ABSTRACT: The paper describes results of the CO₂-reduction potential for different forest management strategies and utilization of the timber for products and energy. Forest management can create very different carbon pools but on the long term timber utilization has a much higher effect than forest carbon pools. The use of wood for products contributes much more (2-4 times) than energetic use (displacement factors). Wooden building products are ranking first because of their long service life. The carbon product pools have generally shown the lowest effects.

KEYWORDS: CO₂-aspects, carbon pools, forests, wood utilization, building with wood, displacement factors

1 INTRODUCTION
Forest captures CO₂ from the atmosphere and stores the carbon in wood and other biomass. According to the Kyoto-Protocol carbon sinks in forests generated from forest growth and enlargement of forest areas are considered as a measure for emission reduction. Harvesting of timber is accounted as C-emission in the year of harvesting. In future also the C-storage in timber products (medium and long term) are acknowledged as emission reduction measure. In the national greenhouse gas inventions lower energy consumption (and therefore lower CO₂-emissions) for the manufacture of timber products compared to alternative products is not accounted for the Forestry-Wood-Chain (FWC) but for the general energy or industry sector. On the other hand, environmental certification for buildings includes the energy consumption and CO₂-aspects as one of the main issues.

Many studies have been published in order to describe CO₂-aspects associated with buildings (summary in [1]) but no clear information is available about the emission reduction of the timber building sector as a whole or for the wood sector in total.

Recently the authors finished the first part of a study dealing with the role of forests and timber utilization in different uses [2]. As an example the Forestry-Wood-Chain in the State of Northrhin-Westfalia/Germany was selected. Representing 915,000 ha forest area, a timber production of 6 – 7 Mio. m³/y, a timber market consisting 18 Mio. customers and a timber market turnover of some 15 billion Euro.

2 METHODS
The carbon aspects were divided into four parts: (1) C-storage in forests, (2) C-storage in timber products, (3) emission reduction through use of timber for products and (4) for use as energy. The modeling included time spans until 2050 and 2100 respectively. For forest management three base scenarios were used: (a) volume oriented timber production, (b) value oriented timber production and (c) carbon stock optimization. Three combinations of the base scenarios including non-harvest were also modeled. For the timber markets and timber utilization 16 typical product groups (10 relating to building with wood) were identified, their process chain studied and market volumes calculated. Alternative products for the 16 groups were identified and on basis of LCA-results. Displacement factors were developed similar to [1]. Later the 16 product groups were summarized into four product areas in order to get results for communication to stakeholders. Similar procedures were developed for the use of wood for energy purposes.

3 RESULTS
1. The forest management strategy defines the forest carbon pool and harvested timber volumes. Carbon sink was calculated between 0.15 and 1.65 tC/ha,y for the base scenarios. Timber production figures ranged between 6.0 and 12.0 m³/ha,y.

2. Depending on the forest management strategy and timber production, timber utilization contributes to 25% and 85% of the overall reduction of CO₂. The use for wood as products is much higher than the use for energy.
3. Considering the replacement of non-wood products and the fact that wooden products can be turned into energy at the end of their life the effect of product use is 2 to 3 times higher than direct burning of wood.

4. The displacement factors developed for some uses are as follows (units given in tC/tC, [1]): softwood lumber wet 1.80, softwood lumber dry 1.40, glue lam, CLT 1.30, wood based panels 1.10, flooring 1.35, doors, windows 1.62, furniture 1.46-1.62, packaging 1.35, energy 0.67.

5. The carbon storage in wood products depends on their life time but has the lowest emission reduction compared to forest carbon storage and material end energy displacement.

### Table 1: Carbon sink effects of the forestry-wood-chain (average values per year 2011-2100)

<table>
<thead>
<tr>
<th>forest management strategy</th>
<th>emission reduction in t C per ha, y of forests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>forest sink</td>
</tr>
<tr>
<td>timber volume</td>
<td>-0.3</td>
</tr>
<tr>
<td>timber value</td>
<td>2.2</td>
</tr>
<tr>
<td>C-storage</td>
<td>3.4</td>
</tr>
</tbody>
</table>

4 CONCLUSIONS

Long service life, low maintenance requirements during service life reduce CO₂-emissions. The use of wood for building purposes has the highest carbon mitigation potential, especially attributed to the high displacement factors and the long service life of products. The carbon mitigation of wooden building products is between 7.0 and 8.5 tCO₂ per m³ of products and between 5.5 and 6.5 tCO₂ per m³ of harvested wood respectively.

REFERENCES
