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Specific indicators for characterisation of cascading use of wood based materials

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1. Introduction

Shifting towards a bio-based economy increases the demand for natural fibres as renewable raw material. Their sustainable use is of significant importance, hence the usage time of natural fibers should be as long as possible. The raw material wood can be applied in different structure levels – starting from solid wood, to chips of different size, up to fibers for paper and board. Along their whole life cycle wood based materials could be used in various products, even repeatedly in the same type of product. The major limiting factor of its multiple use is contamination of various ways, causing down-cascading. As a result the utilization cascades of wood based materials can be very complex, often consisting of multiple sub-cascades.

2. Knowing Cascade parameters

Different authors have introduced parameters to characterize the depth of a cascade.
- (Total-) cascade factor (Mantau, 2012): C_T
- Simplified Cascade factor (Indufor, 2013): C_S
- Bio-mass usage factor (nova, 2015): C_{BUF}

All 3 factors are defined as certain ratios of material mass flow within the whole balance area. C_T and C_S are factors for the whole cascade. The factor C_{BUF} can also be generalized for sub-cascades. But all factors are not very descriptive.
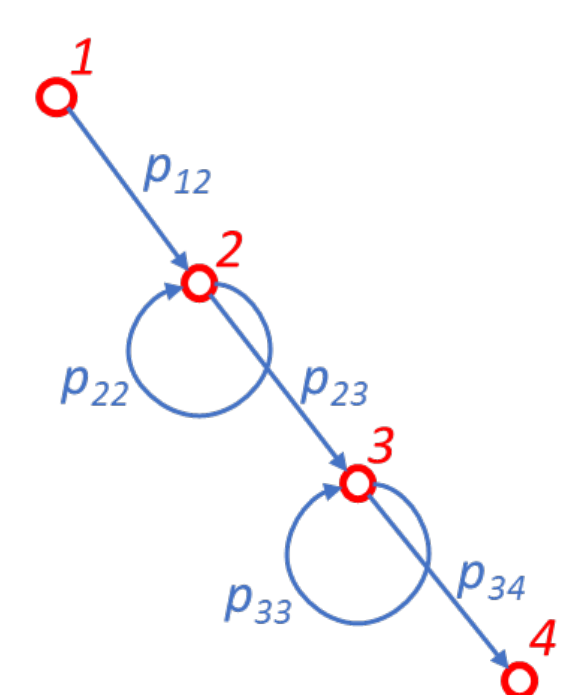

Fig.1: Example of a simple cascade

3. Introduction of mean number of uses (*MNU*)

We assume a general cascade as a set of *N* material states (products) 1,…,*N* where 1 is the raw material an *N* the final state. The values p_{ij} denotes the transition probability that material goes from status *i* to status *j* due to recycling. Clearly $\sum_{j=1}^{N} p_{ij} = 1$ for all products *i*. *Fig.1* presents a very simple example of a cascade for paper industry where 1 is the virgin pulp, 2 resp. 3 are graphical resp. packaging papers and 4 are paper losses (e.g. incineration, disposal). The mean number of material uses (*MNU*) is now defined as the mean number the same material is used in different products along the whole life cycle beginning as raw material and ending in the final state.

4. Calculation an application of MNU

Let us assume a starting state *k*=0 where all material is only raw material. In every following step *k*=1,2,… material goes from one status *i* to another status *j* according to the probability p_{ij}. We define a_{ik} as the percentage of raw material which has reached the status *i* in the *k*-th step. For every *k* it follows a vector $\underline{a}_k = (a_{1k},…,a_{Nk})^T$. The sum of the components of the vector equals 1 for every *k*. *MNU* results from the infinite sum $MNU = \sum_{k=0}^{\infty} k \cdot a_{Nk}$. For calculation of $\underline{a}_k$ we introduce the (N,N)-matrix P of transition probabilities P=$(p_{ij})_{N,N}$. Beginning with $\underline{a}_0 = (1,0,…,0)^T$ it yields $\underline{a}_k = P \underline{a}_{k-1} = P^k \underline{a}_0$.

Fig. 2 to Fig 4 present in a comparative way *MNU* values for different wood material cascades. The primary wood as input material is used in average between 0.6 and 2.49 times before energy recovery, indicating that the combined board/paper cascade in *Fig.3* right is the most favourite cascade in terms of multiple use.

5. Remark

The concept, which was developed for wood usage in board and paper products, can also be applied to other materials and offers an approach to eliminate existing shortcomings of allocation in open-loop LCAs.

Bibliography:
- Mantau: U. Mantau et al.: Wood flows in Europe. Project report. Celle 2012
- Indufor: Study on the Wood Raw Material Supply and Demand for the EU Wood-processing Industries. Final report, Helsinki 2013
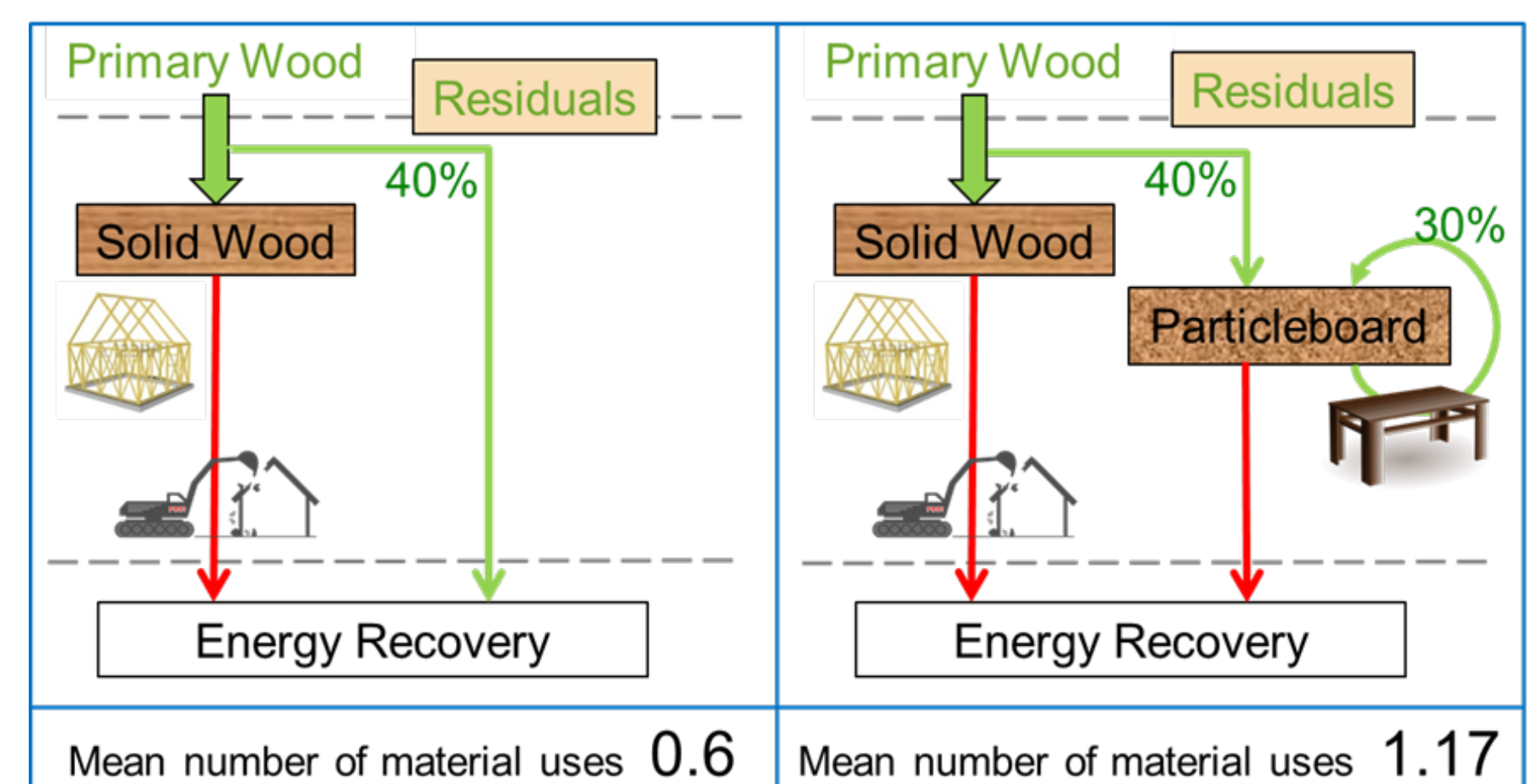- nova: "Biomass Utilization Factor". Workshop "The Optimised Cascading Use of Wood". Brussels, 30 June 2015.

Fig.2: Single Stage Cascade – Production of Solid Wood with energy recovery after usage; residual materials are completely energetically recycled (left) or partly recycled for Particleboard production (right)
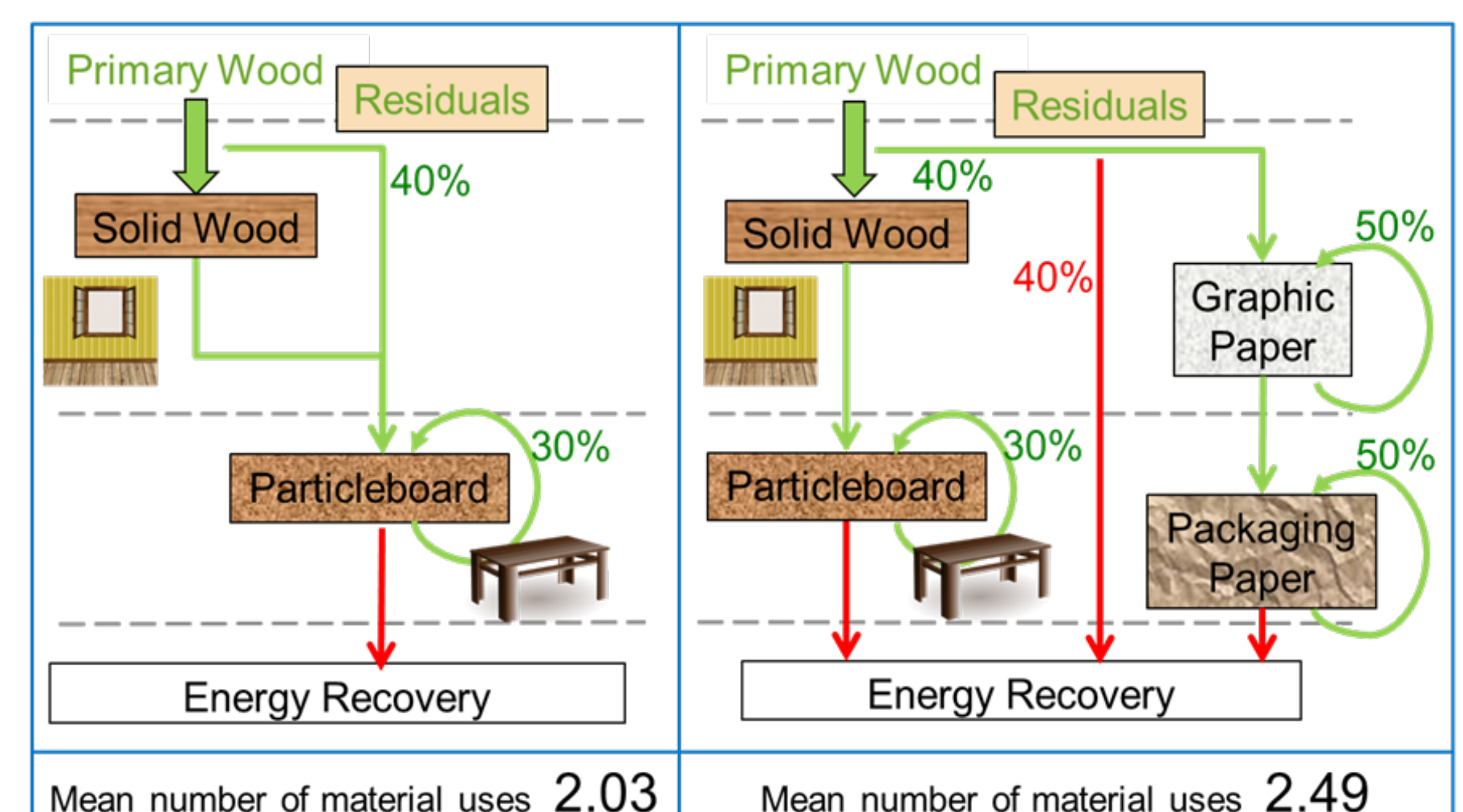

Fig.3: Multi Stage Cascade – Production of Solid Wood with recycling for Particle Board (left) or partially use of residuals for Paper Production (right)
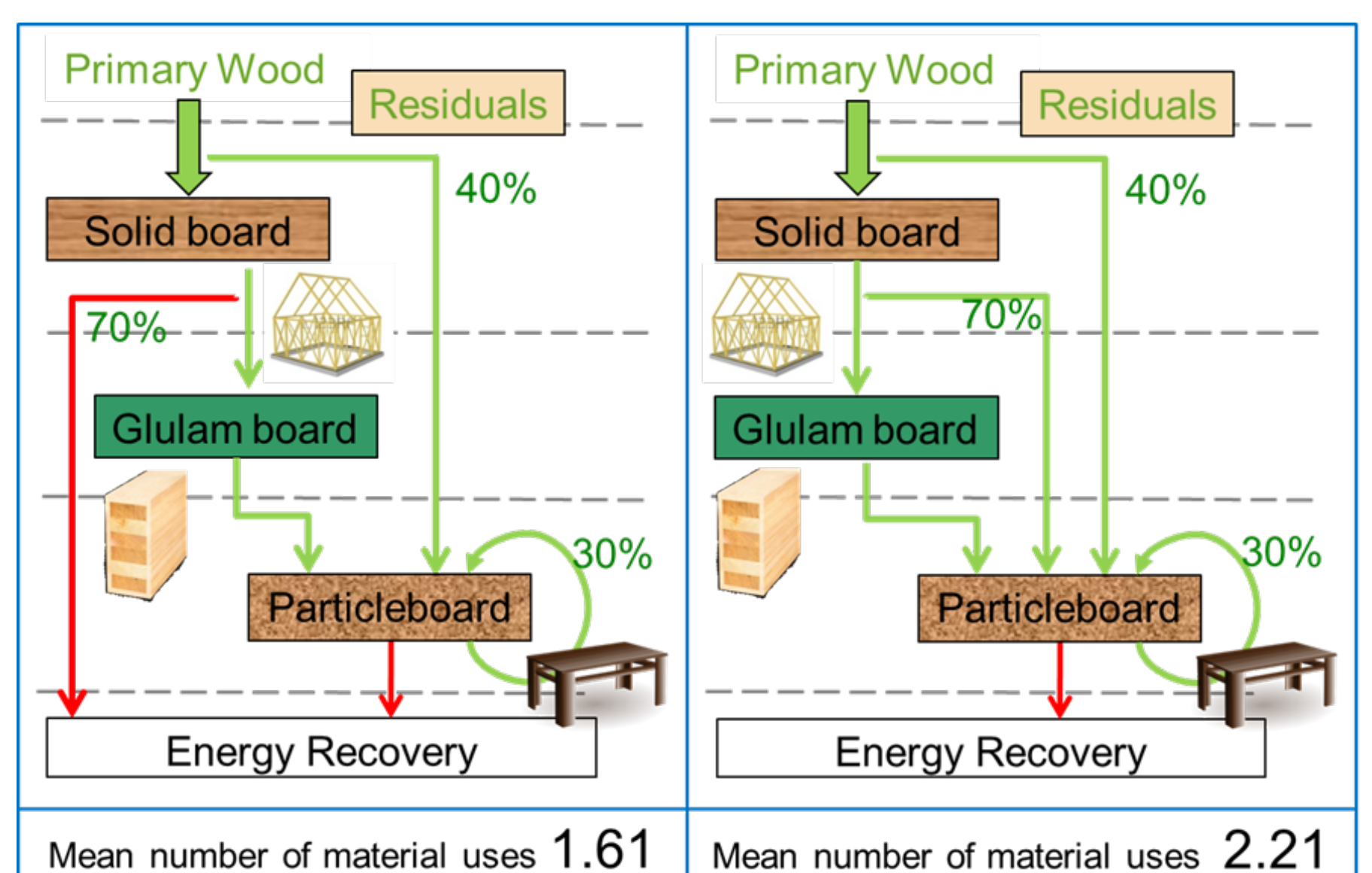

Fig.4: Multi Stage Cascade – Production of Solid Board with partially (left) or full (right) recycling for Glulam and Particleboard

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