Dynamic eco-efficiency modeling for recycling of C&D waste

Rolf André Bohne , Håvard Bergsdal and Helge Brattebø

Industrial Ecology Programme, NTNU

Waste Projections

Waste amounts (C&D-waste) from the Architecture, Engineering and Construction industry (AEC) in Norway are growing, and so is the concern regarding the treatment of this waste, both on a national and European level. The purpose of this work is to evaluate C&D waste strategies in order to present meaningful and relevant information for decision makers, regarding specific and overall most important issues. Knowledge of future waste amounts and composition is necessary for making long term decisions on waste treatment. To be able to reach these goals, we need to develop dynamic projections regarding the future situation, taking into account past changes that affects the future as well as present and expected future trends. The starting point is therefore projection of future waste amounts, as described by the following three steps:

1st Step = Estimate the amount of activity (m2/year) of i) construction, ii) rehabilitation and iii) demolition of buildings.

2nd Step = Determine the specific waste generation factors (kg/m2) for different fractions of solid waste related to each type of activity.

3rd Step = Calculate the overall waste generation projections (tons/year), on the basis of defined development scenarios.

Buildings have different characteristics, and are grouped into three main categories according to size and furnishing, being; residential buildings, larger buildings and other buildings, as displayed in Table 1.

Category	Buildings	Area	Furnishing
Residential	Single houses, Chained houses etc.	Small	High
Larger	Office buildings, High houses etc.	Large	High
Other	Industrial-, Agricultural buildings etc.	Large	Low

Table 1: Building categories

1st step is carried out for the building categories, determining the level of activity. The 2nd step uses waste generation factors collected from 311 building projects in Oslo, by Statistics Norway (1998), to assess the waste amounts related to each activity and building type. This information is displayed as percentage of waste generation in Table 2.

Composition	Construction	Rehabilitation	Demolition	Total
Asbestos	-	0,70	0,32	0,38
Hazardous waste	0,23	0,04	0,04	0,07
Concrete/Bricks	45,79	47,69	84,16	67,24
Gypsum	6,25	5,72	0,15	2,77
Glass	0,47	0,41	0,12	0,26
Insulation/EPS	1,87	0,51	0,07	0,49
Metal	1,32	3,59	4,33	3,63
Paper/Cardboard/Plastics	4,50	0,89	0,27	1,14
Wood	13,67	30,31	6,42	14,58
Unknown composition	25,89	10,13	4,13	9,44

Table 2: Waste composition for different activities

The 3rd step combines the previous steps to give total waste amounts for both the national and regional level, as well as the local level. Figure 1 shows the activity distribution, while Figure 2 shows the total C&D waste distribution in Norway. Projections of total future C&D waste amounts are displayed in Figure 3, for different population growth.

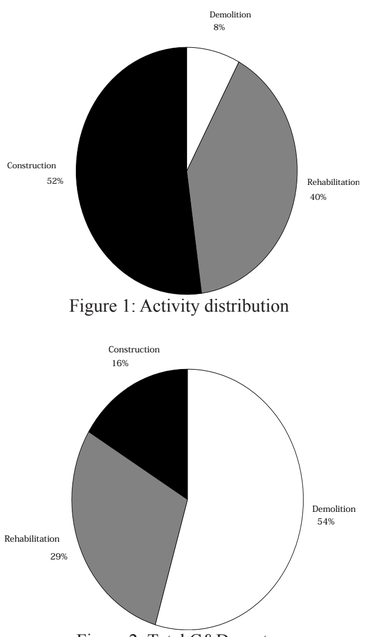

Figure 1: Activity distribution

Figure 2: Total C&D waste distribution in Norway

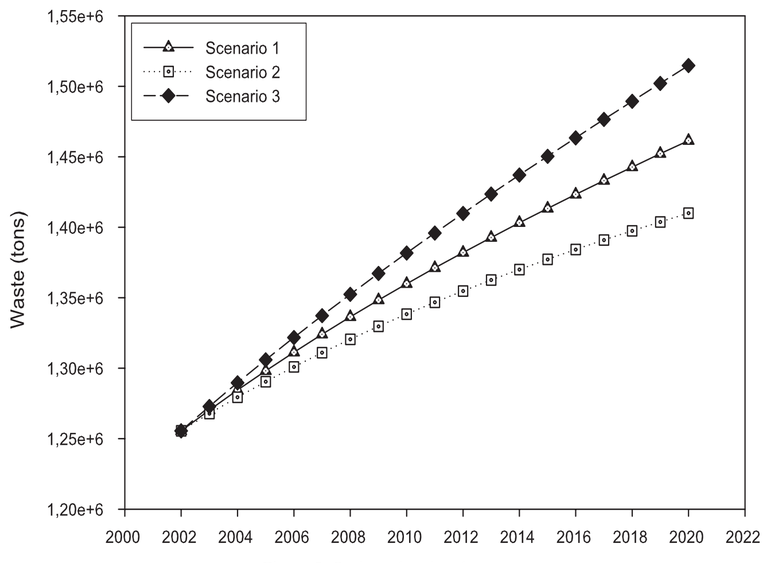

Figure 3: Projected national waste amounts

There is great variation in C&D activity within the country of Norway, so we want to build a model that is flexible and capable of coping with local variations. We have used Trondheim, Norways third largest city, as an example on how to get more reliable, local waste projections. From a national register, annual information on construction of buildings is found. For rehabilitation and demolition, the available information is too poor for use in waste projections, so assumptions have to be made, and these are based on the construction activity. Trends regarding the average size of buildings with time are combined with expectations of lifetime and rehabilitation need for different buildings. Equation 1 demonstrates the concept.

$$W(t)_{act,bt,f,t} = A(t)_{bt,t} \cdot \lambda^{c}_{bt,f} + A(t-30)_{bt,t} \cdot \lambda^{r}_{bt,f} + A(t-60)_{bt,t} \cdot \lambda^{r}_{bt,f} + A(t-90)_{bt,t} \cdot \lambda^{d}_{bt,f} \quad \forall act, bt, f, t$$

Equation 1: Calculation of local waste amounts

Results of the projections are shown in Figure 4 for the years 1995 to 2018 for all accounted waste fractions. Monte Carlo simulation is used to reduce uncertainties in the models input parameters.

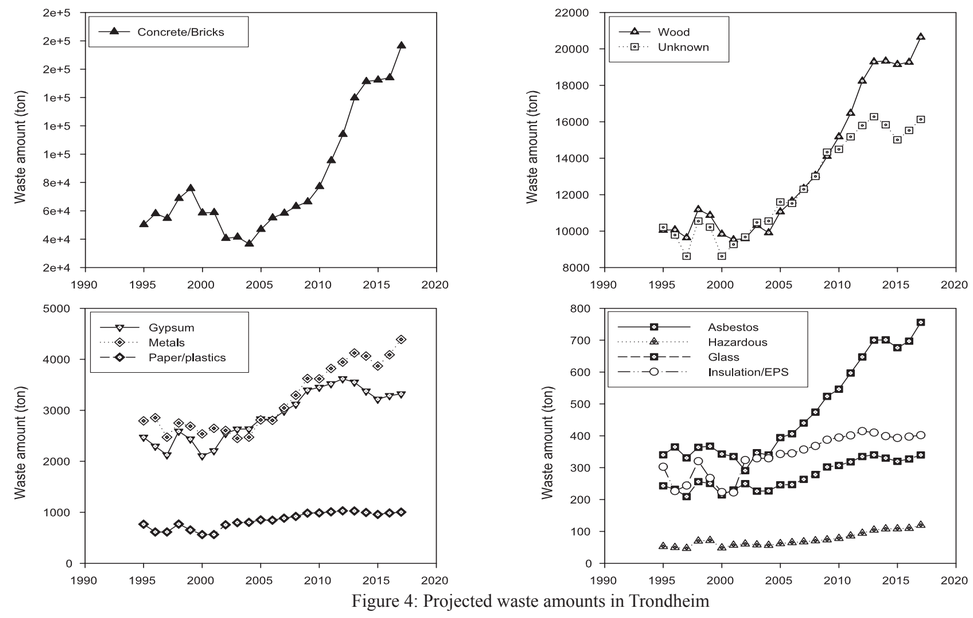

Figure 4: Projected waste amounts in Trondheim

The graphs show increasing waste generation for all waste fractions in the years to come. This trend is mainly due to past years increases in construction activity and size of buildings. This calls for greater concern being paid to appropriate end of life treatment solutions to reduce the potential stress on the environment, caused by C&D waste.

Eco-efficiency modeling

Having developed a model for projection of waste amounts, the results are used as inputs to evaluate different waste treatment scenarios. The evaluation is performed using eco-efficiency methodology. This methodology assesses the relationship between environmental and economic performance, such as to provide information on which strategies should be preferred, and which waste fractions and parts of the waste handling system should be prioritized.

Different scenarios are developed and evaluated, with todays practice as the baseline. The Federation of Norwegian Construction Industries has developed a national action plan (NAP) with goals to be reached by 2005 for different waste fractions. This scenario and the baseline scenario are shown in Table 3.

C&D Waste	Scenario 0				Scenario NAP			
Fraction	Landfill	Recycle	Energy	Reuse	Landfill	Recycle	Energy	Reuse
Concrete/Bricks	0,70	0,30	0,00	0,00	0,20	0,80	0,00	0,00
Wood	0,60	0,00	0,39	0,01	0,20	0,00	0,70	0,10
Gypsum	0,95	0,05	0,00	0,00	1,00	0,00	0,00	0,00
Paper/Cardboard	0,50	0,30	0,20	0,00	0,20	0,70	0,10	0,00
Glass	0,80	0,20	0,00	0,00	0,20	0,80	0,00	0,00

Table 3: Different treatment scenarios

The BASF approach from Saling P. et al (2002) and Huismann (2003) is used for visualization of changes in both economic and environmental performance, as well as the relative performance of scenarios. Examples are shown in Figure 5 for the waste fractions concrete/ bricks, wood and gypsum.

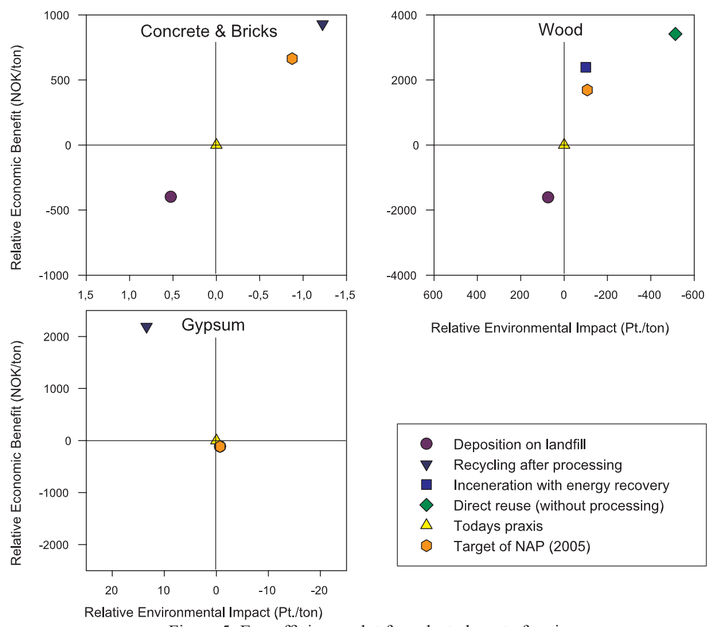

Figure 5: Eco-efficiency plot for selected waste fractions

As can be seen from the eco-efficiency plots, recycling is not always the best solution. For gypsum, the long transportation distance to the nearest recycling facility more than counters the environmental gains from recycling.

Conclusion

Long term models are needed due to increasing amounts of waste and ageing of buildings. These have to be based upon dynamic waste generation projections, yet detailed models and data are somewhat lacking. Eco-efficiency models are suitable in guiding local policy makers and actors.