# IEooc_Application4_Exercise7:

# Accounting for carbon flows and stocks around biomass use

***Goal**: Apply MEFA to wood use as material and as energy carrier. Define and quantify climate-relevant metrics for wood use. Distinguish between actual carbon flows and counter-factual flows (avoided emissions).*

**For assessing the climate impact of wood use, the following system definition is given.**

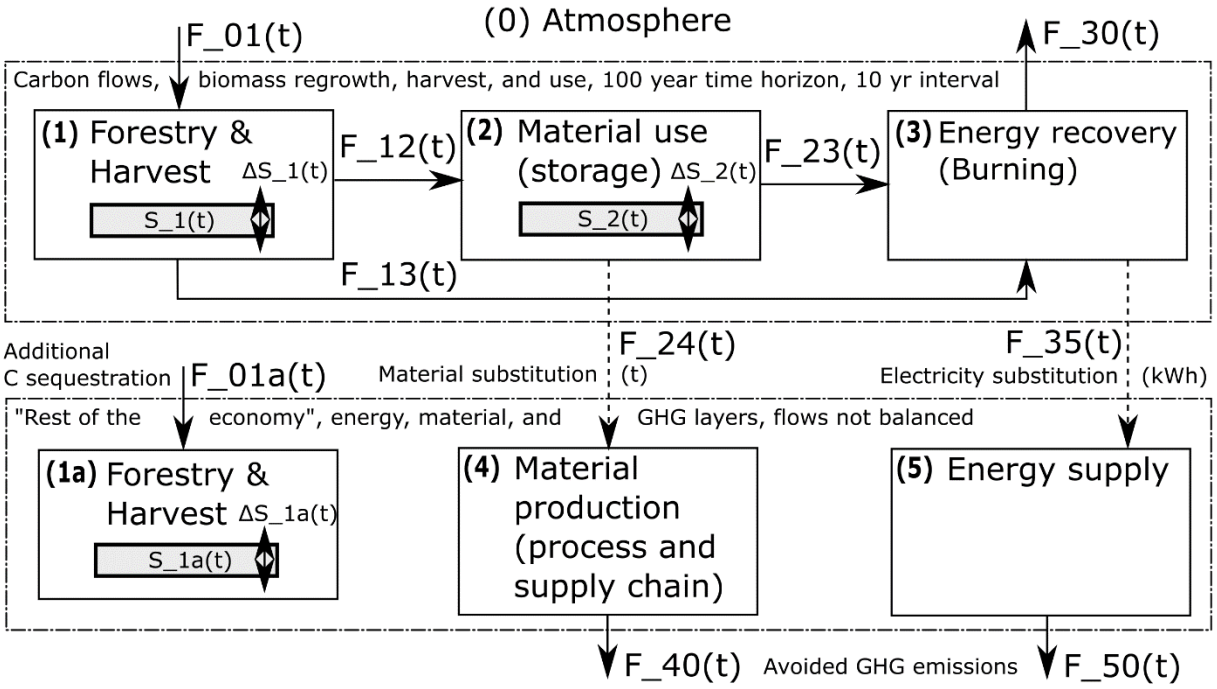


**Fig. 1:** System diagram for the major carbon flows related to forestry and wood use (top), and the system of substitution processes for avoided wood harvest, avoided material production, and avoided energy supply when using wood.

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## 1) Energy use of wood harvested from climate neutral forestry

In climate-neutral forestry, at the landscape level (aggregate over the different age-groups of trees), forest have a constant carbon pool in trees and soil. Assume that in such a forest, 100 tons of atmospheric carbon are sequestered each year by trees, and that, at the same time, 100 tons of carbon leave the forest in form of harvested wood products (HWP). Assume further that all of this wood is directly used for electricity generation in the same year.

a) Actual carbon flows I: For this case, give and calculate, for a 30 year time series from 2020 to 2050, all the flows in the system: F_0_1, F_1_2, F_2_3, F_1_3, F_3_0, Delta_S1, Delta_S2. Unit: t of C/yr.
b) Actual carbon flows II: How large is the net carbon balance (F_0_1 - F_3_0), as net sequestration, actual flows, t of C, and what does that result mean?
c) Counter-factual (avoided) flows I: Determine the energy substitution and avoided GHG emissions for a fossil-intensive grid mix of 500 g $CO_2$-eq/kWh and a low-carbon electricity mix of 50 g $CO_2$-eq/kWh: F_3_5 and F_5_0 (in kWh and tons of $CO_2$-eq).
d) Counter-factual (avoided) flows II: Calculate the relative performance compared to non-use: carbon avoided - carbon emitted, what do the results mean?
    a. For a flow F_0_1a of 0, assuming no further C sequestration in forests when no wood is harvested.
    b. For a flow F_0_1a of 50% of F_0_1, assuming some further C sequestration in forests when no wood is harvested.
    c. For a flow F_0_1a of 100% of F_0_1, assuming full C sequestration in forests when no wood is harvested.

    Remark: Since we do not know much about the actual state of the forest (its age structure, species composition, and potential for further sequestration), we perform a scenario analysis, assuming that forests will accumulate additional carbon if no harvest occurs. Three accumulation models are assumed: 100% of the foregone harvest is accumulated, realistic for young forests with a low carbon pool. Or, 0 % additional accumulation, realistic for old or climate-instable forests. 50% for a typical case in between.

    Task d leads to six time series (2020-2050) of the carbon avoided – carbon emitted indicator for the six different combinations. What do these results mean?

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**2) Material use of wood harvested from climate neutral forestry with subsequent energy recovery**

Assume that in such a forest, 100 tons of atmospheric carbon are sequestered each year by trees, and that, at the same time, 100 tons of carbon leave the forest in form of harvested wood products (HWP). Assume further that all of this wood is directly used as material in the same year. The lifetime of the wood material in the use phase shall be 20 years, which is a typical lifetime for wooden furniture.

a) For this case, give and calculate, for a 30 year time series from 2020 to 2050, all the flows in the system: F_0_1, F_1_2, F_2_3, F_1_3, F_3_0, Delta_S1, Delta_S2. Unit: t of C/yr.

b) How large is the net carbon balance (F_0_1 - F_3_0), as net sequestration, actual flows, t of C, and what does that result mean?

c) Determine the avoided GHG emissions for material substitution. Assume that the material production-related GHG saved are 2.4 t $CO_2$-eq per ton of C (typical value via avoided steel and cement production, typical mix of both materials determined from calculating the difference in material composition between several functionally equivalent building types).

d) Calculate the relative performance compared to non-use: carbon avoided - carbon emitted, what do the results mean?

   a. For a flow F_0_1a of 0, assuming no further C sequestration in forests when no wood is harvested.

   b. For a flow F_0_1a of 50% of F_0_1, assuming some further C sequestration in forests when no wood is harvested.

   c. For a flow F_0_1a of 100% of F_0_1, assuming full C sequestration in forests when no wood is harvested.

   Remark: Since we do not know much about the actual state of the forest (its age structure, species composition, and potential for further sequestration), we perform a scenario analysis, assuming that forests will accumulate additional carbon if no harvest occurs. Three accumulation models are assumed: 100% of the foregone harvest is accumulated, realistic for young forests with a low carbon pool. Or, 0 % additional accumulation, realistic for old or climate-instable forests. 50% for a typical case in between.

   Task d leads to six time series (2020-2050) of the carbon avoided – carbon emitted indicator for the six different combinations. What do these results mean?

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**3) Material use of wood harvested from climate neutral forestry without subsequent energy recovery**

Repeat task 2 but this time without the energy recovery at the end of the useful material product life! Interpret your results!

## Hint:

When calculating the avoided emissions vs. actual emissions, you need to get the sign of each flow right. Here, it helps to think of the flows as if they were cost items. You save money (and hence the actual scenario is preferable to the alternative scenario) when the actual cost alternative is lower than the counter-factual one, which is the case when cost avoided – actual costs is larger than 0.

## Some conversion factors and helpful parameters:

**Conversion from C to $CO_2$ (mass flows):** 44/12

**Conversion from $CO_2$ to C (mass flows):** 12/44

**Material GHG saved in t $CO_2$-eq per ton of C:** 2.4 t $CO_2$-eq per ton of C (via avoided steel and cement production, typical mix of both materials determined from calculating the difference in material composition between several functionally equivalent building types)

**Electricity generated from wood waste, kWh per ton of C:** 3.47MWh / ton of C

**Carbon intensity of electricity generation, grid mix:** 500 g $CO_2$-eq per kWh

**Carbon intensity of electricity generation, low-carbon grid mix:** 50 g $CO_2$-eq per kWh

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