology), substitution of mixed fossil fuels with the biomass has resulted with the 4,2 % of CO_2 decrease in 1996.

ENERGY SCENARIOS AND BIOMASS USE

The Energy Strategy of the Republic of Croatia has considered three different scenarios. First of them (S-421, “low”) was based on slow introduction of advanced technologies and does not include any governmental support. Second scenario (S-422, “moderate”) includes stronger concerted policy for introduction of new technologies, use of renewables and increasing energy efficiency. Finally, third scenario (S-423, “high”) is “very environmental” scenario and comprises that problem with pollution and greenhouse effects will significantly affect energy policy in Croatia already in 2010.

All scenarios have the same rate of economical growth, economy structure and number of consumers, but not the same consumption rate. The main differences are in level of governmental support which influence the use of renewables, dynamics of advanced technologies penetration and care for energy efficiency. Unlike other renewables, bioenergy has significant position in all scenarios. This is due to long tradition and experience of biomass use in Croatia as well as large biomass potential. The principal parameters of the scenarios related to biomass use are: current and additional biomass resources, potential user sectors, assessment of the energy demand, and assumption on the type of energies per sector abandoned in favour of bioenergy. The scenarios differ most significantly in the structure of different technologies for biomass utilisation, in the electricity generation from biomass and in the penetration of biofuels in transport (Figures 2-4).

Figure 2. Scenarios for heat production from biomass in Croatia

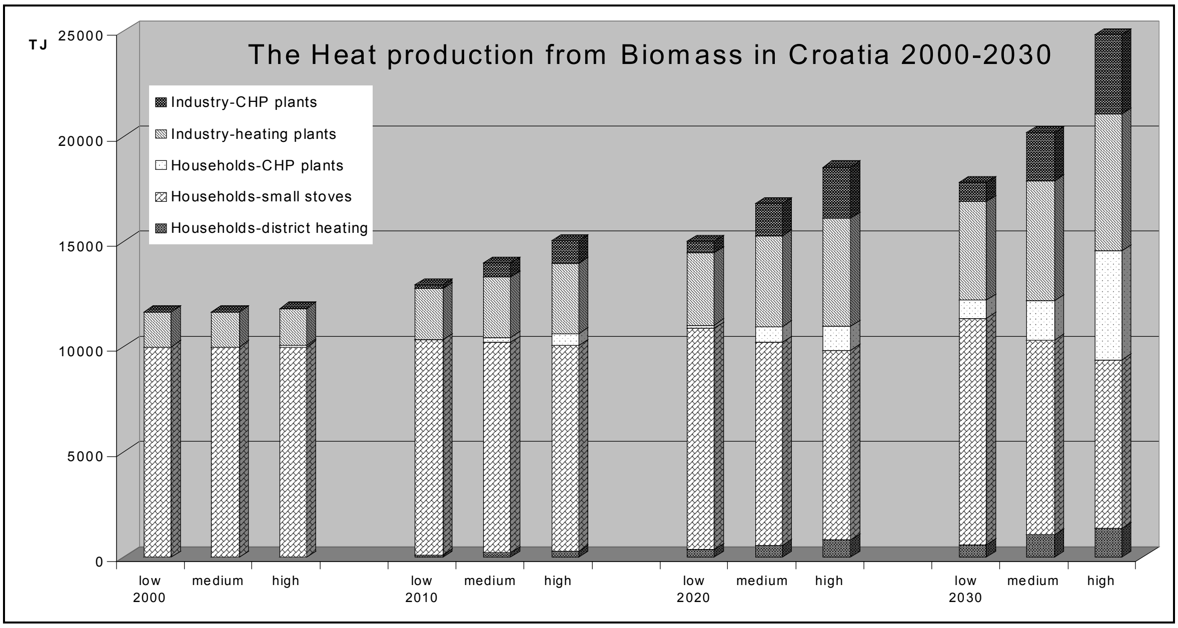


Figure 3. Scenarios for electricity production from biomass in Croatia

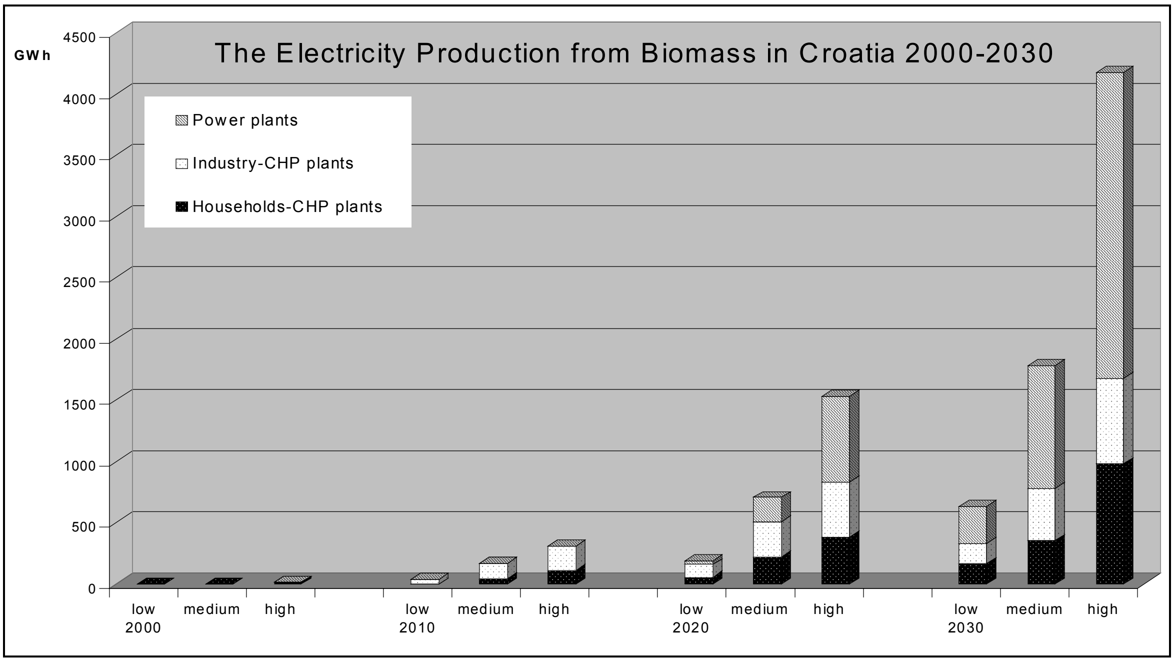
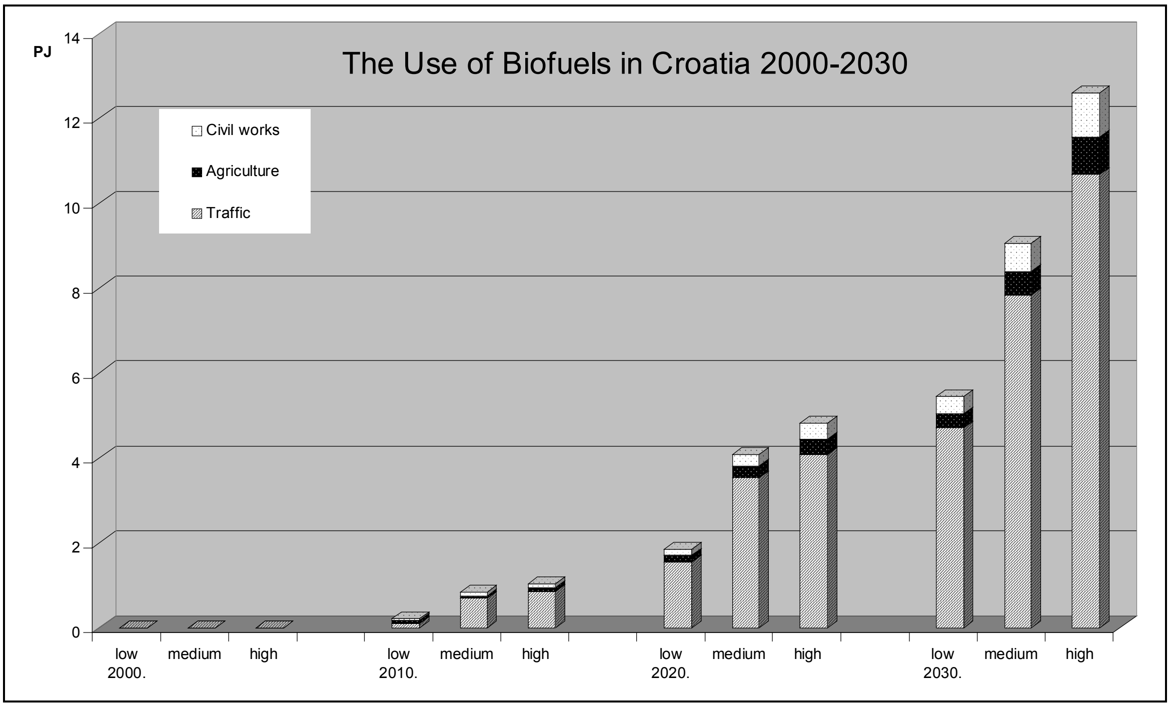


Figure 4. Scenarios for biofuels penetration in Croatia



Estimation of bioenergy potential and energy production was carried out within BIOEN program activities (Domac, 1998). The BIOEN Program (Biomass and Waste Use Program) was launched in March 1997 as one of the ten national energy programs in Croatia.

CONTRIBUTION OF BIOENERGY SYSTEMS IN ACHIEVING KYOTO TARGETS FOR CROATIA

In all analysed scenarios CO_2 emissions in 2010 is higher then obliged emission level from Kyoto protocol for 11-24 per cent (Figure 5). However, the CO_2 emission per capita in Croatia for all scenarios is lower then in majority of the developed European countries and also lower than emissions in other countries in transition.

Biomass as an energy source was regarded as “CO_2 neutral” in all scenarios. Total cycle of biomass use results with net emission of GHG due to biofuels preparation, transport and other activities caused by the use of fossil fuels (mostly diesel oil). As first attempt, during the calculations it is estimated that the net emission from bioenergy systems is comparatively negligible to overall national emission, and may be omitted. Moreover, examples can be given when bioenergy systems is not just CO_2 neutral. Croatian forests are net sinks for carbon, because harvest level is lower than carbon uptake via tree growth. Besides, Croatian forests have relatively high growth rate from 8,9 millions m^3, and forest areas are in constant increase. It may be noted that 44 per cent of the area of Croatia is covered by forests.

Detailed calculation of net GHG emission from bioenergy systems were only made for a few examples within BIOEN Program activities, but net GHG emissions from bioenergy systems will be the subject of constant interest in BIOEN Program, as well as for future energy policy in the Republic of Croatia. Contribution of bioenergy systems in GHG emission reduction in Croatia presuming the substitution of the mixed fossil fuels is given in Table 3. It may be noted that bioenergy systems offer significant possibilities for GHG emission reduction in Croatia (even more than 10 % in scenario 423) and should be given much more attention in the future.

Figure 5. Total CO_2 emission in different scenarios in Gg

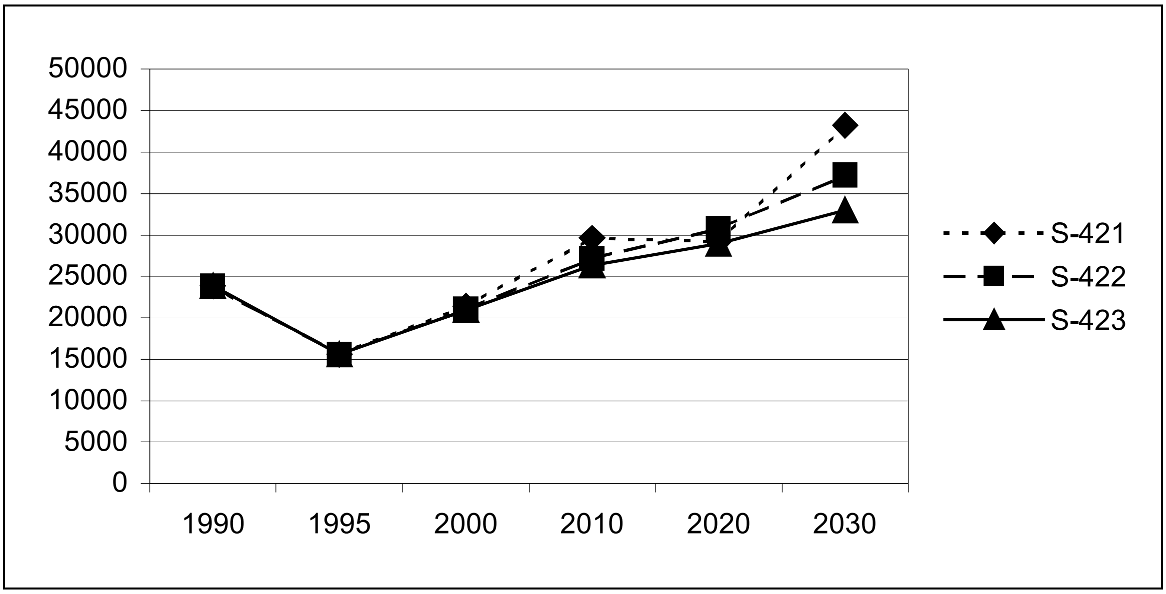


Table 3. Contribution of bioenergy systems in GHG emission reduction in Croatia

Scenario/year	2010	2030
Scenario 421 (“low”)	5,9 %	5,4 %
Scenario 422 (“moderate”)	6,3 %	7,0 %
Scenario 423 (“high”)	6,5 %	10,1 %

Further activities will be focused on full fuel-cycle analysis of the GHG implications of bioenergy systems which will include all inputs and outputs of energy, by-products of biomass systems, examination of different phases of the system, releasing of fugitive emissions like CH_4, etc. Latest results emphasises the need for complete evaluation of bioenergy systems and for working on various strategies of reforestation and forest management, as the options for the reduction of the net CO_2 emission to the atmosphere.

CONCLUSION

Due to the very low emission, it will be very difficult for Croatia to fulfil the obligations from Kyoto protocol. To the year 2010, a significant increase of CO_2 emission is expected even for scenario with significant share of renewables and strong concerned governmental policy for introduction of new technologies and energy efficiency.

Biomass utilisation is recognised as an effective option for the reduction of net GHG emission and achieving targets from Kyoto protocol. It was estimated that use of bioenergy in Croatia would reduce GHG emissions from 5,4 to 10,1 per cent in year 2030.

Detailed analysis and strategic decisions for fulfilling obligations from Kyoto protocol are still to be done, as well as the choice of the base year as the most important issue. Also, a question of power plants outside the Republic of Croatia, financed and built by Croatian Electricity Company (HEP) is still open.

Bioenergy systems are expected to contribute significantly in the reduction of GHG emission and achievement of Kyoto targets for Croatia. In the future, due to large available resources, potential for GHG emission mitigation and other benefits, bioenergy systems are expected to have much more important place in energy policy of the Republic of Croatia. Successively, methodology for total GHG balances of bioenergy systems and evaluation of different scenarios of biomass utilisation and forest management will be given special attention.

REFERENCES

DESSUS, B. et al. 1998. Fuelwood in Europe, Les cahiers du CLIP, N°8, pp 112

DOMAC, J. et al. 1998. Biomass and Waste Use Program (BIOEN) – Preliminary Results and Further Activities, Energy Institute "Hrvoje Pozar", Zagreb, pp 179

GRANIC, G. et al. 1998. Energy Strategy of the Republic of Croatia, Ministry of Economy & Energy Institute "Hrvoje Pozar", Zagreb, pp 271

IPCC 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventores

UNFCCC 1992. United Nations Framework Convention on Climate Change, Convention on climate change, published by UNEP's Information Unit for Conventions (IUC), Http://www.unep.ch

UNFCCC 1997. Kyoto Protocol to the United Nations Framework Convention on Climate Change. Document FCCC/CP/1997/7/Add.1., http://www.unfccc.de.

VUK, B. et al. 1997. Energy in Croatia 1992-1996, Annual Energy Report, Ministry of Economy, Zagreb, 92 pp.

EC 1995. CORINAIR, Nomenclature and software

Fuelwood in Europe for Environment and Development Strategies (FEEDS): an overview

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ABSTRACT

In this 2020 prospective study, a methodology has been developed for analysis of the possibilities of increasing the use of fuelwood, and the socio-economic and environmental implications of the kind of mobilization which would result therefrom. The study deals with five countries within the European Community: Austria, Finland, France, Portugal and Sweden.

The fuelwood share of the energy supply in these five countries could be increased to 9% by the year 2020 if a scenario with an interventionist policy of fuelwood use is assumed in potential user sectors. This could be compared to the present fuelwood share of 5%. There are, however, large differences amongst the five countries. The increased fuelwood use could reduce carbon dioxide emissions by 7% for the year 2020, compared to the present level. The study shows that fuelwood is an economically competitive fuel for energy production in many user sectors. There are, however, a number of non-technical-economic factors (institutional, sociological, political, ...) which may stand in the way of an increased fuelwood use.

The method of analysing the possibilities for - and consequences of - an increased use of biomass which has been developed in this project could be used for similar analyses of other groups of countries in the European Union.

INTRODUCTION

This project on conditions necessary for higher fuelwood consumption in Europe is in line with the objectives of energy, environmental, agricultural and regional development policies in many European countries. Fuelwood is the most commonly used form of renewable energy in Europe, after hydro power. Fuelwood resources are abundant in many regions, and several factors contribute to an increase of these resources. In particular these factors are the improved performance of fuelwood systems, making more fuelwood available, and for many countries the release of agricultural lands, leading to a „natural“ increase in forest land. Due to the currently low prices for fossil fuels the use of fuelwood has not been increasing except for Sweden. In most countries, the current tendency is towards a drop in the use of fuelwood when no policies to encourage its use are implemented. The goals adopted by most European countries for the stabilization and even the reduction of CO_2 emissions by 2010 require an assessment of the scope and implications of interventionist policy in this domain, in terms of avoiding greenhouse gas emissions and of cost for the community. This study with a 2020 perspective aims at estimating, on the one hand, the evolution of fuelwood consumption and the additional potential of available fuelwood, and, on the other hand, new possible uses and socio-economic and environmental implications of promoting such use. This study deals with five European Countries: Austria, Finland, France, Portugal and Sweden.

METHOD

Given two baseline scenarios of fuelwood availability according to the energy conservation policy, four scenarios of fuelwood penetration have been evaluated (Table 1). Behind the scenarios lies the assumption of an interventionist policy of fuelwood development use to increase fuelwood consumption (more so than under the baseline scenario for 2020), or to stop the fuelwood consumption decrease in the case of Portugal.

The principal parameters of the scenarios are the additional fuelwood resource, the potential user sectors, the assessment of the energy demand and assumptions on the type of energies switched to fuelwood per sector. A regional analysis gives the opportunity to compare the available fuelwood resource and potential uses.

The additional available fuelwood resource was calculated as the difference between the annual growth of standing tree stocks and a share of biomass left on the ground for soil regeneration, the wood industry, and fuelwood consumption - to which untapped waste wood (old packaging...) was added. A typology of potential fuelwood users considering national characteristics and developments with the aim to cover the most relevant and common technology per sector was set up. Based on a business as usual projection for energy consumption, assumptions on substitution of fossil fuels and their related technology were made.

Table 1: FEEDS scenarios constructed

Fuelwood availability	Scenarios of fuel-wood penetration	Scenario reference
Business as usual energy conservation	Moderate scenario	Scenario 1a
	High scenario	Scenario 2a
Interventionist policy of energy conservation	Moderate scenario	Scenario 1b
	High scenario	Scenario 2b

On the basis of a common methodological framework, rates of fuelwood penetration have been defined for each energy source and each sector. They represent the share of conventional energy consumption that will be accounted for fuelwood in 2020. They are defined according to an "expert judgment" as maximum rates of fuelwood penetration for 25 years per sector, with reasonable economic assumptions: priority is given to the sectors and energy sources where fuelwood already competes or can compete more easily. A typology of the most common existing installations in each country has been built, defining the kind of equipment that would be substituted per sector by fuelwood plants. It is assumed that today's most advanced and efficient technologies will be commonly used by 2020.

To analyse the potential of fuelwood to reduce greenhouse gas (GHG) emissions, emissions per kWh of useful energy were calculated both for energy systems based on fuelwood, and energy systems based on fossil fuels. These emission factors were then used to determine the total GHG emissions reductions in 2020 for the defined fuelwood energy scenarios, on the basis of data concerning the amount of fuelwood used in various sectors in 2020, and the amount of fossil fuels displaced. Due to technological improvements, with respect to average annual efficiencies of fuel conversion and transmission, best currently available technologies were assumed to be the average technologies in 2020. To be able to calculate the cost of useful energy for different alternatives, relevant data were collected and similar calculations for different fuels were made. Including and excluding fuel taxes and the value added tax (VAT) fuelwood was compared with several fossil fuels, whereas each user sector was analyzed separately. Techno-economic factors are not always sufficient to explain the use or non-use of a given fuel. In order to analyse this situation, a large number of non-techno-economic factors have been considered, integrating four categories: (i) sociological and cultural aspects, (ii) organisational aspects, institutional, (iii) structural and political aspects, and (iv) environmental factors. This analysis has been done taking into account the particularities of each customer category or the service required behind the energy used, and looking at five different sectors or markets. Furthermore, a survey of existing use of technologies in different user sectors was developed to compare the fuelwood systems (efficiency and capacity) and to show which type of fuelwood systems are the most commonly used in each sector and in each country.

RESULTS

Fuelwood resource

The wood stock is considerable in Finland and Sweden compared to the population, whereas France and Portugal are much more populated with a lower density of forests. Austria is in between. For all these countries, the distribution of the forest areas is quite irregular, and does not correspond to the population distribution and the potential uses.

The current fuelwood consumption (excluding black liquors) represents around 4% of the primary energy consumption in France (106 TWh), 7% in both Sweden (40 TWh) and Finland (24 TWh), as well as both 9% in Austria (31 TWh) and Portugal (18 TWh). Assuming that no change will occur in current national policy towards fuelwood use, this energy consumption should increase in Austria, Finland and Sweden, especially in the industrial sector and district heating. In France, the trend is towards a decrease due to the improvement of energy conservation and equipment efficiency. A major decrease of fuelwood consumption is expected in Portugal, due to the abandonment of this energy use for cooking.

In the year 2020, the available fuelwood resource will be about 30 TWh in Austria, 70 TWh in Finland, 55 TWh in France, 10 TWh in Portugal and 80 TWh in Sweden. In Portugal and Austria, the additional fuelwood resource is more or less equivalent to the expected fuelwood consumption in the baseline scenarios. In Sweden, the additional fuelwood resource is twice as high as consumption, and more than three times as high in Finland.
Between 7 and 15% of the available fuelwood resource would be released as a consequence of an interventionist policy of energy conservation.

Technologies

The survey of existing use of technologies in different user sectors in the five countries revealed a number of important facts about the present situation.

Single-family housing generally remains one of the main consumers of biomass for energy. In this sector, there is a great diversity of heating equipment (fire-places, stoves...) with various technical characteristics. The efficiencies of single-room devices and central heating boilers range respectively from 50 to 55%, and from 60 to 70%.

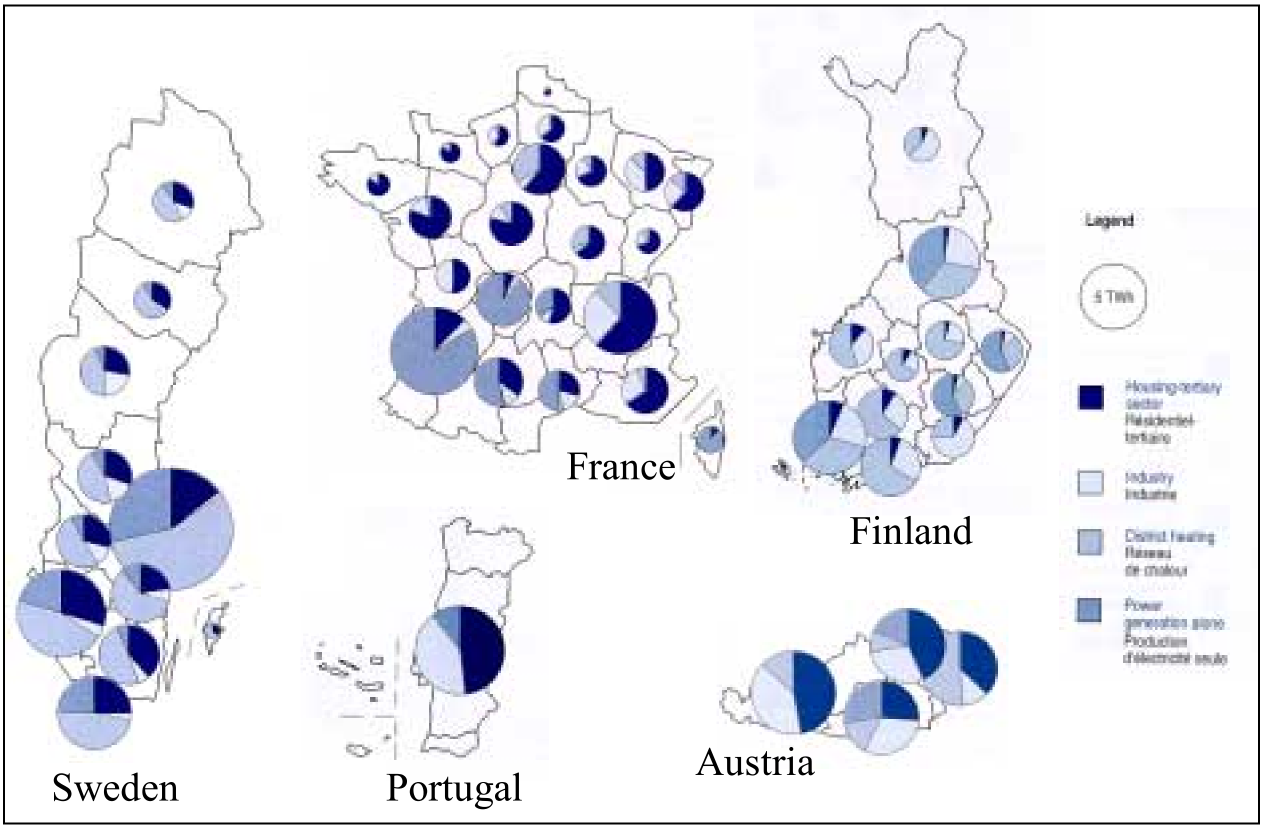
Considering multi-family housing and the tertiary sector, available technologies (low and medium power range) can be classified in two groups: a first one includes standardized components which are not specifically designed for biomass, and a second one includes plants especially designed for biomass. The efficiencies range from 60% to 75%.

Biomass combustion technologies have been considerably improved in the last few years, mainly through the development of new combustion systems (e.g. fluidized bed combustion) and to the adaptation of automatic feeding systems to a large range of biomass products.
In small and older medium scale plants, the biomass is burned by grate combustion. In medium and large scale fuelwood plants, the biomass is burned by stationary or moving grate combustion or, more recently, by stationary (bubbling) and circulated fluidized bed combustion. The integrated gasification combined cycle (IGCC) and pyrolysis options, though being demonstrated in various countries, are not yet commercially available. Fuelwood cogeneration plants typically have an overall efficiency of 80-90%. Fuelwood heating plants equipped with flue gas condensing technology can reach a LHV efficiency of 110%. Electric power plants have an overall efficiency of 30 to 40%. Among the power generation plants, IGCC-plants are the most promising with efficiencies that could theoretically reach 42% to 45%.

Fuelwood usable potential for 2020

For the five countries, the total fuelwood resource will be 460 TWh in 2020. In the baseline scenario, the fuelwood consumption should be 210 TWh, which is less than half the resource. The additional consumption could be about 90 TWh in the moderate scenario and 170 TWh in the high scenario. So, the total fuelwood consumption would be from 300 TWh to 390 TWh, i.e. 65% and 88% of the total fuelwood resource.

Figure 1. Additional fuelwood consumption per user sector in 2020 (high scenario)



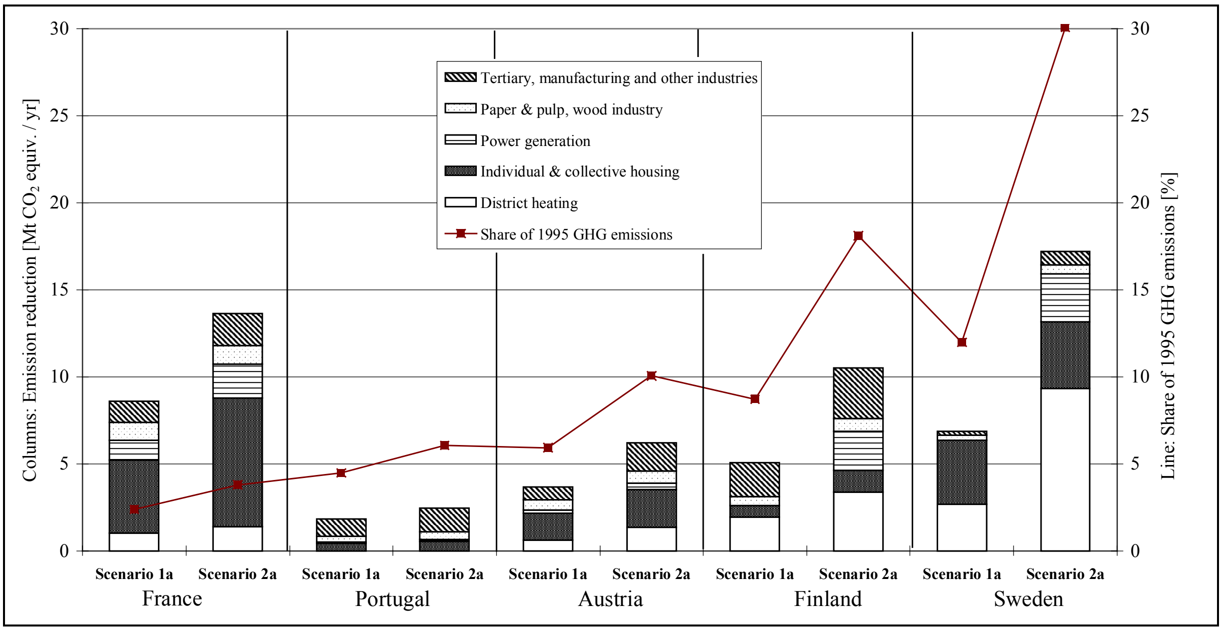
In the moderate scenario, the fuelwood consumption increase should reach 58% in Finland (+15 TWh), 49% in Austria (+17 TWh), 46% in Sweden (+22 TWh) and 35% in France (+33 TWh), compared to the baseline scenario. In Portugal, the aim is to avoid a drop in fuelwood consumption (8 TWh in the baseline scenario). Total fuelwood consumption decrease is only 13% in this scenario. Figure 1 gives an overview of the additional fuelwood consumption per user sector in the year 2020 (high scenario).

In general, the residential and services sector will remain the principal user sector. But in order to increase significantly fuelwood use, a large penetration of fuelwood is necessary in district heating systems and in industrial sectors (especially in other industries than the wood and pulp and paper industries). The development of power production either in CHP plants or power production only plants could also be necessary.

Greenhouse gas emissions

Thanks to fuelwood penetration, emission reductions in Sweden in the year 2020 amount to 7 (moderate scenario) and 17 (high scenario) Mt CO_2 equivalents, which is 12 and 30% of total energy-related GHG emissions in 1995. In Finland a reduction of 5 and 10 Mt (9 and 18%) is expected.

Figure 2. Total annual emission reduction in 2020 for scenarios 1a and 2a by country and sector and share of 1995 GHG emissions.



For France (9 and 14 Mt; 2 and 3%), Austria (4 and 6 Mt; 6 and 10%) and Portugal (2 Mt; 4 and 6%) relative emission reductions are lower, because the usable fuelwood potential - but also fuelwood penetration rates - are lower. The largest emission reductions in 2020 are expected in the following sectors: individual housing, collective housing (France, Austria and Sweden - moderate scenario), tertiary, manufacturing and other industries (Portugal) and district heating (Finland, Sweden - high scenario).The scenarios indicate that fuelwood has significant yet limited possibilities to reduce total emissions of GHG in the five countries, with greatest relative reductions in Sweden and Finland (especially high scenario).

Costs

Fuelwood is presently either competitive or close to competitive for heat and steam production for the majority of user sectors and countries. This is encouraging in the perspective of increased future utilization of fuelwood for energy production. However electricity production in condensing power plants based on fuelwood is not competitive.

Table 2. Cost for useful energy in single family housing (incl. taxes)

ECU/MWh	Austria	Finland	France	Portugal	Sweden
Fuelwood	89	110	94	70	84
Oil (1)	101	105	118	64	90
Electricity	166	101	140	159	99

As a sensitivity study, we have analysed which levels of fuelwood price and boiler investment cost have to be reached - for the applications which are not presently competitive - in order to make fuelwood the most competitive alternative. The calculation shows that relatively moderate reductions are sufficient to make a number of applications competitive. The calculations also show that taxes can be an effective method to increase the competitiveness of fuelwood.

Non technical-economic factors influencing the fuelwood development

The influence of each factor is very different from one market to another. This means that the definition and implementation of a strategy to develop the use of biomass as an energy source must be market-oriented. The definition of general measures is not sufficient and could have opposite effects to those planned. Nevertheless, it seems that two factors are strongly affecting negatively the penetration of fuelwood in almost all the markets. These two factors are related to the development of the natural gas network in Europe, and to the competing distortions between alternative fuels. The aggressive commercial strategy adopted by NG companies - and the public support they generally enjoy - are strong factors which have a very negative influence on fuelwood penetration. Competing distortions refer to direct and/or indirect benefits given to alternative fuels (NG, electricity, ...). As the case of Sweden demonstrates, the reduction of competing distortions is an efficient tool for fuelwood development in all sectors of energy consumption.

The positive influence of non technical-economic factors on biomass development is not homogeneous. Sociological and cultural aspects related to the image of wood as a fuel and the effects of new technologies/projects, influence positively the use of fuelwood in housing, tertiary, district heating and power generation. The use of fuelwood in wood industries is essentially positively influenced by organizational factors (namely the existence of professional organizations and of supply guarantee). Regarding institutional, structural and political aspects, factors like energy policy and local policy will be extremely important namely in multi-family housing, tertiary, district heating and power generation. The environmental benefits at local and global ranges are also pointed out in all the markets. The prevention of forest fires in some countries (France and Portugal) and the reduction of CO_2 emissions are important benefits associated with the use of fuelwood. Nevertheless, people's perception of biomass energy remains ambiguous and could constitute a strong barrier in some cases (visible atmospheric emissions, forest depletion, ...) and a good opportunity in other cases (forest fire prevention, global warming, ...).

CONCLUSIONS

According to the scenarios, the stakes of a fuelwood mobilization policy in the five studied countries are an additional fuelwood consumption from 90 TWh (moderate scenario) to 170 TWh (high scenario) for the year 2020. The total fuelwood consumption in 1995 is 218 TWh, the fuelwood consumption expected in 2020 is about the same (210 TWh) according to the baseline scenario, if there is no change in the current national policies. That is to say that the objectives of a volontarist policy in favour of fuelwood use could be to bring the fuelwood consumption from 45% of the fuelwood available resource (baseline scenario) to 65% (moderate scenario) or 88% (high scenario) in 2020.

The stakes are obviously different between countries. The objective is to keep the fuelwood consumption stable in Portugal, to increase the fuelwood consumption of about 35% in France and 60% in Austria, while it could be possible to double the fuelwood consumption in Finland and Sweden.

If such a fuelwood consumption increase is implemented, from 27 to 50 Mt CO2 equivalents could be avoided in the year 2020. It represents from 4% to 7% of the total 1995 energy-related GHG emissions of the five countries. Among the avoided 50 Mt CO2 equivalents in the high scenario, 17 Mt CO2 equivalent would come from Sweden, 14 Mt from France and 10 Mt from Finland. These amounts are equivalent to 17% and 19% of the total 1995 energy-related GHG emissions respectively of Finland and Sweden.

It appears that the available resource is quite important and is actually not a barrier for a higher mobilization of fuelwood, even in Portugal where volontarist measures are necessary to stop the decrease of fuelwood consumption. Difficulties could appear at the regional level because of the various distribution of the fuelwood resource and the potential uses. Therefore, the question is : could we consider (as it has been done in Sweden for the high scenario) that fuelwood transportation is not a strong barrier? Is it sometimes more relevant to produce electricity in condensing power plants where there is a large untapped fuelwood resource and to transport electricity to the final users by existing transmission and distribution network?

In general, the residencial and services sector will stay the principal user sector. But in order to increase significantly the fuelwood use, a large penetration of fuelwood is necessary in the district heating networks and in industrial sectors (not only wood and pulp and paper industry but also other industries). The development of power production either in CHP plants or power production only plants should be also planned.

Fuelwood is presently either competitive or close to competitive for heat and steam production for the majority of user sectors and countries. If we consider the sectors per country in which fuelwood can already compete with all other calculated alternatives (comparing the cost of useful energy), the additional potential of fuelwood consumption is 37 TWh (including 20 TWh in Sweden) according to the moderate scenario and 66 TWh (including 41 TWh in Sweden) according to the high scenario. It is about 40% of the additional potential of fuelwood consumption in 2020. Moreover, 25% of the additional fuelwood use concern sectors in which fuelwood are not yet competitive but less than 20% more expensive than the cheapest alternative. However, electricity production in condensing plants based on fuelwood is not competitive for the time being. For example, in Sweden, the gap is about 20 Ecu/MWh compared to electricity production from oil or hard coal which is free of energy tax and CO2 tax.

Technico-economic factors are not sufficient enough to explain the fuelwood use or non-use. The analysis of the non technico-economic factors influencing the fuelwood development shows that two factors are strongly affecting negatively the penetration of fuelwood in all the markets or almost. The aggressive commercial strategy adopted by natural gas companies and the public support they generally have, are strong factors which have a very negative influence on fuelwood penetration. The second factor is related to the competing distortions which refer to direct and/or indirect benefits given to alternative fuels (natural gas, electricity...). Sociological and cultural aspects related with the image of wood as a fuel and the effects of new technologies/projects, influence positively the use of fuelwood in housing, tertiary, district heating and power generation. Regarding institutional, structural and political aspects, factors like energy policy and local political will are extremely important in these sectors. The use of fuelwood in wood industries is essentially positively influenced by organisational factors (namely the existence of professional organisations and of supply guaranty).

The results of this comprehensive study highlight the stake associated to fuelwood development in Europe, both from the point of view of local activity and of global environment. Resource is present, technologies do exist, greenhouse gas emissions savings are established, competitivity is often reached, especially if we get rid of competing distorsions. Nevertheless, institutional, organisational and cultural barriers have to be overcome if Europe wants to reach such a target. Europe should envisage seriously how to clear these obstacles on the way to sustainable development.

SELECTED REFERENCES

CLIP, 1998. *Fuelwood in Europe. Evaluation of the usable potential for 2020, effect on global environment and socioeconomic conditions of its mobilisation.* Les cahiers du Club d'Ingénierie Prospective Energie et Environnement (CLIP) No. 8, January.

A Unified Wood Energy Terminology (UWET)

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ABSTRACT

The aim of this paper is to examine and review the currently used terminology and definitions for woodfuels and other biofuels in the data bank dedicated to the collection and compilation of bioenergy statistical data and present some suggestions for improving this information in the future. For obvious reasons, the paper is mainly focused on the woodfuel statistics compiled by FAO in the current FAOSTAT and reproduced in the Forest Products Yearbook. However, many of the issues of the Unified Wood Energy Terminology (UWET) suggested in this paper for improving the current FAO information system on biofuels would also apply to other data banks of other international and national organizations and agencies involved in similar fields.

INTRODUCTION

The existing information on biofuel in general, and woodfuels in particular, is highly aggregated and focused on consumption of few biofuels (commodities or products) without giving due attention and recognition to other related aspects on the demand side and supply sources.

Therefore, properly desegregated biofuel data with their respective unit of measures and conversion factors clearly described and defined is crucial for collection, compilation and presentation of statistical data and information on bioenergy.

At the international level, FAO collects and disseminate annual data on fuelwood and charcoal and is suffering the above mentioned drawbacks. For this reason, the FAO's Wood Energy Programme in conjunction with other relevant agencies have initiated actions for a progressive improvement of our Wood Energy Information System (WEIS).

LIMITATIONS OF CURRENT FAO WOOD ENERGY DATABASE

This presentation is exclusively focused on the description of currently used terminology, definitions, units of measures and conversion factors currently used by FAO and other relevant organisations involved in this subject

This presentation suggests an approach for the review of the old terminology currently used and propose changes to overcome the above mentioned drawbacks and thus, to improve the visibility and the understanding of the role played by woodfuels as a relevant forest product for the energy sector.

The main problems commonly encountered in the compilation and presentation of current bioenergy data bases can be categorised within the following main general areas:

- **Coverage**: currently FAOSTAT includes data and information only on fuelwood and charcoal, omitting other important kinds of fuels produced from wood. For instance, data about black liquor (the most important form of wood energy in many developed countries) are left out.

- **Desegregation**: regardless the importance of no-forest supply sources of wood energy and the large use of recycled products, the supply side is not desegregated in FAO wood energy database. In other hand, although there is a clear shift of wood energy demand from traditional to modern uses, presenting considerable impacts on whole wood energy systems, in current FAO database demand information is not presented.

- **Definition and units incompatibility**: the absence of a comprehensive framework and clear set of definitions limit the possibility of comparison between other data source on wood energy.

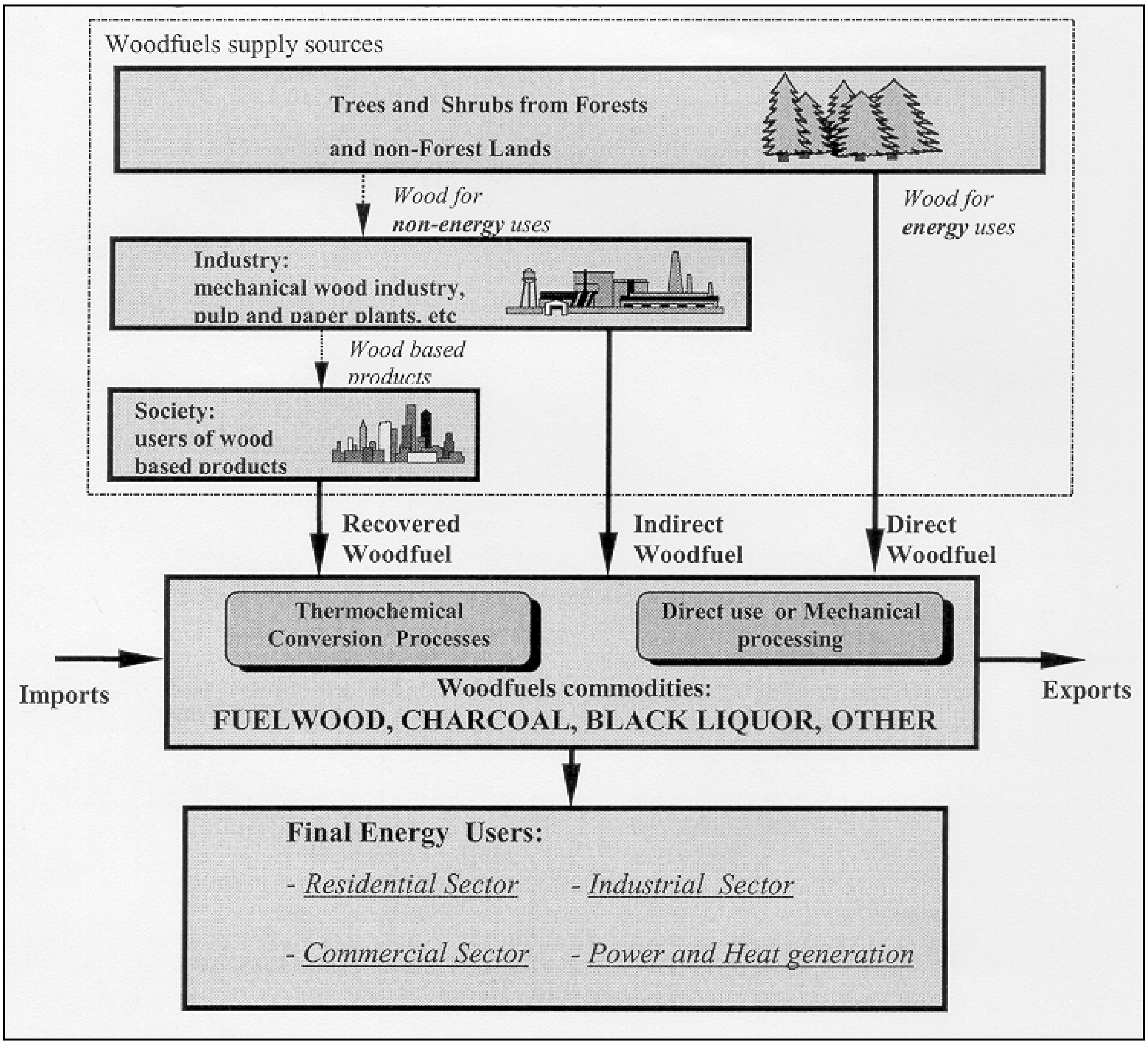
THE UNIFIED BIOFUEL TERMINOLOGY (UBET) SUGGESTED

Considering the important background available in the existing wood fuel data banks at FAO and other relevant international agencies and guided by documents such as the

- Energy Statistics: a Manual for Developing Countries
- Energy Statistics: Definitions, Units of Measure and Conversion Factors
- Concepts and Methods in Energy Statistics, with special reference to Energy Accounts and Balances

(all from the UN Department of International Economic and Social Affairs) for the suggestions of reviews and changes and keeping in mind that most of the wood fuel flows schemes are following the one presented in **Figure 1;** the following biofuels classification is presented in **Table 1**.

Figure 1. Wood energy from supply sources until user's demand



This biofuel classification intends to identify those commodities and products (first column) accordingly with their supply sources (second column) for the recognition of biofuels supply sources. In other words, the main intention is to distinguish whether the biofuel are connected to forest, agricultural or municipal activities.

Table 1: Definition of Biofuel Classifications Proposed

1st level **Major commodities**	*2nd level*	*Brief definition*
Woodfuels	**Direct Woodfuels**	Wood used directly or indirectly as solid, liquid and gaseous fuels produced from forest and non-forest lands
	Indirect Woodfuels	Solid, liquid and gaseous woodfuels produced from wood processing industries and activities
	Recovered Woodfuels	Recovered wood used as fuel, derived from socio-economic activities outside the forest sector
Agrofuels	**Fuel crops**	Growing plants for the production of biofuels
	Agricultural by-products	Mainly residues from crop harvesting and other kinds of by-products from agricultural activities left in the field
	Animal by-products	Basically excreta from cattle, horses, pigs and poultry
	Agroindustrial by-products	Several kinds of materials, produced chiefly in food processing industries, such as bagasse and rice husks
Municipal by-products		Solid and liquid municipal residues

UNIFIED WOOD ENERGY TERMINOLOGY (UWET) PROPOSAL

In line with the general approach developed for UBET, the following descriptions provides additional details of the **Unified Wood Energy Terminology**

Conceptual approach

The proposed terms presented in the Table 2 not only follow as much as possible the existing definitions currently used in the FAO's Forest Products Yearbook and available in the document "Classification and definitions of Forest Products" (FAO Forestry Paper 32) but also include woodfuels categories and respective terminology in line with ISIC (Standard International Trade Classification, Revision 3, United Nations) developed and widely used for all conventional fuels and forest products

The proposed UWET is organised following the different woodfuels types (fuelwood, charcoal, black liquor and other) as **major commodities/products** for all the data collection, compilation and presentation while data for **woodfuel supply sources** and **woodfuel end-users** is been categorised following the multiple interrelations between commodities, supply sources and end users as shown in the scheme presented in the **Figure 1.**

Table 2. UWET proposed

Supply sources	COMMODITY		Users
Direct woodfuels	**Fuelwood**	**WOODFUELS** Solid Liquid Gaseous	Household
Indirect woodfuels	**Charcoal**		commercial
Recovered woodfuels	**Black liquor**		industrial
	Other		heat and power

In this way, the main **woodfuel supply sources** can be classified into three major groups: *Direct woodfuels, Indirect woodfuels and Recovered woodfuels* and data on the demand side is desegregated by main users as described in **Table 2.**

SOME CONSIDERATIONS ON UNITS OF MEASURE AND CONVERSION FACTORS

Considering that data and information on biofuels in general and woodfuels in particular are products and commodities recorded by agencies from both the forestry and energy sectors, the units generally used are different and not always properly indicated. Similar situations occur with different conversion factors used for the analysis of different products such as fuelwood and charcoal.

Woodfuel can be measured by volume or weight. Nowadays, FAO, as well as foresters and other related experts, prefer to measure timber and fuelwood using **solid volume** units, usually in cubic meter (CUM). The more water per unit weight, the less fuelwood. Therefore, it is imperative that the moisture content be accurately specified when fuelwood is measured by weight.

The accounting of biofuel flows and bioenergy balances (covering several kinds of biofuels) using data expressed in different units of measures requires the use of different conversion factors which are often not properly defined and clearly described. The presentation of data under other units different of those originally established can cause great differences in the final results. Therefore, it is recommended that commonly used conversion factors be properly and clearly described with biofuel data.

Given that the objective is to obtain the energy worth of a mass or volume flow of different sort of biofuel involved, expressions for the calculation of such a volume, mass and energy involved must be used with the help of different conversion factors which must be clearly described. These calculations should take into account the substantial variations of energy with heating value and volume/weight with moisture. Therefore, especially for the accounting of biofuel consumption analysis and energy balances, it is advisable to express the values of biofuels on a dry and without ash basis.

MEASURES TO IMPROVE WOODFUEL DATA

UWET is being progressively adopted for the compilation and presentation of exiting woodfuel statistical data recorded in FAOSTAT and tested for the collection of new data under current wood energy projects and activities. However, a lasting solution to improve bioenergy statistics will require the collaborative effort of several national and international organisations in order to:

- disseminate and promote the wide utilisation of this terminology; and
- develop activities for building capabilities at national and international level for improving techniques on data collection, compilation and presentation and developing in-country skills.

REFERENCES

DEPARTMENT OF INTERNATIONAL ECONOMIC AND SOCIAL AFFAIRS, 1991. Energy Statistics: a Manual for Developing Countries, Studies in Methods, Series F, No. 56, United Nations.

DEPARTMENT OF INTERNATIONAL ECONOMIC AND SOCIAL AFFAIRS, 1987. Energy Statistics: Definitions, Units of Measure and Conversion Factors, Studies in Methods, Series F, No. 44, United Nations.

DEPARTMENT OF INTERNATIONAL ECONOMIC AND SOCIAL AFFAIRS, 1982. Concepts and Methods in Energy Statistics, with special reference to Energy Accounts and Balances (A Technical Report), Studies in Methods, Series F, No. 29, United Nations.

FAO, 1982. Classification and definition of forest products, FAO Forestry Paper 32.

FAO/FONP, 1994. Yearbook Forest Products, FAO.

FAO, van den Broek, R., 1997. Wood Energy Today for Tomorrow, The Role of Wood energy in Europe and OECD FAO/ FOD/ FOPW/97/1.

FAO and climate change

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ABSTRACT

The mandate of FAO touches on a number of areas which are of direct relevance to the current international climate discussions such as: the assessment of land-use, land-use changes and forestry sources of green-house gases; the formulation of programmes and policies which can reduce the emissions and assist countries in complying with their commitments under the UNFCCC and the Kyoto Protocol; and the collection and maintenance of relevant datasets, through agricultural statistics and dedicated observation systems such as FRA (Forest Resources Assessment) and GTOS (Global Terrestrial Observation System).

The Organization can play, among others, a useful role in the definition of typologies of agricultural and forestry sources; the formulation of the appropriate agricultural statistical methods that will enable the Conference of Parties to verify the compliance with commitments and the relevance and effectiveness of projects implemented under the „flexibilisation mechanisms"; the standardisation of observation techniques and data exchange; and the formulation of regional and national policies.

Finally, it is suggested that the Inter-Agency Committee on the Climate Agenda, which was specifically set up by several UN agencies to harmonise their climate related programmes, should be resorted to ensure that the inputs by several Agencies, and their relations with countries under the UNFCCC, are properly co-ordinated.

INTRODUCTION

Although the fundamental texts of FAO do not specifically mention climate, atmospheric conditions are so pervasive in all areas of agriculture[1] that the Organization had to develop a strong interest in the subject, covering all forms of agricultural planning and impact assessments in the broad area of food security.

This includes not only the regular programme activities of the Organization, but also formal and informal links with the major international partners in the area, such as WMO, in particular the World Climate Programme from its creation in 1979.

[1] In the definition of FAO, agriculture includes crop and livestock husbandry, forestry, sea fisheries and aquaculture.

The Organization has closely been following the recent international climate negotiations, particularly since the entry into force of the UN Framework Convention on Climate Change (March 1994) to which the recent World Food Summit (1996) makes explicit reference[2].

This document examines the role of FAO in the ambit of the international climate discussions in the light of its mandate and competence.

AGRICULTURE IN THE UN FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The preamble of the UNFCCC states some basic principles and recalls the international legal context in which the Convention was prepared. Several points are of direct relevance to the agricultural community and to FAO, in particular the fact that

- various actions to address climate change can be justified economically in their own right and can also help in solving other environmental problems;
- the access to resources to achieve sustainable, social and economic development, in particular the increased access to sources of energy, and increased energy consumption by developing country parties;
- the recognition of the basic differences between developing and developed country parties.

Regarding the first point, note that the sentence describes the approach known as „no regrets" which has also been adopted by FAO in the promotion of actions to reduce emissions of green-house gases from the agricultural sector. Such emissions constitute losses to farmers and obstacles to sustainability of agricultural production systems.

Regarding the second point, it should be underlined that the UNFCCC has relatively little direct reference to agriculture, i.e. sustainable development is mostly implicitly seen as sustainable economic growth.

The third point (differences between developed and developing countries), is stressed again in article 4 on the Commitments of the different parties, where forestry is repeatedly mentioned among the sources and potential sinks of green-house gases.

THE ROLE OF FAO

This section examines the potential role of FAO in the context of the current climate negotiations and discussions, in the light of on-going climate-related and climate-relevant activities of the Organization. Note that the active participation of international organisations in the international climate issues is clearly mentioned in the Kyoto Protocol (KP 13.4(i); The Conference of Parties will (...) seek and utilize, where appropriate, the services and cooperation of, and information provided by, competent international organizations and intergovernmental and non-governmental bodies.)

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[2] Under objective3.2 A fact sheet on Climate and Foot Security was jointly prepared by WMO and FAO as background documentation for the World Food Summit.

Inventories of sources and sinks

As per UNFCCC Article 4.1(a) all countries have the obligation to carry out detailed inventories of anthropogenic sources of green-house gases3. The Kyoto Protocol (KP 3.3) is more specific in that it states that countries are committed to verifiable changes in carbon stocks, including those deriving from land use changes and which are of direct relevance to the agricultural community.

The FAO Global Forest Resources Assessment 1990 is the most recent systematic attempt to estimate the rate of deforestation, and will permit a more accurate assessment of the contribution of deforestation to green-house gas emissions. The assessment is organised into three climatic zones: tropical, temperate and non-tropical developing. For developing countries, FAO collects existing reliable information on forested areas, using Landsat scenes for calibration and change estimates. Inventories conducted by "developed" countries provide the data for the rest of the world.

In the same context, the AFRICOVER project, an FAO co-ordinated effort to assemble national vegetation maps in Africa using compatible methodologies, formats and a common nomenclature, also constitutes an exercise relevant to improving the knowledge of the carbon cycle.

Programmes to mitigate climate change

All countries are encouraged to take measures to mitigate anthropogenic emissions (UNFCCC, 4.1(b)), to enhance carbon sinks (UNFCCC 4.1(d)) and energy efficiency (KP 2.1a(i)), afforestation and reforestation (KP 2.1a(ii)) as well as to promote new and renewable forms of energy and CO2 sequestration (KP 2.1a(iv)).

According to KP 10(b), all Parties have to formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change in the (KP 10(b)(i)) energy, transport and industry sectors as well as agriculture, forestry.

The specific issue of the role of forests in the carbon budget was first debated in FAO in an Expert Consultation on Forestry and Climate Change (1990) to provide the Forestry Department with general guidelines on how to best serve its member countries in this field, and to help it develop a related programme of work. More recently, the Forestry Department has established an in-house Task Force on the role of forestry in carbon sequestration, with particular emphasis on carbon sequestration (timber) and substitution (biofuels).

To assess the feasibility of biofuels as a sustainable substitute for fossil fuels, an expert consultation was held in 1993. Among the most important results of the meeting was a recognition of the potential of biofuels from both the development and environmental points of view and of the need for FAO to take the lead in an international programme in this field. This central recommendation was backed by technical and policy discussions calling for a multidisciplinary approach in which land use policies, agronomy, forestry, energy and environmental issues are treated in an integrated manner.

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3 Strictly: green-house gases not covered by the Montreal Protocol.

Clean development mechanism

Article 12 of the Kyoto Protocol defines a Clean Development Mechanism with the purpose to have Annex 1 and Non-annex 1 Parties collaborate on projects resulting in certified emission reductions. Annex 1 Parties will be able to use the reductions to comply with their reduction commitments, while developing countries will benefit from the technology transfer.

Education

UNFCCC Article 4.1(i) and 6 on Education, Training and Public Awareness stress the need to train scientific, technical and managerial personnel (UNFCCC 6.(a)(iv)), and to cooperate in and promote, at the international level, and, where appropriate, using existing bodies: The development and implementation of education and training programmes, including the strengthening of national institutions and the exchange or secondment of personnel to train experts in this field, in particular for developing countries (UNFCCC 6(b)(ii)). Similarly the Kyoto Protocol calls for international co-operation in education and training, in particular strengthening of endogenous capacities and capabilities to participate international and intergovernmental efforts (KP 10(d) and 10(e)).
Although not directly involved in education, FAO has the experience of the preparation of training programmes and the development of appropriate techniques which can be used to improve the focus of the curricula of agricultural personnel at all levels as regards climate change considerations.

Adaptation

UNFCCC Article 4.1(e) underlines the need to prepare for climate change impacts, including rehabilitation and protection, drought and desertification, especially in Africa.
Much of the work of FAO derives directly from the need to adapt farmers' practices to adverse conditions and help stabilise and possibly increase production under a vary variable environment. As such it directly responds to UNFCCC preoccupation.

Policy formulation

UNFCCC 4.1(f) encourages countries to take climate change considerations into account in the formulation of their national policies, not only in the field of environment but, also in the broader socio-economic policy development. The Kyoto Protocol insists more specifically on the promotion of policies that limit emissions (KP 4.1a(vi)) and goes a step further in suggesting that Parties would benefit from exchanging their experience of the effectiveness of policies (KP 4.1b).

Policymakers should remember that, although agriculture can be regarded as one of the main culprits in the emission of some green-house gases, this situation largely derives from the necessity of subsistence farmers to keep increasing production in spite of very low inputs. Many agricultural green-house gases are thus linked to the poverty and ignorance of farmers (policies to be fair to subsistence farmers) and their reduction cannot be dealt with without serious equity considerations.

FAO has a part to play to ensure that such considerations be taken into account in the future.

Collaboration with Subsidiary Body for Scientific and Technological Advice (SBSTA)

Of the two Subsidiary Bodies established by UNFCCC (Article 9: SBSTA, and article 10, Subsidiary Body for Implementation, SBI), it is mainly with SBSTA that there is a potential for collaboration with FAO.

The mandate of SBSTA is to provide the Conference of the Parties (...) information and advice on scientific and technological matters relating to the Convention. (...) under the guidance of the Conference of the Parties, and drawing upon existing competent international bodies (UNFCCC 9.1 and 9.2).

Among others, SBSTA will (UNFCCC 9.2(c)) identify innovative, efficient and state-of-the-art technologies and know-how and advise on the ways and means of promoting development and/or transferring such technologies and (UNFCCC 9.2(d)) provide advice on scientific programmes, international cooperation in research and development related to climate change, as well as on ways and means of supporting endogenous capacity-building in developing countries.

Methodology

Although most commitments currently apply to Annex 1 Parties, it is worth noting that the implementation of the commitments and their control will imply serious problems of methodological homogeneity (UNFCCC 12.1(a)).

It is foreseen that support may be provided by other Parties, by competent international organizations and by the secretariat, as appropriate (UNFCCC 12.7). The Kyoto Protocol (3.4) indicates that the CoP[4] will decide on modalities for reporting the emission reductions and removal by sinks in the agricultural soils and the land-use change and forestry categories, taking into account the work by IPCC and SBSTA.

The information submitted under Article 7 of the Kyoto Protocol (annual reporting) by each Party will be reviewed by expert review teams coordinated by the secretariat and (...) composed of experts selected from those nominated by Parties to the Convention and, as appropriate, by intergovernmental organizations, in accordance with guidance provided for this purpose by the Conference of the Parties.

4 In practice, this will be CoP-4 (Buenos Aires, November 1998).

Article 10 (KP 10(a)) stresses the formulation of cost-effective national and, where appropriate, regional programmes to improve the quality of local emission factors, activity data and/or models which reflect the socio-economic conditions of each Party for the preparation and periodic updating of national inventories of anthropogenic emissions by sources and removals by sinks of all green-house gases (...), using comparable methodologies (...).

It is clear that the point above implies methodological work in the area, for instance, of land-use type definitions, types of agricultural systems and management, as well as the assessment of national measures. The latter point may be particularly difficult in the case of the gradual adoption of measures reducing emissions, as in the case of improved nutrition of ruminant livestock.

FAO has demonstrated experience in the definition of typologies and terminologies. As to the quantitative assessment of reductions from agricultural sources, it is obvious that it constitutes a typical task for agricultural statistics, and that new indicators will have to be developed and sampled.

FAO ACTIVITIES ON CARBON SEQUESTRATION AND SUBSTITUTION

In order to coordinate the multiple activities to be undertaken by different technical units on Climate change, FAO has set up the **AD HOC GROUP ON CLIMATE IN RELATION TO AGRICULTURE AND FOOD SECURITY** within the SUSTAINABLE DEVELOPMENT DEPARTMENT. It is composed of representatives, at the technical level, of the Departments, Divisions and Services with an interest in climate, its variability and changes.

The main functions can be summarized as follow:

- Ensure that climate resources and their fluctuations (variability and change) are given due attention in FAO normative work
- Provide a co-ordination mechanism and exchange function for climate related data and work within FAO;
- Provide a forum for assessing internal and external work, data, knowledge and information on climate and their implications;
- Ensure the co-ordination of inputs to the FAO Programme of Work and Budget for climate-related matters;
- Assist in the review and preparation of IPCC and other UN documents related to climate and climate change and its potential impact on agriculture, forestry and fisheries;
- In the other hand, the FAO's FORESTRY DEPARTMENT has created the **TASK FORCE ON THE ROLE OF FORESTRY IN CARBON SEQUESTRATION** aimed to:
- Provide better coordination and visibility to FAO's work on carbon substitution and carbon sequestration and the reduction of Carbon emissions;
- Suggest mechanisms for the mitigation/reduction of Carbon emissions throughout the use of forests, trees and their derived products (woodfuels and timber), and

- Assist member countries by providing them with information on the opportunities in the implementation of the Kyoto Protocol and its related programmes
- And with the following main functions:
- Exchange of information and experiences between main normative activities developed by the Department at both HQs and regional/subregional level and field projects;
- Provide an informal framework for the articulation of the activities developed by the Department;
- Contribute to the formulation and implementation of policies on the mitigation of GHG emissions through forests, forestry activities and wood energy and identify;
- Collect, collate and compile information to assess potential contributions to GHG mitigation/ reduction through wood energy, forests and forestry activities;
- Liaise with other groups and networks within and outside FAO;
- Assist and advice to member countries, field projects, public and private organisations (incl. NGOs)

Bioenergy and power production; power company's perspective

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ABSTRACT

In this presentation, the current situation of the Finnish electricity market have been shortly discussed. The main dynamics are currently the deregulation of the markets and the adaptation to the commintments of the Kyoto protocol. Also, some aspects of Imatran Voima Oy's (IVO) relation to the bioenergy have been described.

Keywords: power production, wood, deregulation, CO_2

INTRODUCTION

In Finland, bioenergy has been utilised largely in industrial sector. The biggest share of wood based fuels is burned in the recovery boilers of the pulp mills. Also, other forest industry plants are using their by-products like sawdust in energy production. It has been a natural choice to use wood in energy production in the Finnish industrial sector, because the bioenergy is often a by-product of other processes and on the other hand, we don't have our own fossil fuel reserves (except peat).

In other sectors, where the bioenergy is not a by-product, fossil fuels have quite often been the cheapest and the easiest solution to produce heat and electricity. So, the share of bioenergy has been quite low in large scale public heat and power production. In recent years, new burning and acquisition technologies have been developed for wood fuels and also, environmental properties of wood fuels have increased their competiveness compared with the fossil fuels.

DYNAMICS IN POWER SECTOR

There are two big issues in the Finnish electricity market: the deregulation of the electricity market and the Kyoto target for controlling the CO_2-emissions. Both of these factors should be taken into account in the consideration of bioenergy's role in the power production.

Deregulation of electricity market

In this autumn, the deregulation of the electricity market have reached all consumers in Finland. Also, the small scale consumers like single households may now choose freely their own electricity supplier. This means that the electricity producers have to compete about the customers by offering products that meet the demands of the customers.

One of the important attributes in the market is the price of the product. It is quite obvious that the price of the bioenergy should be relatively competitive compared with the other fuels in the free market system. Bioenergy especially the wood based fuels have quite labour intensive acquisition chain. The wood fuel acquisition systems have been intensively and innovatively developed in Finland. The statistics published by the Ministry of Trade and Industry show that the competitiveness of wood fuels have increased considerably in the recent years as can be seen in the figure 1 "(Energy Review 1/98)". It should be noted that the prices of wood fuels are not representative for the whole country. No unified price data are available, the energy market for wood being local and still in a development process.

The boilers of the power plants are long term investments. In the situation of the tightening competition, the investors should be able to rely on the sufficiency and the availability of the fuels for their boilers. The fuel consumption of large scale boilers (>150 MW_{th}) is so high that it is hard to find enough wood fuels (excluding forest industry) inside moderate (under 50-100 km) transportation distances to cover the annual fuel consumption. Small scale boilers (<50 MW_{th}) have been developed for power production and for this size of boilers wood could be used as a main fuel for example in the combined heat and power production of municipalities. Sufficiency of thinnings and logging residues "(Helynen and Nousiainen, 1996)" in the (former) county of Keski-Suomi, which land area is about 16000 km^2, is compared with the annual fuel consumptions of large scale Rauhalahti and small scale Toranki combined heat and power plants in the figure 2. Still, wood can be also utilised flexibly in Rauhalahti large scale power plant as a co-fuel because of the modern fluidized bed boiler.

Figure 1. Consumer prices of hard coal, natural gas and indigenous fuels (VAT not included), mk/MWh

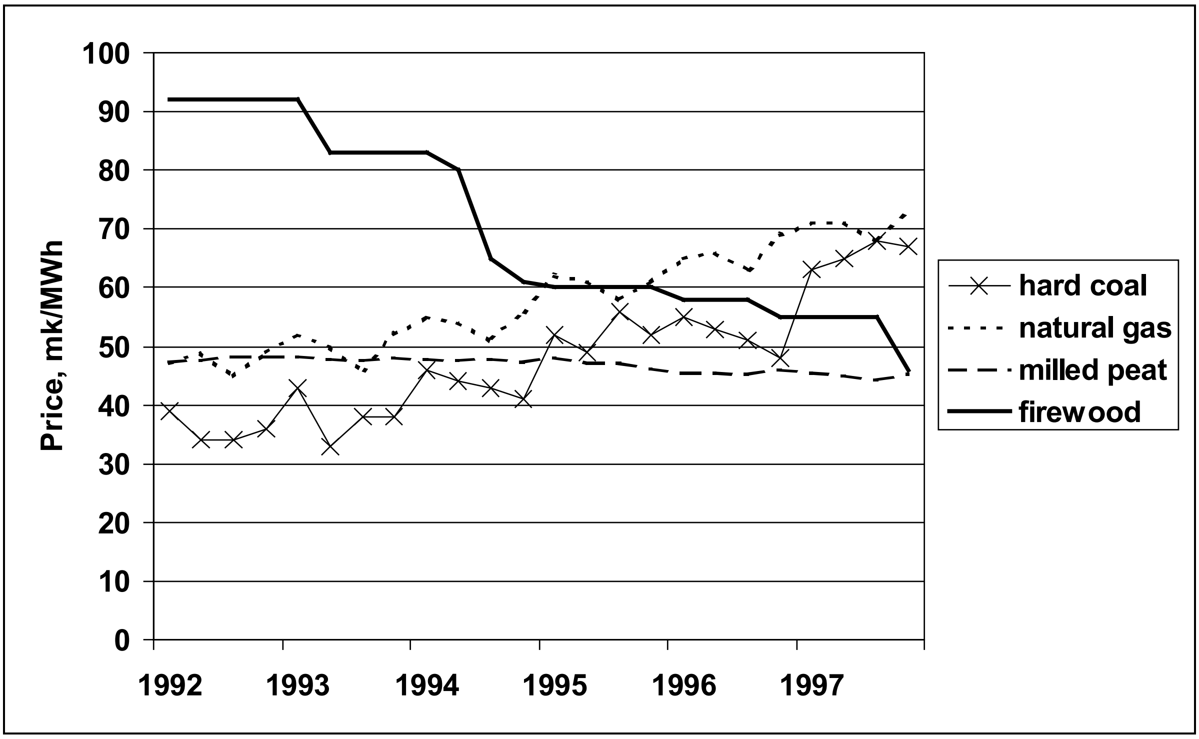
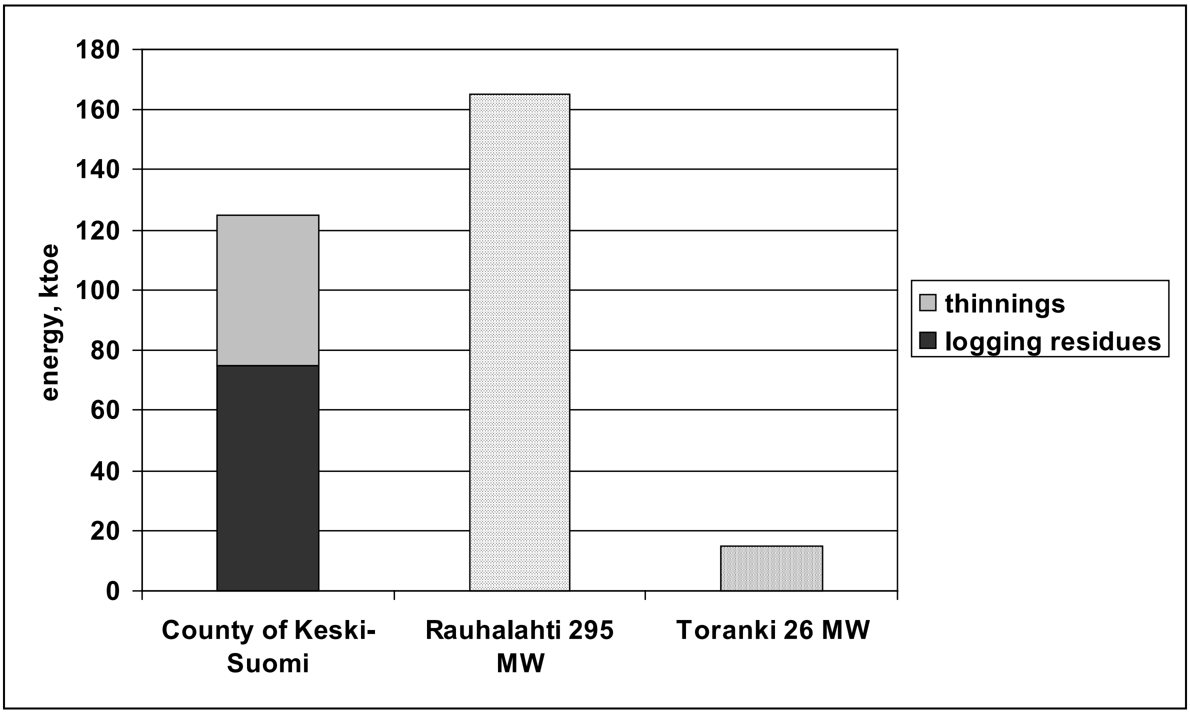


Figure 2. The production potential of the thinnings and the logging residues in the County of Keski-Suomi and annual fuel consumptions in Rauhalahti and Toranki power plants



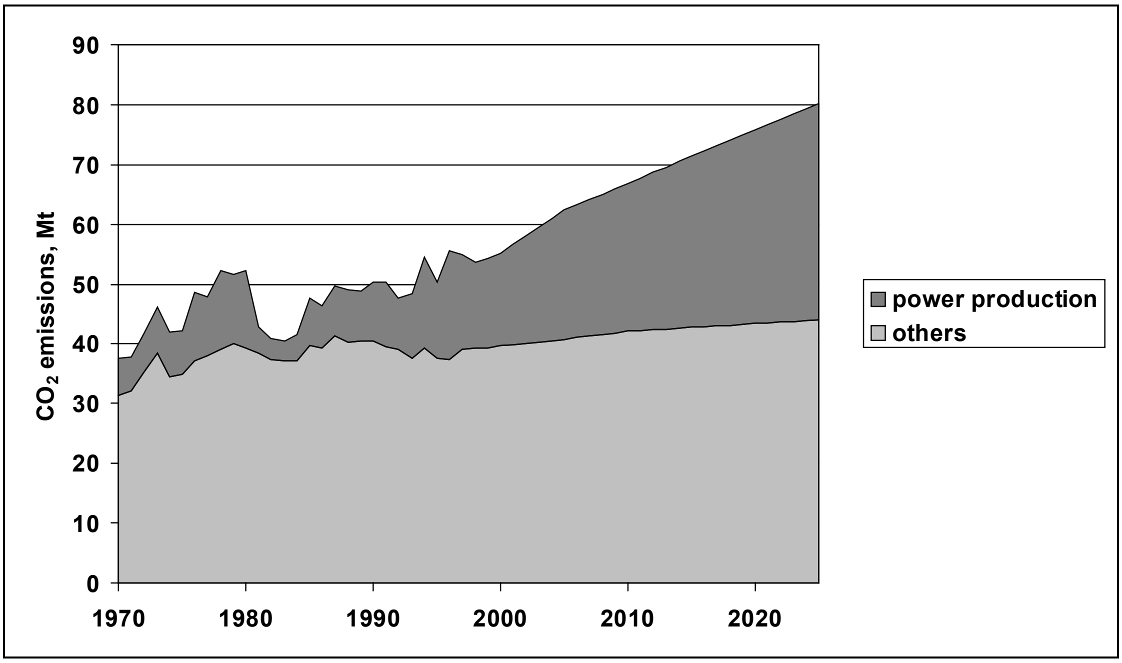
The wood fuels are widely considered environmentally friendly products as far as the forests are sustainably managed. Some of the customers prefer the green values of the products quite high in their decision making. The Finnish Association for Nature Conservation has brought a ecoenergy label to the market "(http://www.sll.fi/, in Finnish)". The wood based energy production is considered as ecoenergy in the ecoenergy criterias of the association. In the situation of the deregulated market, the growing demand of the green products could increase the competitiveness of the wood fuels.

Kyoto target

The European Community (EC) has committed to cut anthropogenic carbon dioxide equivalent emissions of the greenhouse gases by at least 8 per cent below 1990 levels in the commitment period 2008 to 2012. According to the burden sharing of the EC countries, Finland has committed to stabilize her aforementioned emissions.

The latest official energy scenario (pre-Kyoto) of Finnish energy market published by the Ministry of Trade and Industry is called the enegy market scenario (EMS) "(Energy Market 2025 - Scanarios)". In the EMS scenario the new base load power production is mainly based on the coal power. The estimate of CO_2 emissions in Finnish energy sectors is shown in the figure 3.

Figure 3. The estimates of CO_2 emissions from power production and other energy sectors in Finland for the energy market scenario



The use of conventional fuels in the Finnish electricity production in the recent years compared with the year 1990 is presented in the figure 4. The consumption of fossil fuels has increased considerably since 1990. One of the explanation for the trend is that 1990 was a better than average hydro power years for Norway and Sweden, therefore Finland imported a lot of electricity from Sweden. Another explanation is that the annual electricity consumption has increased more than 15% since 1990 in Finland.

Figure 4. The use of fuels in Finnish power production

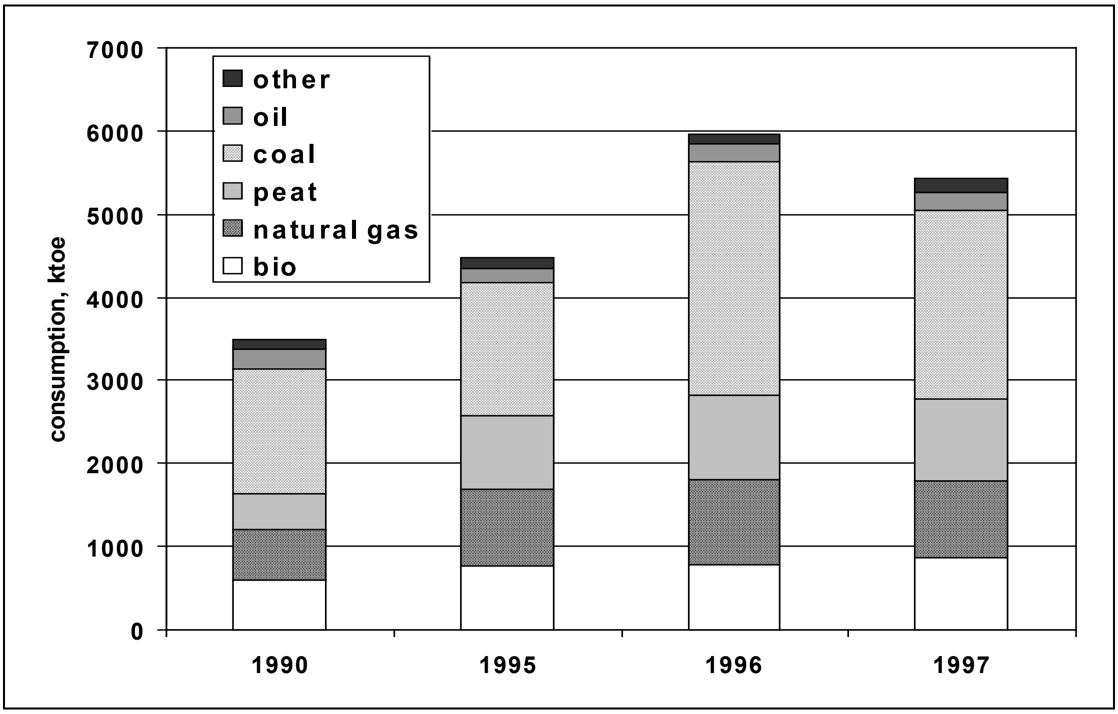
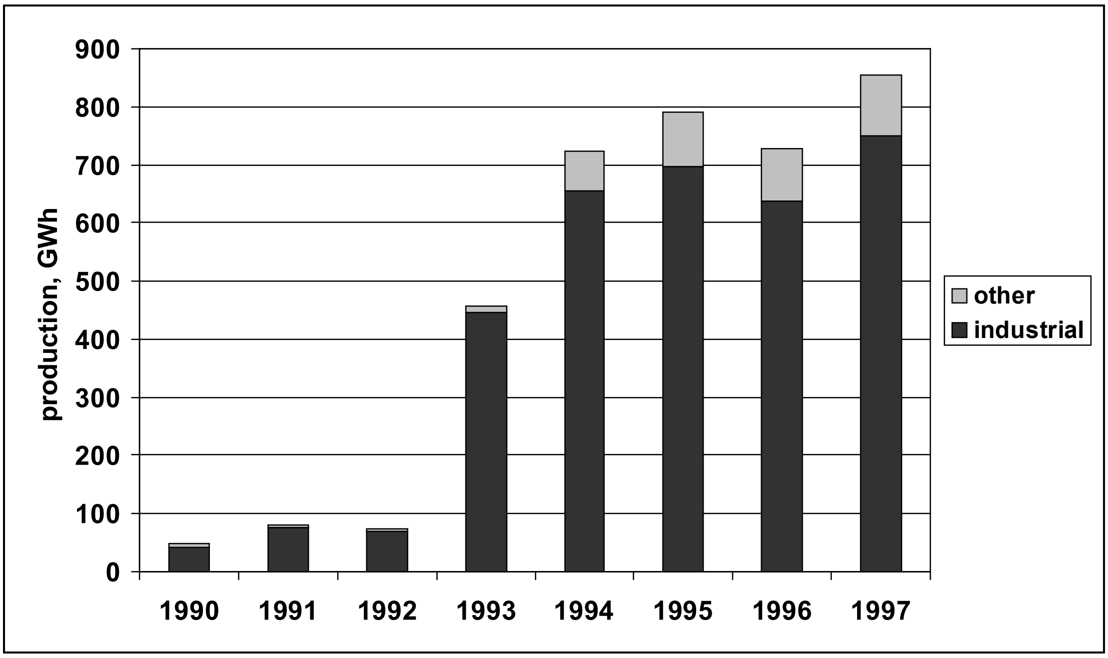


Figure 5. The estimate of IVO's biopower production in Finland



In the light of the EMS scenario and the latest statistics, it seems that the Kyoto target will bring challenging tasks for the power sector.

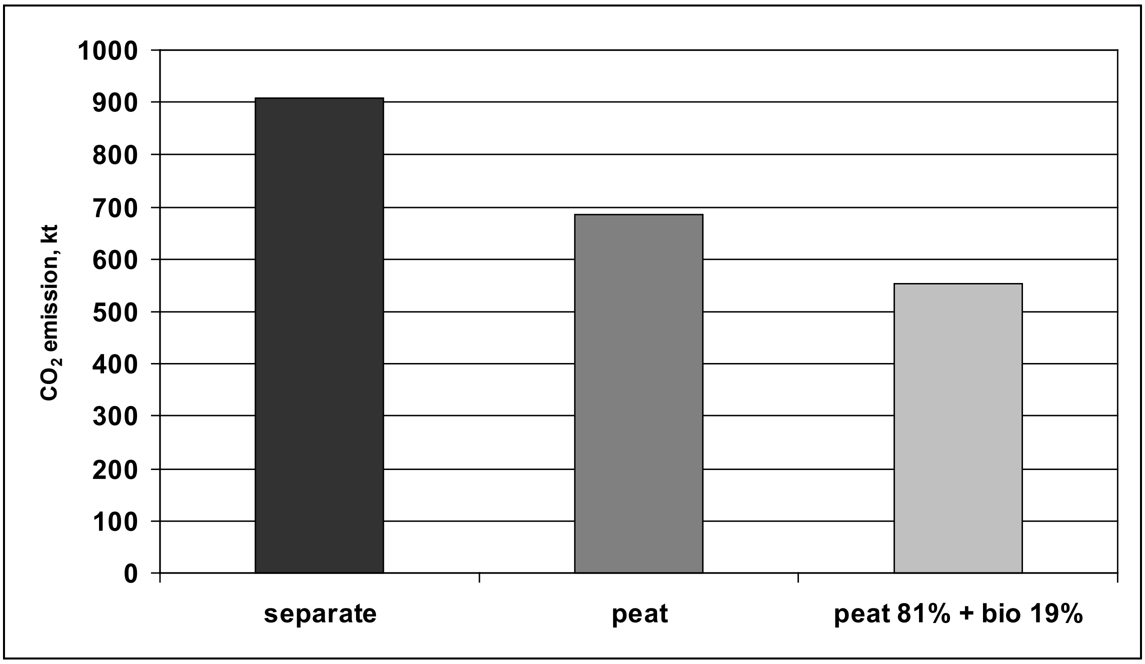
IVO AND BIOPOWER

The estimate of the IVO's biopower (electricity produced by wood based fuels) is presented in the figure 5. The share of biopower was about 4% of IVO Group's electricity generation in 1997. IVO's powerplants using biofuels range from large scale power plants like Rauhalahti to small scale plants like Toranki. Common aspect for almost all biopower is that it is produced in combined heat and power plants (CHP).

The co-operation with the forest industry has played an important role in the increase of IVO's biopower production. Most of the biopower have been produced in the industrial combined heat and power plants.

Rauhalahti power plant is an example of cutting CO_2 emissions by the efficiency of CHP production and using energy wood. The electricity production with the fluidized bed boiler of Rauhalahti power plant was 445 GWh and the heat production 1056 GWh in 1997, the corresponding fuel consumption was about 1795 GWh. Currently, the main fuel of the power plant is peat and wood is used as a co-fuel. The share of wood was about 19% in 1997. Assuming that the wood's net CO_2 emission is zero and 19% of the fuel consumption is wood and the rest is peat, the total CO_2 emission corresponding the fuel consumption of 1997 is about 555 kt. If the plant had only used peat, the emission would have been about 23% higher than in the case of 19% wood / 81% peat. Assuming that the efficiency of separate heat production is 85% and the efficiency of separate power production is 39%, the CO_2 emission of separate production by peat corresponding the productions of 1997 would be about 909 kt (64% higher than 555 kt), see also figure 6.

Figure 6. CO_2 emissions of 445 GWh electricity and 1056 GWh heat productions in three different cases



IVO has also a substantial Technology Centre, which employs 270 people. Renewable power production options are one of the research areas of Technology Centre. One example of IVO's R&D work concerning biomass products is that IVO has been cultivating energy willows at the Kopparnäs energy park since 1983. The growth and endurance of more than 250 willow species in the Nordic conditions have been tested on an area of 5 hectares. So far it has not been possible to generate economically competitive energy from willow.

CONCLUSION

Bioenergy has potential in cutting CO_2 emissions. The Kyoto protocol will bring a challenging target to Finnish power sector. It seems that all practical solutions are needed to reach the CO_2 commitments.

The wood fuel resources are limited especially outside the forest industry. It is hard to find enough wood fuels inside reasonable transportation distances for large scale power plants, but for small scale power plants there are plenty of wood fuel resources. But, large power plants equipped with new fluidized bed boilers can flexibly utilise wood as co-fuel.

The substantial increase of IVO's biopower production has been made possible by the co-operation with forest industry. The co-operation between forest industry and power sector has also potential in cutting the acquisition costs of wood fuels.

Bioenergy has green image, which gives biopower some advantage in the deregulated electricity markets. Wood fuel resources are not unlimited as it can be seen for example in the comparison of figure 2. Therefore, it is important to notice that the large scale use of wood fuels should be carefully organised and studied to avoid the unsustainable use of the resources.

REFERENCES

FINNISH MINISTRY OF TRADE AND INDUSTRY, 1997. Energy Market 2025 - Scenarios. Ministry of Trade and Industry, Energy Department, Helsinki 1997. (In Finnish)

FINNISH MINISTRY OF TRADE AND INDUSTRY, 1998. Energy review 1/98. Ministry of Trade and Industry, Energy Department, Helsinki. (In Finnish)

HELYNEN, S., NOUSIAINEN, I., 1996. Production and Consumption Potentials for Bioenergy. Ministry of Trade and Industry, Helsinki 1996. (In Finnish)

Potential impact of forestry initiatives on Canada's carbon balances

Discussion Paper of the Canadian Pulp and Paper Association

(presentation given by Doug BRADLEY;
see "List of Participants" in the Appendix for affiliation details)

The Canadian Pulp and Paper Association has prepared the following report which describes several carbon-sequestering forestry initiatives and gives estimates of their potential impact on Canada's carbon balance, using available data from empirical studies and current scientific thinking. The report is being presented as a discussion paper initially, to encourage discussion on the concepts and calculations. The C.P.P.A. intends to follow with a position paper, containing refined numerical estimates and also recommendations.

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FORESTRY AND THE KYOTO PROTOCOL

While direct reductions in GHG emissions will be a major focus for Canada, cost-effective options for fossil fuel reduction may not be sufficient either for Canada to achieve its target of 6% emission reduction by 2008-12, or anticipated additional targets in future commitment periods. Relying on fossil fuel reductions may require retooling our industrial and transportation sectors and/or a significant slowing of economic growth. The inclusion of offsets from forestry, and acceptance of their benefits, can make a substantial contribution toward Canada achieving its commitment, especially in the long-term, with less dislocation in industry and transportation.

Portions of Article 3 of the Kyoto Protocol, shown below, address how forestry can impact a country's net emissions. Article 3.3 specifies what land use change and forestry activities will be used in the accounting to adjust GHG emission reductions in the first commitment period. Article 3.4 specifies potential additional categories, to be negotiated, which may eventually be used to adjust reductions in GHG emissions in *subsequent* commitment periods, beyond 2012.

> **Article 3.3:** The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each Party included in Annex 1.......

According to the Canadian Forest Service (CFS), NRC , Article 3.3 specifies that ONLY human induced activities and ONLY those related to afforestation, reforestation and deforestation activities after 1990 will be used to meet Canada's quantified emission limitation and reduction commitments (QELRO) in the first commitment period. While the reference to afforestation, reforestation and deforestation appears limiting, these terms remain to be defined, and so far are open to interpretation. The amount of the offset will be the change in carbon stock from Jan.1 2008 to Dec. 31 2012, and the change must be verifiable. The increase in carbon stock will reduce a country's emissions reductions required to achieve its target.

> **Article 3.4:** ....The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules, guidelines as to how and which additional human-induced activities related to changes in greenhouse gas emissions and removals in the agricultural soil and land-use change and forestry categories shall be added to, or subtracted from, the assigned amount for Parties included in Annex 1. ....

Article 3.4 leaves open the possibility of adding activities to those in 3.3 through negotiation. Currently, any new activities will only affect a country's GHG accounting after 2012.

The Protocol does not attempt to address the global carbon budget. In considering only three activities, it ignores the huge GHG impacts of fire, harvesting and growth in pre-1990 forests. The following illustrates how narrow is the focus of the Kyoto Protocol. Canada covers approximately 1 billion hectares (land and water) of which 418 million ha. is forested and 117 million ha. is managed forest. Losses through fire and insects are a natural part of our forest makeup. Fires in Canada burn an average of 6.3 million ha per year releasing a large portion of the biomass carbon into the atmosphere, of the order of **1 billion** tonnes CO_2. Insect defoliation impacts about 4 million ha. p.a., but the Protocol considers neither of these impacts unless in forests grown since 1990.

Restrictive wording in the protocol may result in peculiar situations for accounting. For example, some interpretations suggest that for areas burned and subsequently reforested in 1991-2012, Canada would not be debited for the loss of carbon but would be credited for the average incremental growth occurring during the commitment period. However, we would be debited if a post-1990 forest burned during the commitment period.

A plain-language summary (T. Rockingham - Ontario Delegation) noted the agreement provides flexibility, adopting mechanisms to define different paths for parties to achieve reduction targets that recognize the benefits of offsets of forestry and agricultural initiatives to sequester carbon, while granting flexibility in how parties make and measure their emission reductions. Examples include emissions trading and clean development mechanisms that enable industrialized countries to finance emission-reduction projects in other countries and receive credit.

As indicated in Article 3.4, the Protocol allows for negotiations on what additional direct human-induced land-use activities related to agricultural soils and land-use change and forestry activities could be added to the current list of reforestation, afforestation and deforestation. Forestry activities that can increase carbon storage and might be open for negotiation include forest protection from fire, pests and disease, stand thinning and extending the life of forest products. While it is important to begin discussions on these activities leading up to COP4 in

November 1998, its is anticipated that the window of time for changes to the agreement could be years.

The Protocol specifies that the impact of afforestation, reforestation and deforestation since 1990 is to be measured as the verifiable change in carbon stock between 2008 and 2012, thus international understanding and agreement on how we measure forest volumes is required.

The Protocol also requires countries to have government policies and measures in place to reduce emissions, and requests that countries provide an indicative list of possible actions related to changes in greenhouse gas emissions and removals in the agricultural soil and land-use change and forestry activities, for future inclusion or exclusion at the fourth session of the Conference of the Parties (COP4), November 1998.

Canada is faced with three measurement requirements: 1) an annual inventory of greenhouse gas emissions and removals, 2) 1990 carbon sinks on managed forest land, and 3) by 2008, and annually thereafter, Canada will need to report changes in carbon stocks associated with reforestation, afforestation and deforestation. At present, Canada does not have complete time-series inventory data on changes in forest cover, wood volume or forest biomass. Currently, two general sources of information will be helpful in improving this situation – the Canada's Forest Inventory (CanFI) which is an estimate of Canada's forest and its general characteristics, and the Carbon Budget Model, which includes the stock of carbon in above and below ground biomass and soils and the exchange of carbon between these reservoirs.

As a basis for measurement, the C.P.P.A. proposes using growth and yield curves to measure volume growth. Such curves should be specific to the site, species, treatment and origin of the stands being accounted. Excellent information will be needed for Kyoto forest-sink calculations and verification. This data would enable foresters to model future growth more accurately, and be a valuable contribution to the knowledge base of a country so dependent on forest management and the manufacture and export of forest products.

FOREST GROWTH IMPROVEMENT

Below, we have addressed three ways in which forest growth can be enhanced: site productivity enhancement, new growth and yield data, and genetics. All of these can fall within the Protocol already, as they promote tree growth and can be measured in the 2008-12 period. It is important, however, that the benefits of these initiatives are understood and agreed to internationally. All the effects of these treatments and factors would be reflected in a well-designed growth and yield study.

Site productivity enhancement

Site productivity can often be improved by techniques such as fertilization and drainage. However, drawbacks currently render them infeasible throughout most of Canada, including high cost, significant fossil fuel CO_2 release (eg. during fertilizer production) and adverse environmental impacts (eg. drainage effects on stream quality). Furthermore, if site productivity enhancement involves rehabilitation of wet or dry ground, or low productivity, deciduous, brush, etc., these lands probably support some fibre (carbon) already, and are serving some purpose that limits their forest management potential. For instance, much of this land is environmentally sensitive, or fish/wildlife habitat, or riparian protected zone, or community watershed, or all of the above, and therefore is administratively and politically off-limits. Any land that is not supporting trees, and is feasible to manage, should fall under the afforestation category.

New Growth and Yield Data

Growth and yield, the study and quantification of stand development over time, may have some influence in assessing past or historic estimates of fibre volume growing on forested (managed for forestry purposes) lands, but mostly because past yield estimates used in determining annual allowable cuts (AACs) have been conservative. New data does not increase growth rates but does increase the verifiable estimates of growth. *"The State of Canada's Forests",* CFS*, 1997*, indicates an AAC of 232.9 million m^3 from a commercial forest area of 234.5 million hectares. Plantations and seeded stands in Northern Ontario (fairly typical f central and eastern Canada) are growing at 3.0 m^3/ha/year or better, and over 7.0 m^3/ha/year in the Maritimes. These growth rates may not be fully captured in provincial or national-scale statistics. Similarly, recent research of the past 5-10 years in BC and the Maritimes is finding that MAIs of most species and stand mixes are much higher than attributed in past. For example, current AAC/harvest in BC (including private lands) of about 75 million m^3 over 26 million productive ha gives an indicated MAI of 3.0 m^3/ha/yr, when the actual MAI figures from growth and yield work averages 4.0-4.5 m^3/ha/yr. It can be assumed that since 1990 there is greater standing volume than previously estimated. Good growth and yield data is essential for accurate forest modelling. It also would enhance the credibility of forest carbon sequestration projects and the verification of growth estimates.

Genetics

Next to afforestation, gains in tree growth rates due to genetic improvement may have the greatest potential to increase carbon storage over the long term. This is because tree breeding is designed to create more efficient (faster growing), plants for future planting over very large land areas. Incremental fossil fuel inputs to obtain improved seed are also comparatively low, thereby preserving most of the carbon gains. Programs are ongoing for most commercial tree species - particularly conifers - throughout Canada. First generation seed orchards began to yield operational quantities of seed in the early 1990's.

The tree improvement community, both researchers and practitioners, are in general agreement that volume increases of 10% (in the east) to 30% (in the west) will be achieved from first generation orchard seed, for all major commercial softwood species. Second generation programs, under initiation for seed delivery ca. 2025, will produce similar gains that will be <u>additive</u> to first generation improvements. Additional gains from genetic improvement will follow.

The national impact of these gains would be considerable. Over the past 15 years, Canada has annually planted or seeded an average of approximately 374,000 hectares (CFS, 1997). About 89% of this total, or 333,000 hectares, was planted (CPPA, 1991) - principally to conifer species that either have or will have supporting tree improvement programs. Based on consultation with forest industry staff in various locations across Canada, we can assume that at least 50% of our national planting program will employ seedlings arising from first-generation seed orchard seed by 2005. Assuming that plantations of these seedlings will grow 15% faster than the 3.0 m^3/ha/year (Heit, 1997) attributed to unimproved conifer plantations, the resultant growth benefit would be:

> 330,000 ha/year x 3.0 m^3/ha/year x 15% gain = 148,500 m^3/year
> assuming 330,000 ha/year. Current programs are running at 420-450,000 ha/year.

This volume can be expressed in terms of additional annual storage of CO_2 as forest carbon according to the following calculation:

CO_2 Accumulation = incremental bole wood volume x wood density (oven-dry) x bole to full-tree ratio x bole to soil and litter carbon ratio x carbon content of wood x CO2 t C weight ratio
= 148,500 m3/year x 0.45 tonnes/m3 x 1.2 x 2.0 x 0.5 x 3.667
= **294,056 tonnes per year.**

These incremental benefits apply to those areas planted with improved stock each year, and continue to accumulate additively on those areas each year that they remain in tree cover. Thus, assuming relatively constant programs, total national benefits would be about 294,000 tonnes in 2005, **588,000** tonnes in 2006, **882,000** tonnes in 2007, and so on.

In addition to the conifer program described above, localized opportunities for hybrid poplar planting exist in the southern regions of BC, the northern Prairies, Ontario and Quebec. Intensive tree breeding and testing efforts have produced clonal stock capable of growing at rates of 6 to 10 m^3/ha/year of bolewood, 25-40 m^3/ha/yr in Alberta and B.C. However, the scale of existing and future programs can be limited geographically by climate, Septoria canker, exacting soil requirements, and a requirement for intensive cultivation and weed control for several years after planting.

PRODUCT SUBSTITUTION

Global emissions of greenhouse gases (carbon dioxide, nitrous oxides, and methane) may be affected by using forest products instead of alternative materials with different life-cycle energy requirements. In three recent studies, scientific research confirms that wood is the most environmentally friendly material, is renewable, requires less energy to manufacture, produces much less air and water pollution and helps combat the greenhouse effect.

"Comparing the Environmental Effects of Building Systems" is the result of a 5-year research program involving architects, environmentalists, economists and engineers coordinated by Forintek Canada and Natural Resources Canada. Comparing alternative wood, steel and concrete structural designs, using energy and emission factors for these basic materials, the case study found that overall wood had the lowest environmental impact for all the factors

considered in the construction of an office building. The study found that the wood designs had the lowest greenhouse gas emissions, energy use, water pollution index, solid waste by-products and ecological resource use index. For example, the concrete design required 1.5 times the energy and the steel design used 1.9 times the energy of the wood building; similarly, the steel option generated 1.45 times more and the concrete building 1.81 times more greenhouse gases than the wood design.

The *"Study of Wood/Steel Substitution Effects on Greenhouse Gas Emissions in the Canadian Commercial Building Sector"* by the Athena Institute compared the energy savings and thus the greenhouse gas emissions reduction by substituting wood construction materials for steel construction materials for those commercial building application where wood could be a viable substitute. The case study compared alternative wood, steel and concrete designs for a series of structural assemblies common in small commercial buildings, and limited to the maximum size and height allowed by the *National Building Code of Canada*. These buildings include only those of less than 100,000 sq. ft. and four stories or lower in height, including religious, commercial, office, assembly, warehouse, lodging, schools and public buildings. The report concluded that, on an annual basis, wood substituting for steel would result in the use of about 2.2 PJ less energy and the emission of 0.2 MT less greenhouse gases (CO_2, NOx and CH_4). Carbon dioxide would account for 90% of the greenhouse gas reduction using CO_2 20 year equivalence methods for the other two gases.

If biomass fuel energy and emissions used in the production of wood products is discounted in this analysis, the overall net annual effect would be the use of about 2.5 PJ less energy and 0.23 MT less greenhouse gas emissions.

A second study by the Athena Institute, "*Energy Consumption and Greenhouse Gas Implications of Steel Substituting for Wood Framing in U.S. New Single Family Housing-1995*", estimated the impact on greenhouse gas emissions by comparing **all** new residential housing starts in the U.S. as steel construction versus all as wood construction. A more meaningful measure would be to estimate the emission impact of replacing with wood the current **proportion** of annual residential construction now using steel (less than 1%) . Athena estimated the greenhouse gas emissions from an average of 1.1 million wood housing starts at 7,910,004 tonnes CO_2 and equivalent. Assuming 1% steel construction, approximately today's level, would result in emissions of 8,313,098 tonnes, a difference of only 403,075 tonnes. Applying these findings to Canada, with annual housing starts of about 140,000, would result in an annual improvement of only 48,372 tonnes.

Therefore, for Canada, the annual combined impact of substituting wood for steel in all new housing starts (.05 Mt) and in all new commercial construction for which wood would be considered viable (.2 Mt) results in an annual emission reduction of only .25 Mt, not a large enough impact to pursue as a key strategy. However, policies that promote the use of concrete or steel instead of wood will have a small but increasing negative effect on Canada's ability to meet its emissions reduction target.

FUEL SWITCHING

Most of the biomass waste produced by the forest products industry is used for energy generation to supply process heat, steam or electricity, in the form of bark, waste wood, dewatered sludge, sawmill residues and process by-products such as pulp mill liquors. While much of this material is already used for fuel, potentially displacing fossil fuels, a significant volume is still disposed of in bark piles, waste burners and land fills. This volume could be used to further replace fossil fuels if the economic and policy environments were appropriate.

A study by Forintek, March 1998, estimates that roughly 5 million bone dry tonnes (MBDt) of surplus wood and bark residues are produced each year from Canadian sawmills, that are not already used for energy production. The majority of the estimated current level of surplus residues is in British Columbia and Quebec, BC - 3.2 MBDt , Quebec - 0.6 MBDt. Alberta is also a significant source of surplus residues. For the rest of Canada, there is insufficient data on current levels of surplus residue produced from sawmills. Residue levels were estimated for these areas by using established by-product yield factors to calculate residue production based on 1995 lumber production figures. The 5 million estimate is continually decreasing as residue utilization in cogeneration facilities increases. However, the estimate contains sawmill residues only, and does not include logging residues which are more expensive to access but are significant in volume. Environmental considerations may preclude the use of logging residues in energy production.

The carbon impact is calculated assuming that **all** of the remaining residues can be used as replacements for fossil fuel to generate steam and electricity, such as at pulp mills and sawmills where such residues are generated. Since not all residues can be used, this is an overestimate that is used for calculation purposes only. In the calculation below, biomass substitutes for natural gas.
(5 MM BD tonnes residue x 17.22 Gj/tonne ÷ 34.856 Gj/1000M^3 gas x .000724 tonnes gas/1000M^3 gas x 74% tonnes carbon/tonne gas x 44 tonnes CO_2/12 tonnes carbon =
4.85 million tonnes CO_2)

The result is approximately a **5** million tonnes p.a. reduction in CO_2 emission by substituting mill residue biomass for fossil fuels. The value would be reduced by any fossil fuel used to transport residue to burners, and may be adjusted further by the heat value of residues if different than the biomass factor used above.

It is acknowledged that this available biomass to generate process heat and energy may not replace fossil fuels in every instance, but when considered within the context of Canada’s overall energy generation and use, it is assumed that fossil fuels will be replaced by biomass where practical and cost effective. A variety of policy and fiscal changes will be required to make the use of biomass a financially attractive option, including; rapid write-off for biomass boilers, R&D to develop technology, and legislation to require hydroelectric commissions to buy surplus biomass-generated electricity at fair and attractive rates.

The simplest yet least intrusive way to promote the use of biomass as fuel is simply to adopt a renewable energy policy such as exists in California and other U.S. states. There renewable energy contracts exclude fossil fuels, large hydro and atomic energy from competition. Typically U.S. states limit these contracts to some fixed percentage of new acquisitions, for example the limit is set at 15 % in California.

ACTIVITIES CURRENTLY NOT IN THE KYOTO AGREEMENT

As indicated earlier, Article 3.4 of the Kyoto Protocol allows for future discussion and negotiation potentially to include ‘additional human induced activities which sequester carbon’ in subsequent COP agreements for GHG accounting. Examples of such human-induced activities include forest protection (from fire, pests and disease), spacing and thinning operations (which reduce rotation times and also replace fossil fuel usage) and extending the life-time of wood-products. All of these activities are included in the abstract ‘Sequestering Carbon in Natural Forests’- Binkley, Apps, Dixon, Kauppi, Nilsson-1995. However, the true benefits of such activities are often site-specific and may require considerable further study to quantify accurately. Any calculation must include all carbon impacts to be correct.

While there may be many such opportunities, G. Marland, Oak Ridge National Laboratories, U.S., has suggested that fine-tuning this Kyoto agreement may only result in further perversions to the total carbon system. As such, he suggests presenting two sets of carbon accounting; one set which includes ALL carbon effects, including sequestration initiatives not currently in the Protocol, and one set which only reflects activities IN the Protocol. Such a presentation would expose the shortfalls of the current Protocol and also illuminate those actions which perhaps should be included in later agreements.

Fire Protection

Fire is a natural but major factor in most Canadian forests, burning a significant percentage of our forests each year (1.5%). In 1994, 9,761 fires burnt 6.4 million hectares of our forests (*Canada's Forests*, August 1995), while the ten year average is about 9,600 fires p.a. burning 3.0 million ha. p.a. Fires cause the direct release of carbon to the atmosphere, since wood is 50% carbon, and also cause the release of nitrogen oxides and combustion driven methane from the forest. Protection from forest fires thus prevents considerable emission of CO_2.

Considerable resources go into containing fire. In the commercial forest, an average of 736,000 ha. have burnt annually. 93% of forest fires received full response from fire fighting resources, while 7% were left to burn naturally. Fires that did not receive full response burnt 27 times more area of forest than those that did receive full response. On this basis, 6 million ha. of forest has been saved from fire annually which, assuming 240 tonnes CO_2 per ha., has prevented the emission of 1.4 billion tonnes CO_2 p.a.

It is argued that our fire fighters are doing a good job, and that further prevention may be undesirable, impossible or economically infeasable. Effective fire management raises the level of carbon storage but also extends the age class structure of our forests, leaving them more open to disturbances such as pests, disease and catastrophic fires. Also, a certain level of natural burning may be desired to preserve certain natural processes, such as the periodic cleansing of pathological agents. Some concerns have been expressed that global warming is contributing to an increase in the severity of fires in Canadian forests.

From the point of view of C storage, fires may be categorized into two types: non-stand replacing and stand-replacing. Stand-replacing fires are dramatic events having locally catastrophic effects leading to complete mortality of the overstory. Large, intense conflagrations are the dominant type of fire in many boreal systems (Apps & Kurz, 1993).

The effects of these fires are:

i) to redistribute carbon amongst the various ecosystem pools;
ii) release carbon to the atmosphere as CO_2 and other compounds including CO and CH_4;
iii) change the forest structure as the stand age is "reset" and seral succession is restarted.

To protect and enhance carbon sinks and reservoirs is a commitment of the Framework Convention on Climate Change, however, protection against fire is not largely taken into account in the Protocol. While credit for successful protection is a good thing, being debited for a natural and unpreventable fire is not. It may be that a meaningful solution to promoting fire control is by developing a baseline for fires where losses below a baseline would be considered as a credit.

Pest and Disease Control

Insects are one of the dominant causes of disturbances in most of Canada's forests. An estimated 11.6 million hectares, representing 2.8% of Canada's total forest land, was affected by insect defoliation in 1994.[1] In the commercial forest 6.8 million ha was lost to insects or disease in the 1979-93 period, or 523,000 ha. p.a. (*State of Canada's Forests- 1995-96, CFS*).

Insects often cause temporary but moderate-to-severe defoliation. For example, Canada's National Forestry Database (CFS, 1997) indicates an average annual moderate-to-severe defoliation by spruce and jack pine budworm of 20.5 million hectares. Studies by CFS (Gross, 1992) of moderate-to-severe jack pine budworm defoliation in Ontario found an average of 30% annual growth loss in each year of the infestation. Assuming a similar pattern for spruce budworm, annual growth losses in the order of 18.5 million m^3 of softwood (20.5 million hectares X 3 m^3/ha MAI X 30% loss of increment) may occur across Canada in an average year. On a full-tree basis, this is the approximate equivalent of 18 million tonnes per year of CO_2 per annum. Assuming that one-third of this area could be sprayed annually with biological insecticides, uninterrupted carbon sequestration of an additional **6** million tonnes of CO_2 could be realized.

Juvenile Spacing

Spacing is the deliberate removal of excess stems from overstocked stands of young trees (age 10-14 years) in order to reduce competition for space, light, water and nutrients. Spacing allows the live crown area to expand and results in enhanced growth of the remaining trees on productive sites.

[1] The predominant insect pests in Canada are spruce budworm, jack pine budworm, hemlock looper, mountain pine beetle, gypsy moth and forest tent caterpillar, however there are significant regional variations. The population dynamics of these species vary greatly, for instance the spruce budworm is the more prevalent insect in the forest regions of the Manitoba/Ontario border, and the mountain pine beetle occurs predominantly in western Canada, specifically in BC and Alberta.

There is independent evidence specific to jack pine on highly productive sites that suggests spacing results in an average of 15% higher volume than in unspaced control sites. Examples include a Plonski Class 2 site in Sewell Township, Ontario, and a Class 1 site near Nipigon, Ontario (Haavisto, 1995). Results are controversial however, since many sites produce larger diameter stems and higher lumber yield but no proven increase in overall biomass. As a result, increased site biomass is NOT assumed for this analysis.

An undeniable benefit however is that larger tree diameters due to spacing allow harvest operations to occur with the same yield at age 45-50 instead of the normal 70-75 years on control sites. Early harvesting enables three rotations per 150 years that would normally only produce two rotations in the same time frame. This means that harvested trees can be converted to long term carbon storage (lumber) three times instead of two, followed by immediate reforestation of the site.

In Canada today, approximately 375,000 ha. p.a. are undergoing stand tending to remove competition, largely juvenile spacing. In the long term, because of reduced rotation, these sites will produce the same amount of forest products as 560,000 ha. of unthinned sites do today.

According to “Sequestering Carbon in Natural Forests” (above), shortening rotations can make a positive sequestration contribution in the long term (20-50 years), and controlling stand density by thinning can sequester carbon in several ways, depending on both the type of thinning and the fate of the thinned biomass. Thinning to waste, where thinnings are left on-site to decay, would generally be neutral to negative in terms of carbon sequestration. As such, benefits related to spacing must ensure that all carbon impacts are reflected.

Commercial Thinning

Commercial thinning is the activity of harvesting a certain portion of a stand before rotation age. Increasingly, Canadian forestry companies are carrying out commercial thinning operations as a means of improving yield and timber quality. In Europe and many countries of the world, thinning is a routine silvicultural practice. Despite many well-documented thinning trials and experiments, thinning has only been practised at an operational scale in Canada during the last decade.

Commercial thinning has now become a major source of fibre in Eastern Canada, where some of the more progressive forest management companies, such as J. D. Irving, are now obtaining 40% of their wood furnish from thinnings. In Nova Scotia, where an estimated average of 900 hectares of commercial thinning was carried out between 1991-1995, it is projected that up to 5,000 hectares of commercial thinnings will be carried out within the next five years. The principle increase in yield in Ontario in the 1990s and beyond may well be from thinnings.

The Crop Planning method for forest crops grown silviculturally was introduced in 1986 in Ontario to address the lack of growth and yield tables and growth models. This method conservatively assumes that unthinned and thinned crops grown in Canada will produce yields equal to those presented in normal yield tables for the very dense, unmanaged natural stands (e.g., Plonski).[2]

In the paper *Principles of Thinning for Improved Growth, Yield and Economic Profitability of Lodgepole and Jack Pine,* the Crop Plan method is applied to lodgepole grown on 62-year rotations without thinning and with two thinnings, and for Jack pine on a 52-year rotation without thinning and with three thinnings. The findings show that thinning greatly increases the yield of both species, comprising 30% and 38% of the total volume production of the thinned lodgepole and Jack pine crops respectively. Thinning salvages a significant volume that would otherwise be premature natural mortality.

While thinning does not result in a greater amount of standing biomass at rotation age, it does result in a considerably higher yield over a rotation period, as a result of the thinnings and a similar end-of-rotation harvest. The carbon benefit of commercial thinning can be very roughly calculated either as the additional amount of biomass taken from a site over a rotation, or conversely, a fewer number of hectares required to produce the same amount of forest product thus leaving other forest reservoirs standing.

In the above study, Jack Pine and Lodgepole pine produced an average of 128 M^3/ha. of additional biomass over a rotation. While today in Canada thinning is done on a relatively small scale, it is anticipated that such activity will be ramped up in future to the order of 200,000 ha. p.a. This level of thinning would produce an additional 26 million tonnes of biomass over one rotation that would not have to be harvested elsewhere, representing approximately **25** million tonnes of CO_2 p.a. that would not be emitted.

REFERENCES

A Framework for Canada's National Circumstance Related to Climate Change. Unpublished report prepared for Environment Canada. March 1997.

A Plain-Language Summary of the Kyoto Protocol. T. ROCKINGHAM, Ontario Delegation, Canada. Article, FCCC/CP Internet site. December 10, 1997.

A Plot-based National Forestry Inventory Design for Canada. G. BONNOR and S. MAGNUSSEN, Essa Technologies Ltd. Unpublished report prepared for CPPA. December 1997.

A Summary of the Role of Forest Products as Carbon Pools. W. A. KURZ and S. J. BEUKEMA. Unpublished report prepared for CPPA. September 1998.

Afforestation and CO_2 Storage: Towards a National Program. M HEIT.Unpublished report for CPPA. December 1997.

[2] Stand density is the single most important factor affecting the amount and quality of timber produced by a given tree species on a given site. This is particularly true for lodgepole pine, which can regenerate and survive at extremely high densities following wildfire or logging.

Can Afforestation Contribute to a Reduction in Canada's Net CO_2 Emissions? R. D. GUY and A. BENOWICZ, Faculty of Forestry, University of British Columbia. Unpublished report prepared for CPPA. March 8, 1998.

Canada's Emissions Outlook: An "Events-Based" Update for 2010 - Working Paper. Internal Document for Natural Resources Canada. October 1998.

Canada's Second National Report on Climate Change: Action to Meet Commitments Under the United Nations Framework Convention on Climate Change. Environment Canada. Published May 1997.

Canada's 1996 Greenhouse Gas Emission Summary - Draft. Internal document prepared for Environment Canada. October 1998.

Comparing the Environmental Effects of Building Systems. A Case Study by the Athena Project. Unpublished document prepared for the Canadian Wood Council, 1994

Criteria and Indicators of Sustainable Forest Management in Canada. Unpublished technical report prepared by the Canadian Council of Forest Ministers for Department of Natural Resources Canada/Canadian Forest Services. 1997.

Energy Consumption and Greenhouse Gas Implications of Steel Substituting for Wood Framing in U.S. New Single Family Housing. Unpublished document prepared for CPPA, 1995.

Estimate of Surplus Sawmill Residues Produced in Canada. K. GROVES, Forintek Canada Corporation. Unpublished study prepared for CPPA. March 1998.

Greenhouse Gas Initiative: A review of Solid Wood Consumption in Selected Residential, Commercial & Agricultural End-Uses. Unpublished report prepared for the Canadian Wood Council. September 1998.

Harvested Wood Module: A Methodology for the Estimation of CO_2 Emissions from Harvested Wood. Land-use Change and Forestry Expert Group, IPCC. 1997.

Increased Use of Wood Residue for Energy. Unpublished report prepared by MWA Consultants for CPPA. August 1998.

Kyoto Protocol to the United Nations Framework Convention on Climate Change. United Nations. December 1997.

Land Use Change & Forestry in Canada: An Estimate of Net GHG Emissions for 1990. Unpublished report, Environment Canada. May 1997.

Preliminary Estimates of Carbon Sequestration from Reforestation - Draft. Internal document, Natural Resources Canada. February 20, 1998.

Principles of Thinning for Improved Growth, Yield and Economic Profitability of Lodgepole and Jack Pine. R. J. DAY AND D. M. NANANG. Faculty of Forestry, Lakehead University, Ontario, Canada. Abstract, 1997.

Sequestering Carbon in Natural Forests. M. J. APPS, C. S. BINKLEY, R. K. DIXON, P. E. KAUPPI, and L. O. NILSSON. Faculty of Forestry, University of British Columbia, Canada; Canadian Forest Service, Edmonton, Alberta; United States Environmental Protection Agency, Washington, DC; Finnish Forest Research Institute, Helsinki, Finland; Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala, Sweden. 1997.

Some Technical issues regarding land-use change and forestry in the Kyoto Protocol. B. SCHLAMADINGER and G. MARLAND, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, USA. Draft. E-mail: uvu@ornl.gov . March 4, 1998.

State of the World's Forests. United Nations Food and Agricultural Organisation (FAO). Rome, Italy. 1997.

Study of Wood/Steel Substitution Effects on Greenhouse Gas Emissions in the Canadian Commercial Building Sector. Unpublished report prepared by the Athena Group (Forintek Canada Corporation) for CPPA. 1998.

The State of Canada's Forests - 1995-96. Canadian Forest Services/Natural Resources Canada. Published 1996.

The Canada Country Study: Climate Impacts and Adaptation. Internal document, Environment Canada. 1997.

The Decomposition of Forest Products in Landfills. J. A. MICALES and K. E. SKOG, United States Department of Agriculture (USDA) Forest Services. International Blodeterioration & Biodegradation. Vol.39, No. 2-3, Blsevier Science Ltd, 1997

The growth and yield of commercial thinning in pre-commercially thinned softwoods. T. McGRATH. Canadian Forest Industries. CPPA Woodlands Forum Paper. November/December 1997.

Trends in Canada's Greenhouse Gas Emissions 1990-1995. Environment Canada. Published April 1997.

T*urning Down the Heat: Emissions Trading and Canadian Implementation of the Kyoto Protocol.* C. ROLFE. West Coast Environmental Law Research Foundation, Canada. Published May 1998.

Wood Used in Non-residential Construction. Unpublished study prepared by Wood Products Promotion Council for CPPA. 1985.

Project-based greenhouse gas accounting: guiding principles with a focus on baselines[1]

(Final Draft)

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INTRODUCTION

The United Nations' Framework Convention on Climate Change (UNFCCC, 1992) states in Article 2 that its ultimate objective is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner."

The UNFCCC obliges the Parties to the Convention to inventory and report their anthropogenic emissions by sources and removals by sinks of greenhouse gases (hereafter simply referred to as net emission of greenhouse gases). At the Third Conference of the Parties to the UNFCCC (1997 in Kyoto, Japan) the parties agreed to "quantified emission limitation or reduction commitments" for those 38 developed countries, or countries with an economy in transition, listed in Annex B to the Kyoto Protocol (UNFCCC, 1997). The protocol does not impose limits on emissions from those countries not specifically listed in Annex B.

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[1] An extended version of this paper, in which the baseline principles elaborated here are applied to selected case studies, is in preparation. Comments on this paper would be appreciated.

Ratification of the Kyoto Protocol would put in place a set of mechanisms assumed to facilitate the reduction in net greenhouse gas emissions through a credit/debit system for activities in a potentially wide range of economic sectors and for cross-border transactions. Examples of these mechanisms are joint implementation activities between Annex B countries (Article 6); joint activities[2] between Annex B and non-Annex B countries (Article 12); and emission trading between Annex B countries (Article 17).

Although the Kyoto Protocol prescribes targets for reduction of greenhouse gas emissions in terms of the 1990 levels of emissions, some articles of the Protocol (Articles 3.4, 6, and 12) call for baselines against which the achievements of specific activities can be compared.

Baselines are clearly required for implementation of Articles 6 and 12, will probably be required for implementation of Article 3.4 (land-use change and forestry - LUCF - activities beyond the limited list of activities already prescribed in Article 3.3), and may be required for within-country guidance to motivate or allocate compliance with national-level commitments. The concept of ‘additionality’ is explicitly raised in Articles 6 and 12 where credit is limited to reductions of emissions that are additional to any that would occur in the absence of project activities.

The role of baselines, however, differs between the various articles. Projects under Article 6 are a ‘zero-sum game’, reducing the assigned amount of one country while increasing the assigned amount of another to the same extent. In contrast, projects undertaken under Article 12 have an impact on the total obligation of Annex B countries, because the obligation of these countries is reduced as a result of emission reductions in non-Annex B countries. Thus, the baselines play a more important role in Article 12 projects.

Here, we articulate four basic principles that can be used to guide the construction of baselines for greenhouse-gas mitigation projects. We point out that there are many challenges in constructing useful baselines but that a conscientious application of these principles will help to assure appropriate credits to projects that serve the objectives of the UNFCCC.

BASIC PRINCIPLES FOR BASELINES

Apps et al (1997) have suggested carbon accounting principles for LUCF projects and the IGBP (1998) has discussed carbon accounting methodologies for LUCF. There remains, however, the difficult task of establishing activity-specific reference levels (baselines) against which credits and debits can be allocated. As a number of authors have pointed out (e. g. Chomitz 1998, Tipper 1998), selection of the baseline can significantly affect the credit allocation resulting from a project. Recognizing that it will be exceedingly difficult to establish suitable baselines for many emission reduction projects, we suggest that there are a few basic principles that could be used to guide the selection of appropriate baselines.

To accommodate the accounting needs of different activities, we adopt a general definition of ‘baseline’ as *“a path through time that an accounting variable would have followed in the absence of a specific greenhouse-gas mitigation activity.”* It is, of course, impossible to know the exact route of the path not followed so the challenge is, for each project, to provide a credible description of its most probable route.

[2] Defined as a clean development mechanism.

We suggest that baselines only have meaning within the broad context of the greenhouse gas accounting system employed. Our goal here is to articulate a set of basic principles that can guide the development of scientifically sound and technically useful baselines for greenhouse gas emissions mitigation. Although our main interest is on biomass-related activities, the principles suggested here should be broadly applicable across all types of mitigation projects and activities.

We recognize that there may be basic principles (such as issues of equity) that transcend the scientific and technical ones, but these are beyond the scope of this technical paper. A primary consideration in the selection of baselines must be their efficacy in helping to achieve the ultimate objective of the UNFCCC, stabilization of greenhouse gas concentrations in the atmosphere.

The first three principles discussed below suggest that baselines should be accurate, comprehensive, and conservative. These principles must be balanced against the fourth principle, practicability, by acknowledging that excessively stringent application of the first principles can discourage implementation of projects and activities that may serve the objective of mitigating the increasing atmospheric concentration of greenhouse gases.

1. Accuracy

A baseline should provide an accurate description of the path of net emissions in the absence of a purposeful intervention. Had not a project been implemented, what would have been the net emissions of greenhouse gases?

We suggest that an accurate enumeration of the full set of net emissions in the baseline is more critical than a precise statement of any portion of the emissions. Precision can be refined and improved once an accurate description is provided. The system description should be as simple as possible. We recognize that data and expertise may constrain the desired accounting - and that we might be obliged to accept this, at least in an initial phase of implementation of the different mechanisms.

It is often perceived that a baseline is a static scenario (determined before the start of a project) against which the performance of a mitigation project is to be measured. However, to avoid unexpected outcomes that run counter e. g. to the UNFCCC objectives, the baseline could be amenable to updating on some regular basis or if it is discovered that there is some error or misconception in the input to the baseline estimates. From a practical point of view, however, the baseline cannot be subject to continual revision; it must have sufficient definition that the project is not continually measured against a weakly defined moving target.

It may be possible to define (in advance) a baseline in the way that a scientific experiment would define a reference treatment. In this way, measurement and verification would evaluate both the treatment and the control and would credit emission reductions according to the difference between the two. This latter approach might be especially appropriate for energy efficiency programs and the approach has already been used broadly for demand-side management projects (Chomitz, 1998). The project scale, however, may limit the application of a control group because large-scale projects may have an influence on the whole sector studied, e. g. retrofits to a large power plant may influence the total national power supply, creating new baseline circumstances.

A baseline for a biotic project may have to consider stochastic changes in variables that have low probability and are beyond the control of the participants, such as damage by weather or insect outbreaks. Control treatments may be less useful here, as stochastic variables with low probability require a large number of independent control and treatment areas. More generalized values based on established and accepted research results may have to be used instead. The stochastic changes in variables will also vary between different biotic projects. Projects located in wet areas and in areas largely surrounded by non-forest areas might be less affected than those located in non-managed forest areas in boreal regions.

Technology improves in incremental ways even in the absence of a mitigation project. Hence, a realistic baseline might converge toward the project technology over time. New technologies will replace old ones, though perhaps at a slower rate than might be achieved through the motivation of mitigating emissions of greenhouse gases. The technologies available and their progress will also depend on the socioeconomic conditions of the countries considered.

While desirable that the baseline be fixed for the duration of a project, it is difficult to provide an accurate description of the path-not-followed over longer periods. Thus to maintain consistency with the UNFCCC objectives, the baseline might have to be revised during the project. One might even envision cases where large investments in a mitigation project are stranded by improvements that result in better alternatives. In such instances a credible baseline may eventually have lower net emissions than the ongoing mitigation project.

2. Comprehensiveness

An ideal baseline should be comprehensive in the sense that it captures all important consequences of alternative, “without project” activities. Thus, the baseline should also consider secondary effects outside of the immediate project. For example, in a forest protection project we would need to consider if wood fuel was produced from that forest earlier and used to displace fossil fuels. Thus, the project case should provide at least the same goods and services as the baseline case. This means that we have to carefully define the system boundaries (both in space and in time) for the system that will be affected by a mitigation project or activity. Some important questions hence arise about leakage across the system boundaries and the extent to which specific project activities have impacts in the larger socio-economic system.

2a. Spatial boundaries

Accounting for a mitigation project should ideally demonstrate that all significant impacts on net greenhouse gas balances are included within the defined system boundaries. Leakage between Annex B and non-Annex B countries is especially important to consider because such leakage is not captured by the emission limitations of Annex-B countries. Accounting systems should be equally appropriate across a range of spatial scales in order to avoid unintended artifacts. With international commitments being made at the national level, accounting at the project level should be such that it is compatible with national level reporting.[3] The selection of a baseline may influence the perceived benefits at these various scales differently. Thus, what is good for a specific project operator may not satisfy the national objective, which in turn may

[3] Andrasko has proposed a method to address the monitoring edge effects in the intersections of project and national scales (Andrasko, 1997).

not be the optimum solution from the global perspective. Recognition and reconciliation of these scale dependent issues need to be a part of the creation and selection of baselines.
Some of the difficulty of project baselines can be avoided with the use of national or regional (top down) baselines. Baselines at this scale require, however, some forecast of national or regional greenhouse gas emission levels and hence of the development of the energy (or other) system. Thus, such baselines of greenhouse gas emissions will depend on the availability and cost of resources and technologies and on policy measures used to shape energy systems, economic growth, and the structure of the economy - all of which change with time. While these are admittedly obstacles to establishing top down baselines, some observers suggest that national (regional) baselines are needed because they may capture leakage between sectors or between project and non-project activities.

2b. Temporal boundaries

Mitigation measures can affect greenhouse gas emissions beyond the temporal boundaries of a project as well as beyond its spatial boundaries. Reductions of net carbon emissions (for which credits are received) can potentially be reversed at later times, with an associated increase in net emissions. In setting baselines we need to recognize the temporal characteristics of mitigation measures. At least two basic circumstances can be envisioned in which temporary boundaries play an important role: the project path converges on the baseline or the baseline path converges on the project.

(i) The project path of net emissions may converge on, or even surpass, the baseline. The carbon mitigation achievements of a project may, for example be subsequently lost to fire or harvest after the carbon credits were received. In most cases this is not a problem for avoided fossil fuel emissions because of the very long residence time of the fossil fuel pools. For biotic mitigation projects this does present potential problems as the carbon turnover times are much shorter and emissions offset by sequestration in such reservoirs have a temporary character (IGBP, 1998). This suggests that we need to recognize that the reductions in net emissions depend in part on the residence time of the reservoir in which carbon is sequestered. For afforestation or reforestation projects the accounting system (and baseline selection) must be able to assess the post-project fate of any carbon stock. To do otherwise at the project scale could potentially undo the global-scale benefits to the atmosphere.

The risks of temporal leakage of sequestered carbon could be reduced if the accounting system ensured that one of the involved parties (with commitments under the Kyoto Protocol) is responsible for a continued stewardship of sequestered carbon. Concepts for minimizing impacts in the absence of continued stewardship include insurance coverage for credited carbon stocks and/or reduced credit for more vulnerable carbon stocks.

(ii) The carbon mitigation achievements of a project can get smaller over time as the baseline of net emissions moves closer to or even below the project case. In an energy efficiency project, for example, some years after the project initiation even greater improvements in energy efficiency might become a general requirement, e.g. due to new building standards.

In both cases project operators could be tempted to choose the project duration such that benefits occur within the project duration, but net losses are beyond the temporal boundary. Temporal boundaries, and baselines, have to be extended far enough into the future to include these effects.

2c. Other objectives

Baselines that encourage projects that run counter to goals like prevention of acidification and soil erosion, protection of biodiversity, or sustainable development of local economies are more unlikely to be implemented. In contrast, projects that contribute to local welfare, including for example job creation and transfer of technology and know how, and are seen to provide multiple benefits will be more likely to succeed. Projects may even be designed to achieve multiple benefits where the climate benefit is only an add-on to other positive outcomes. Thus, baselines will need to acknowledge objectives other than greenhouse gas reduction.

3. Conservativeness

Activities that involve selling and buying of net emission reductions will be evaluated in financial terms, and a large reduction of net emissions will improve the financial terms of projects. Larger reductions will benefit the seller (as his project will be more profitable) and the buyer (as his commitment will be more easily and cheaply fulfilled). Thus, there are strong incentives for both sellers and buyers to overestimate the net emission reduction by establishing artificially high baselines and baselines that are easy to manipulate (Chomitz, 1998; Michaelowa, 1998). The opportunity to trade reductions may even effect projects that would have been carried out in the ordinary course of business. Here, baselines may be selected which would give such projects an appearance of additionality. Similarly, the large uncertainty of several parameters influencing the financial terms (e.g., discount rate, lifetime of activity and value of local environmental impact) may lead to manipulation of project evaluation (Chomitz, 1998). Finally, the overall evaluation will depend on national policies, which could change during the duration of a project. These all add to the difficulties of selecting appropriate baselines and call for conservativeness.

Therefore, it should be shown with sufficient confidence that the credits for emission reduction do not exceed improvements for the global system. The choice of baseline should tend to be “greenhouse gas conservative”. A conservative accounting should make involved parties responsible for demonstrating that the chosen baseline results in claimed credits that are less than or equal to the mitigation effects that occur.

3a. Partial accounting

For reasons of convenience, simplicity, cost, or small numbers, some components of the total system are likely to be omitted in any practical system. If the conservative principle is adopted using the above approach for example, wherein it is demonstrated that the omitted components are not a net source of greenhouse gas emissions, use of the partial accounting system would not be in conflict with the objective of the UNFCCC. Similarly, in cases where the baseline is highly uncertain or where the sequestered carbon is believed to be vulnerable to loss, it might be appropriate to transfer only a predefined share of the estimated credits. Finally, for ease of implementation a default, but conservative baseline could be used without contravening the objectives of the FCCC until such time as the country or project can develop a justifiable, project-specific baseline.

3b. Project portfolios and multiple baselines

A portfolio of different types of projects with different types and levels of uncertainties can decrease the overall risk compared with a single project. Multiple baselines might be used to indicate the level of uncertainties and to assess the risk for a single project. They may include a range from optimistic to pessimistic scenarios. To be conservative, the greenhouse gas accounting could be based on the pessimistic scenario. If it is possible to show during the project that the greenhouse gas reduction is actually greater, then this enhanced level of reduction could be credited (SGS, 1998).

3c. Windfall reductions

An issue that arises is whether baselines should be set to avoid awarding credits for fortuitous or windfall reductions that have not been a direct result of project activities (e.g., beneficial effects of CO_2 fertilization, climate enhanced growth). Similarly, should debits be allocated for unavoidable shortfalls that are beyond project level control (e.g. disturbances exacerbated by climate change)? The concept of additionality suggests there should be neither credits nor debits for such events. Thus, to ensure that only the improvements due to "direct, human-induced activities" are counted and credited, the baseline should include such windfall effects to the extent possible.

4. Practicability

From the UNFCCC perspective, the rules for definition of baselines should favor projects that yield real, measurable, and verifiable reduction in net emissions but discourage projects that do not. The baselines should be accurate, comprehensive, and conservative. Project baselines should be verifiable so that they can be accepted not only by the project host and project investor, but also by an impartial third party or a body that oversees the project in the interest of the UNFCCC. And yet, the rules for setting baselines need to be broadly practical and simple enough to be applicable in a variety of places and circumstances and by a large enough group of people, while not being so simple that other principles are violated. If the costs of implementation and monitoring are too onerous, they will thwart projects that could contribute meaningfully to greenhouse-gas mitigation objectives.

It should be acknowledged that there is effectively a trade-off between practicability and the principles of accuracy, comprehensiveness, and conservativeness. By being conservative one avoids emission credits for projects that do not provide emission reductions that are additional to what have occurred at the absence of a project, "type II error". On the other hand, the principle of conservativeness, if applied too strictly, can prevent worthwhile projects from being carried out, "type I error" (Chomitz, 1998). Similarly, excessive demands for accuracy or comprehensiveness could discourage worthwhile projects or raise the cost of project management to the point that discourages implementation. Since the "true path" of net emissions without the project will never be exactly known, one can only define a likely path. It is not realistic (practicable) to define a project baseline that is below the true "without-project-path" with 100% certainty - because then the type I error would be extraordinarily high and only a few projects would be carried out – eliminating many of those that would have provided real reductions in emissions to the atmosphere.

There may be projects where it is not possible to verify carbon benefits in a cost effective manner; practicability may not always be achievable. The challenge is to minimize type II errors without extreme impacts on the magnitude and frequency of type I errors, thus maintaining a reasonable level of practicability.

CONCLUSION AND DISCUSSION

Implementation of the Kyoto Protocol will require rules for accounting and for defining baselines against which reduction of emissions or enhancement of removals are to be measured. Baselines are clearly required for implementation of Articles 6 and 12 in the Kyoto Protocol, and will probably be needed for Article 3.4. Project accounting needs to provide incentives to assure that the objective of the UNFCCC is served and that the interests of all participating parties are respected.

It is inherently very difficult to define the path-not-traveled baseline and hence to establish the emission reduction achievements of many activities. The overall aim is to have accurate, comprehensive and conservative baselines but this aim needs to be balanced to yield baselines that are as simple as possible, can be practically implemented, and provide incentives to fulfill the ultimate objective of the UNFCCC. Solutions to approach these principles are being worked on (UNFCCC, 1998).

Application of the principles articulated here to different types of emission-reduction projects will lead to a variety of challenges, and yet these principles provide guidance on how baselines could be constructed for projects in such a way as to be ultimately consistent with the intent of the Kyoto Protocol and the objectives of the UNFCCC. Looking at a variety of project types with these principles in mind warns where difficulties in defining baselines are likely to be encountered. Accuracy will be less of a problem for small projects, such as many energy efficiency projects, where it is possible to define a control group. Accuracy will be a greater challenge for all projects where the march of technological progress and socioeconomic development is likely to determine the length of time for which a project provides savings with respect to the without-project baseline. Similarly, accuracy can be an issue for those projects in the biosphere with greater inherent variability and less precise measurements, where verification may be more problematic and permanence of greenhouse gas benefits less certain. Comprehensiveness will for example challenge baseline selection in projects aimed at changing infrastructure, or in projects involving product substitution such as substitution of construction lumber for concrete where the reduction of greenhouse gas is linked to the differences in the production processes and waste management.

In the wake of the Kyoto Protocol, what we need is an accounting system with which to measure our achievements. A system accurate enough to define verifiable carbon credits, sufficiently comprehensive to assure that gains are not eroded outside of accounting boundaries, and sufficiently conservative to assure that rewards are earned. A system that does not place obstacles so onerous that it stifles worthwhile projects and activities. A system that rewards projects and activities that are consistent with global change, and other, human goals.

ACKNOWLEDGMENTS

We are grateful for the comments we received on earlier drafts of this manuscript from the participants in the IEA Bioenergy Task 25 workshop in Nokia in September 1998 and also in written form from Ken Andrasko.

REFERENCES

ANDRASKO, K., 1997. Forest management for greenhouse gas benefits: resolving monitoring issues across project and national boundaries. *Mitigation and Adaptation Strategies for Global Change* 2: 117-132.

APPS, M., KARJALAINEN, T., MARLAND, G. and SCHLAMADINGER, B. 1997. Accounting system considerations: CO_2 emissions from forests, forest products, and land-use change, a statement from Edmonton. http://www.joanneum.ac.at/iea-bioenergy-task25.

CHOMITZ, K., 1998. Baselines for greenhouse gas reductions: Problems, precedents, solutions. Prepared for the Carbon Offsets Unit. Development Research Group, World Bank (Draft1.2rev.28.May 1998).

IGBP TERRESTRIAL CARBON WORKING GROUP, 1998. The terrestrial carbon cycle: implications for the Kyoto Protocol. *Science* 280, 1393-1394.

MICHAELOWA, A., 1998. Joint Implementation – the baseline issue: Economic and political aspects. Forthcoming in Global Environmental Change.

SGS, 1998. Carbon offset verification service, 5 pp., SGS Forestry, Oxford OX2 0JX, United Kingdom.

TIPPER, R., 1998. Carbon Offsets: the Baseline Issue. http://www.ed.ac.uk/~ebfr11/ecor/Itto.html .

UNFCCC, 1992. United Nations Framework Convention on Climate Change, Convention on climate change, published by UNEP's Information Unit for Conventions (IUC), http://www.unep.ch .

UNFCCC, 1997. Kyoto Protocol to the United Nations Framework Convention on Climate Change. Document FCCC/CP/1997/7/Add.1. http://www.unfccc.de .

UNFCCC, 1998. Review of the implementation of commitments and of other provisions of the convention. Activities implemented jointly: Review of progress under the pilot phase (decision 5/CP.1). Document FCCC/CP/1998/2. http://www.unfccc.de .

The role of bioenergy in greenhouse gas mitigation

A position paper prepared by IEA Bioenergy Task 25
"Greenhouse Gas Balances of Bioenergy Systems"

(presentation given by Josef SPITZER;
see "List of Participants" in the Appendix for details)

IEA Bioenergy

Task 25: Greenhouse Gas Balances of Bioenergy Systems

Final Announcement

for the international workshop

Between COP3 and COP4: The Role of Bioenergy in Achieving the Targets Stipulated in the Kyoto Protocol

8-11 September 1998

Spa Hotel Rantasipi Eden

Nokia, Finland

Jointly organized by

VTT ENERGY

P.O. Box 1606
FIN-02044 VTT (Espoo)
FINLAND

JOANNEUM RESEARCH

Elisabethstrasse 5
A-8010 Graz
AUSTRIA

Task 25 Homepage: http://www.joanneum.ac.at/iea-bioenergy-task25

Scope of the workshop

The primary goal of IEA Bioenergy Task 25 (“Greenhouse Gas Balances of Bioenergy Systems”) is to investigate all processes involved in the use of bioenergy systems, on a full fuel-cycle basis, with the aim of establishing overall greenhouse gas balances.

The Task 25 workshop in Nokia, Finland, is part of a series of workshops within Task 25, and the predecessing Task XV, taking place every 6 to 12 months. For more detailed information on the Task and previous workshops, see the World Wide Web Homepage at: *http://www.joanneum.ac.at/iea-bioenergy-task25*.

Altogether six events will take place during the workshop, some of them jointly with IEA Bioenergy Task 18 ("Conventional Forestry Systems for Bioenergy"):

1. Excursion I (organized by Task 18):
   Topics covered: Recovery of logging residue from spruce dominated clearcut; Effects of residue removal on forest regeneration; Visit of the wood-fired Forssa CHP plant; Combustion of wet sawmill residues at the Humppila sawmill; Demonstration of small-scale heating entrepreneurship, including a visit to a chip-fired heating unit at Huittinen primary school **(Tue 8 Sept, all day, starts and ends at hotel)**

2. Discussion of administrative matters regarding Task 25;
   (Wed 9 Sept, half-day morning session, open for Task 25 participants only)

3. Joint session with Task 18 on *"Carbon Balances and Sequestration in Conventional Forestry (Biomass) Systems"*; **(Wed 9 Sept, half-day afternoon session, open to all)**

   Objectives of the joint session:
   - Review research findings from key ecosystems on the effects of land-use change and conventional forestry on (i) soil carbon sequestration/balances; (ii) above- and below-ground partitioning of carbon.
   - Review "common analytical frameworks" for the assessment of GHG balances in forestry, and identify opportunities for research collaboration in modelling ecosystem carbon balances resulting from land-use change and alternative forest management.
   - Evaluate the role of conventional forestry biomass production systems for positive contributions to reducing net GHG emissions or enhancing GHG sinks.

4. All-day open session on the workshop topic, aimed at providing some new input/insights for the elaboration of an IEA Bioenergy position paper (see below).
   (Thu 10 Sept, open to all)

5. Formulation of an IEA Bioenergy position paper on the role of bioenergy in the light of the Kyoto Protocol and the upcoming 4th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP4);
   (**Fri 11 Sept, for IEA Bioenergy participants only)**

6. Excursion II (organized by Task 18):
   Topics covered: Spreading of wood ash and pulpmill sludge in forest (host: Ossi Sippola, Metsä-Serla Oy, Tampere) and Centralized handling and chipping of logging residue on a peat harvesting area (host: Tero Vesisenaho, Vapo Oy, Jyväskylä)
   (Fri 11 Sept, all day, starts at hotel and ends 16:30 hrs at Helsinki airport)

Workshop Propgram

TUESDAY, 8 SEPTEMBER 1998

Excursion I
Departure: 8^{00} (please check locally!), return to hotel around 18^{30}
(optional, see previous page for the topics covered)

WEDNESDAY, 9 SEPTEMBER 1998

9^{00}-12^{15}: *IEA Bioenergy Task 25 Administrative Matters* (Task participants only)

1. Task participation issues
2. Special Issue "Environmental Science and Policy" (Rotorua proceedings, 2nd stage)
3. Baselines paper (Oak Ridge meeting)
4. IEA Bioenergy position paper (organizational aspects)
5. Feedback on the new Task 25 WWW Homepage
6. Finalization of the Task 25 Folder
7. Special Task 25 section in Annual Report 1998
8. Bibliography (updated version)
9. IPCC involvement (e.g. Special report on land-use change and forestry; Third Assessment Report)
10. Next workshop
11. Miscellaneous items (e.g. proceedings)

12^{15} Lunch

13^{30}-18^{30}: Joint session with IEA Bioenergy Task 18 on
"CARBON BALANCES AND SEQUESTRATION IN CONVENTIONAL FORESTRY (BIOMASS) SYSTEMS"

13^{30} ***Introduction***
J. Richardson and J. Spitzer

13^{40} ***Site preparation techniques in energy and fiber plantations to sequester carbon***
M. Buford and B. J. Stokes (USDA Forest Service/USA)

14^{20} ***Framework for assessing the contribution of soil carbon to New Zealand CO_2 emissions***
C. T. Smith[*], J. Ford-Robertson[*], K. R. Tate[**], and N. A. Scott[**]
([*] New Zealand Forest Research Institute Limited/New Zealand, Landcare Research, New Zealand)

14^{50} ***Towards future European forest carbon budget (LTEEF-II project)***
A. Pussinen, T. Karjalainen*, J. Liski*, and G.-J. Nabuurs***
(* European Forest Institute/Finland, ** Institute for Forestry and Nature Research - ibn-dno/The Netherlands)

15^{20} Coffee Break

15^{40} ***Long-term effects of whole-tree harvesting on carbon pools in coniferous forest soils***
B. Olsson (Swedish Agricultural University/Sweden)

16^{10} ***Whole-tree harvesting as a means to avoid nitrogen over-loading in forest ecosystems***
H. Eriksson, J. Vinterbaeck, M. Parikka, and B. Hektor
(Swedish Agricultural University/Sweden)

16^{40} ***Forestry, climate change and carbon in soils***
J. Liski (European Forest Institute/Finland)

17^{10} ***The role of forest growth models in assessments of carbon balance and environmental impact of fibre and bioenergy production systems***
R. Matthews (Forestry Commission Research Agency/UK)
[PRESENTATION WAS SWAPPED WITH THAT OF I. SAVOLAINEN BELOW]

17^{40} Discussion of future directions for Task 18 and Task 25 collaboration

(expected end of session: approx. 18^{30})

THURSDAY, 10 SEPTEMBER 1998

9^{00}-16^{30}: all-day session on the workshop theme
"BETWEEN COP3 AND COP4: THE ROLE OF BIOENERGY IN ACHIEVING THE TARGETS STIPULATED IN THE KYOTO PROTOCOL"

9^{00} ***The Finnish forestry in light of Kyoto Protocol***
H. Granholm (Finnish Ministry of Agriculture and Forestry/Finland)
[PRESENTATION WAS GIVEN BY P. HEIKKINHEIMO INSTEAD]

9^{30} ***GHG emissions and possibilities for reduction using fuelwood and forest waste for energy in Croatia***
V. Jelavic and J. Domac***
(* EKONERG Holding/Croatia; ** Energy Institute "Hrvoje Pozar"/Croatia)

10^{00} ***Role of forestry and biomass production for energy in reducing net GHG emissions in Finland - assessment concerning the history and future***
I. Savolainen, T. Karjalainen**, K. Pingoud*, and J. Liski***
(* VTT/Finland; ** European Forest Institute/Finland)
[PRESENTATION WAS SWAPPED WITH THAT OF R. MATTHEWS ABOVE]

10^{30} Coffee Break

11^{00} ***Fuelwood in Europe for Environment and Development Strategies (FEEDS)***
P. Ballaire (Ademe/France) (to be confirmed)
[PRESENTATION WAS GIVEN BY B. SCHLAMADINGER INSTEAD]

11^{30} ***Application of the Unified Wood Energy Terminology (UWET) for the collection, compilation and presentation of wood fuel data*** and
FAO Task Force on Dendroenergy and CO_2 Substitution and Sequestration
M. Trossero (FAO Forestry Department/Italy)

12^{00} ***Large-scale power generation using forestry and wood industry by-products***
J. Ford-Robertson (New Zealand Forest Research Institute Ltd./New Zealand)

12^{30} Lunch

14^{00} ***Forestry strategies - temporary or permanent solution in carbon mitigation***
P. Kauppi (Helsinki University/Finland)

14^{30} ***Bioenergy and power production; power company's perspective***
A. Heikkinen (IVO Power Company/Finland)

15^{00} ***Global land-use and land-use change with respect to future bioenergy scenarios***
D. O. Hall or *T. Johansson* (to be confirmed, title tentative)
[PRESENTATION WAS CANCELLED]

15^{30} ***Project-based greenhouse gas accounting: guiding principles with focus on baselines*** (Task 25 baselines paper; tentative title)
L. Gustavsson (Lund University/Sweden)

16^{00} ***The role of biomass in greenhouse gas mitigation*** (IEA Bioenergy draft position paper)
J. Spitzer (Joanneum Research/Austria)

16^{30} End of session

(Evening program: boat trip, Finnish smoke sauna, Task 25 workshop dinner. Departure: 17^{00}. For details see further below.)

FRIDAY, 11 SEPTEMBER 1998

Excursion II (optional, departure 8^{00} from hotel; terminates 16:30 hrs at Helsinki Airport)

Task 25 session:
Elaboration of an IEA Bioenergy position paper on the role of bioenergy in the light of the targets set in the Kyoto Protocol and the upcoming 4th Conference of the Parties to the UN Framework Convention on Climate Change, Buenos Aires, 2-13 November 1998 (basis: draft position paper).

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