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**Consortium for Research on Renewable Industrial
Materials (CORRIM)**

**Research Guidelines For Life Cycle Inventories
April 18, 2001 Draft**

Please send comments to:

David Briggs, Chair
CORRIM Panel on Data, Standards, & Procedures
College of Forest Resources
University of Washington
Seattle, WA. 98195
Email: dbriggs@u.washington.edu

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PREFACE

An initial version of CORRIM research guidelines was prepared under subcontract (no. 417346) as the response to the US Department of Energy grant (DOE Agreement No. DE-FC07-96ID13437) as part of the American Forest & Paper Association's Agenda 2020 research priorities. The final report (CORRIM 1998) included an Appendix titled "Data, Standards, and Procedures: Guidelines for LCI and Economic Analysis". Since then, CORRIM formed a partnership with the ATHENA Sustainable Materials Institute and it was decided to harmonize CORRIM guidelines with those of ATHENA. This document represents CORRIM's revision of ATHENA guidelines. Since several portions of the ATHENA guidelines are specific to Canada, many changes reflect CORRIM's focus on the US. In addition, other portions have been clarified or updated due to newly adopted international LCA protocols.

Since the field of life-cycle assessment is continuing to grow and evolve through new research on methodology and a growing body of internationally accepted standards and guidelines, this document must always be considered a work in progress and there will undoubtedly be future revisions.

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CORRIM RESEARCH GUIDELINES

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1. INTRODUCTION

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These research guidelines were developed to ensure a consistent and comparable approach among the various institutions, panels, and task groups conducting CORRIM research. The guidelines detail the information required, include definitions, conventions and measurement units, and cover a range of methodological issues with particular emphasis on establishing boundaries and analysis limits to scope studies.

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The CORRIM research project is designed to (1) *collect environmental and economic data on all life-cycle stages from planting and growing the renewable raw resource through the manufacturing of product, transport, design and construction of buildings as well as activities associated with occupation, use and final demolition (life-cycle inventories (LCI)); (2) ensure that the studies follow consistent definitions and collection procedures; and (3) develop analytical procedures that facilitate integration of results across the full life-cycle for all stages of processing to address environmental performance questions (life-cycle analysis (LCA))* (CORRIM 1998).

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Studies commissioned as part of the CORRIM project will usually be a series of life cycle inventory (LCI) analyses for the various stages of processing. The resulting data show raw resource, energy and water inputs required for the production of a unit of an industry's product and the associated releases to air, land and water. These quantities are often referred to as "unit factors".

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Cradle-to-Gate LCI Examples

To produce one square meter of *Product A* the following **inputs** were required:

0.38 kg of raw material #1

0.22 kg of raw material #2

1.17 MJ of electricity

2.57 MJ of natural gas

0.62 MJ of refined petroleum

32.0 l. of water

The production of one square meter of *Product A* incurred the following **emissions**:

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<p style="text-align: center;"><u>to Air</u></p> <p style="text-align: center;">340g of carbon dioxide</p> <p style="text-align: center;">1.6g of carbon monoxide</p> <p style="text-align: center;">0.3g of sulfur oxides</p> <p style="text-align: center;">3.7g of nitrogen oxides</p> <p style="text-align: center;">0.2g of methane</p> <p style="text-align: center;">0.3g of particulates (as inert mineral, fly ash)</p> <p style="text-align: center;"><u>to Water</u></p> <p style="text-align: center;">72 mg/l biochemical oxygen demand</p> <p style="text-align: center;">320 mg/l suspended solids</p> <p style="text-align: center;">11 mg/l dissolved solids</p> <p style="text-align: center;">7.2 pH</p> <p style="text-align: center;"><u>to Land</u></p> <p style="text-align: center;">0.44 kg of mine overburden waste</p> <p style="text-align: center;">0.09 kg of non-recoverable mill slag</p> <p style="text-align: center;">0.01 kg of inorganic sludge</p>
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138 Users of the CORRIM database and models will be able to select and design
139 commonly recognized building assemblies which are converted into masses and areas of
140 their component materials. This step is not commonly done as part of building design and
141 estimating, and most people in the building industry do not have the necessary
142 information readily accessible to do it. An example of a building assembly is a sheathed,
143 wood frame wall section of a given thickness, including all materials and fasteners.

144 Once conversion has been made to a bill of materials and components, the
145 relevant products are multiplied by unit factors and the results are aggregated to derive an
146 environmental impact profile for a given assembly or structure.

147 Life cycle inventories for industries and product groups involve gathering or
148 estimating data on environmental inputs and outputs and dividing them by production
149 quantities to determine the amounts assigned to a single unit of product. But there is no
150 absolute or correct unit factor of a material.¹ A stated value is a direct function of what is

¹Kohler, N., 1991 Life Cycle Costs of Buildings, *Proceedings of European Forum on Buildings and Environment*, University of B.C., Vancouver, Canada, March 15th 1991, pp 19-36

151 included and excluded from its derivation. Scope and boundary conditions, definitions
152 and assumptions underlying LCI data must therefore be explicit and clear.

153 **2. REQUIRED INFORMATION**

154 Three sets of information are requested from researchers responsible for
155 developing industry unit factors:

- 156 • a general description of the industry;
- 157 • a set of detailed information used to derive the unit factors; and
- 158 • information on the secondary assemblies most closely allied to the primary
159 material.

160 **2.1 GENERAL DESCRIPTION**

161 Reports should include a broad overview description of each industry, with
162 emphasis on the environmental aspects and including the following information:
163

- 164 • Industry description:
 - 165 ➤ categories of products and co-products;
 - 166 ➤ annual operating and production statistics of the industry;
 - 167 ➤ location of markets and typical transportation methods; and
 - 168 ➤ recycling, energy efficiency and emission controls profiles for the
169 industry.
- 170
- 171 • Inputs:
 - 172
 - 173 ➤ types of raw material inputs, their location and transportation profiles by
174 region; and
 - 175 ➤ typical energy sources and fuel types used in the industry including a
176 discussion of energy conservation programs.
 - 177
- 178 • Plant Types:

179

180 ➤ typical plant types, ages, efficiencies and geographical distribution;

181 ➤ typical conversion efficiencies; and

182 ➤ typical emission control measures by plant type.

183

184 • Emissions and Wastes:

185

186 ➤ characteristic emissions to air, land and water from plants.

187

188 **2.2 DETAILED DESCRIPTION**

189

190 The detailed information requested is as follows for a *typical* or *average* plant,
191 with regional breakdowns where feasible (see Section 4.4):

192 • process flow diagrams for plant types or process stages;

193 • detailed raw material inputs;

194 • detailed gross energy use figures, by fuel type, including purchased and self
195 generated energy, per unit of product;

196 • water use per unit of product;

197 • emissions to air per unit of product;

198 • emissions to water per unit of product;

199 • emissions to land (solid waste) per unit of product;

200 • information on emissions control and waste-water treatment methods and
201 degree of application; and

202 • documentation of all data gathering steps, calculations and compilations.

203

204 The development of typical or average plant profiles will be fully explained,
205 including the rationale for the approach used. Where possible, the rationale should
206 include data ranges or other descriptive material to make clear how the typical or average
207 plant parameters were established.

208 Where an industry's total production is made up of the output of different plants
209 with significantly different inputs or outputs as a result of different technologies,
210 pollution control devices or other factors, regional estimates of average or typical
211 practice will be developed by weighting production from the distinctly different types of
212 plants contributing to the total product stream. The selection and derivation of weights
213 (e.g. the percentage contribution of each plant type to total annual regional production)
214 should be clearly explained.

215 The following sub-sections provide a more detailed description of the data
216 requirements for raw material and energy inputs and for air, liquid and solid waste
217 outputs.

218 **2.2.1 Raw Resource & Material Inputs**

219 Raw resource or material inputs should be sufficiently detailed to show all
220 significant requirements and related environmental effects associated with production of
221 the product (see Section 4.3, Level of Detail). The following are examples of raw
222 resources and materials:

- 223 • wood — softwood timber such as Douglas-fir and southern pine and hardwood
224 timber such as aspen and yellow poplar.
- 225 • non-metallic minerals — sand and gravel, clay, limestone, lime, gypsum, silica;
- 226 • metallic minerals — iron ore, alumina, zinc;
- 227 • fossil fuels used as feedstock materials rather than for energy production —
228 metallurgical coal, natural gas to make PVC, petroleum products used to make
229 roofing products; and
- 230 • scrap metal.

231 **2.2.2 Categories of Energy Inputs**

232 The categories of energy that will be used are:

- 233 • electricity (hydro, thermal and nuclear);
- 234 • natural gas (including LPG's);
- 235 • coal (thermal and metallurgical);

- 236 • refined petroleum (including heavy oils);
- 237 • wood fuels (hog fuel and post-consumer wood scrap);
- 238 • spent pulping liquor; and
- 239 • other (derived from spent oils, plastics, rubber etc.).

240

241 Gross energy input figures are to be used without allowance for the primary
242 energy required to produce and deliver energy to the process. This pre-combustion
243 energy will be separately estimated by region and included as Resource Utilization
244 Factors (RUF's). Industry sector analysts are responsible for deriving RUFs for any
245 energy sources not provided by public utilities. All energy figures are to be expressed in
246 metric units (e.g. megajoules). Conversion factors from other energy units are in Table 1,
247 Appendix A and energy contents of fuels are presented in Table 3, Appendix A.

248 Waste energy reclaimed from within a plant will not be treated separately, but
249 will be reflected in the overall energy efficiency of the process.

250 Self-generated energy which is used in a plant should be indicated as such and the
251 fuel input, emissions and energy output estimated. This includes energy drawn from
252 exothermic processes, waste to fuel operations and utilities owned by the industry. These
253 figures will not be multiplied by the Resource Utilization Factors. If excess energy is
254 generated by a plant and the surplus sold to a public utility or used outside the process,
255 the fuel inputs, energy values and emissions for the surplus should be deducted from the
256 figures used to calculate unit factors for the industry.

257 **2.2.3 Categories of Emissions to Air and Water**

258 Emissions from industries must include both those from processes and from
259 energy use. For example, all industries that burn fuels produce CO₂ and CO, but those
260 that heat materials containing carbon also release process CO₂.

261 Most air and water emissions are categorized by their chemical composition from
262 which their biological, regional or climatic effects are determined. A few, such as
263 Biological Oxygen Demand (BOD) are classed by their biological effect such as oxygen

264 depletion. Because each industry has a unique profile of emissions, the following
265 comprehensive lists are included.

266 **Emissions to Air**

267

268 Following are the air emission categories and units, including their common
269 industrial sources and effects. (Note: Those in **bold** are considered essential to all
270 industry evaluations.)

271

- 272 • **Carbon dioxide (0.00g):** Produced primarily by combustion, by calcination
273 of carbonate minerals and by smelting and heating of carbon containing
274 materials. Carbon dioxide is a greenhouse gas.
275
- 276 • **Carbon monoxide (0.00g):** Produced by incomplete combustion and partial
277 oxidation of carbon containing materials. Carbon monoxide is toxic and is a
278 local and regional air pollutant.
279
- 280 • **Sulfur oxides (0.00g):** Produced primarily by combustion of fuels containing
281 sulfur, smelting of sulfite ores, scrubbing of natural gas and sulfate and sulfite
282 paper-making. Sulfur oxides are toxic and are major contributors to acid rain.
283
- 284 • **Nitrogen oxides (0.00g):** Produced primarily by high temperature
285 combustion. Nitrogen oxides are local and regional air pollutants,
286 contributors to acid rain and greenhouse gases.
287
- 288 • **Nitrous oxides (0.00g):** CORRIM determined that this should be a separate
289 category.
290
- 291 • **Particulates and fumes (0.00g):** Produced primarily as combustion by-
292 products and from smelting and milling. Particulates include metals, are local
293 air pollutants, and lead to soil and water contamination. They are widely

294 varied in composition and may have toxic effects. Particulates should be
295 characterized (see Section 3.3, Categories of Data).

296

297 • Volatile organics (0.00g): Volatile organics are produced by incomplete
298 combustion, heating, refining and distillation of organic (carbon based)
299 compounds and by industrial use of solvents. Volatile organics are local and
300 regional air pollutants (photochemical oxidants) and greenhouse gases. They
301 are widely varied in composition and may have toxic effects. Volatile
302 organics should be characterized (see Section 3.3, Categories of Data).

303

304 • Methane (0.00g): Methane is a specific volatile organic produced by
305 incomplete combustion, evaporation or loss of fossil fuels, coal mining, coal
306 coking and by anaerobic bacterial activity (i.e. decomposition of organic
307 waste). Methane is a regional air pollutant (photochemical oxidant) and a
308 potent greenhouse gas.

309

310 The final categories of air emissions included will be grouped by effect (i.e. those
311 which are greenhouse gases, those which are contributors to acid rain, etc.).

312 **Emissions to Water**

313

314 Following are the categories and units for emissions to water, including their
315 common industrial sources and effects. (Note: Those in **bold** are considered essential to
316 all industry evaluations.)

317

318 • **Biochemical oxygen demand (0.00g/l):** BOD load is generated by effluents
319 containing organic material. BOD is the measure of oxygen per liter of
320 effluent that will be required by aerobic bacteria to digest organic wastes
321 (primarily their nitrogen component). It is a useful indicator of the impact on
322 aquatic ecosystems because oxygen demand is competitive with other

- 323 organisms. High BOD reduces water quality for marine life and human
324 consumption.
325
- 326 • **Suspended solids (0.00g/l):** Suspended solids are produced by any mining,
327 milling or processing operation which releases insoluble particles small
328 enough to be suspended in effluent. Suspended solids are of concern for their
329 role in transporting pollutants, reducing light penetration of water (increased
330 turbidity) and eventually settling as bottom sludge. All effects are destructive
331 to aquatic organisms and reduce water quality for human consumption.
332
 - 333 • **Dissolved solids (0.00g/l):** Dissolved solids are produced by any mining,
334 milling or processing operation which releases soluble particles. Dissolved
335 solids are of concern for their chemical composition, i.e. their toxicity,
336 contribution to salinity, changes to pH, oxygen demand and nutrient content
337 of receiving water. All effects are destructive to aquatic organisms and
338 reduce water quality for human consumption.
339
 - 340 • **pH (1.0 to 14.0):** Discharges from mining and processing contain acids and
341 alkalies which directly alter pH of the receiving water. Many aquatic
342 organisms are acutely sensitive to alterations of pH. Alterations of pH also
343 mobilize naturally occurring metals such as lead, aluminum, copper, mercury,
344 cadmium and zinc which have toxic effects.
345
 - 346 • **Polynuclear aromatic hydrocarbons (0.00g/l) (as benzo-a-pyrene):**
347 Polynuclear aromatics are by-products of coking and petroleum refining as
348 well as of incomplete combustion. They are contained in soot and tars. The
349 best known is benzo-a-pyrene (BaP), a potent carcinogen that is the reference
350 standard for polynuclear aromatics. These substances are highly toxic to
351 marine organisms and carcinogenic for humans.
352

- 353 • Chemical oxygen demand (0.00g/l): Similar to BOD (above) but with the
354 measure of oxygen required for chemical oxidation, primarily of the carbon
355 and hydrogen components of organic wastes.
356
- 357 • Oil and grease (0.00g/l): Oil and grease are produced by petroleum processing
358 and handling, machining and rolling operations and as lubricant losses from
359 all types of machinery. They contain toxic compounds and are persistent
360 water contaminants that suffocate aquatic life, foul bird feathers and are
361 difficult to treat. All effects are destructive to aquatic organisms and reduce
362 water quality for human consumption.
363
- 364 • Sulfur compounds (0.00g/l): Sulfides, sulfates and sulfites are produced by
365 pulp and paper operations, by a wide variety of industries utilizing acids and
366 as a result of coal mining. Sulfates are the predominant form in water and are
367 of direct concern because they alter the pH of receiving waters.
368
- 369 • Non-ferrous metals and metal compounds (0.00g/l) (identified by type):
370 Metals are released from mining, mineral concentrating and smelting
371 operations as well as tanning, dyeing and pulp and paper plants. The main
372 metals of concern are the toxic heavy metals: mercury, lead, cadmium, nickel,
373 and chromium (hexavalent). These are toxic, persistent and will bio-
374 accumulate in the food chain. Other metals with toxic effects on aquatic
375 organisms and humans are aluminum, copper and zinc.
376
- 377 • Cyanide (0.00g/l as CN): Hydrogen cyanide is produced by coking of coal and
378 is used in beneficiation of metal ores. Cyanides, particularly hydrogen
379 cyanide, are highly toxic to marine organisms.
380
- 381 • Phenols (0.00g/l): Phenols are released from coal coking and petroleum
382 refining as well as organic synthesis. Phenolics are toxic to marine organisms
383 and humans.

384

385 • Phosphates (0.00g/l): Phosphates are released by fertilizers and by detergents
386 used in industrial washing operations. Phosphates are nutrients that cause
387 algal bloom and will lead to oxygen depletion in aquatic ecosystems,
388 eventually causing eutrophication (disturbance of ecological balance due to
389 excess nutrients).

390

391 • Ammonia and ammonium (0.00g/l): Ammonia and ammonium are released by
392 fertilizers used in reforestation and agriculture and by petroleum refineries.
393 Ammonia is directly toxic to fish and leads to production of nitrate and nitrite
394 which are toxic to humans. Ammonia and ammonium also contain nitrogen
395 which fertilizes algae and leads to oxygen depletion and eutrophication (see
396 phosphates above).

397

398 • Non-halogenated organics (0.00g/l): Organic compounds such as solvents
399 used in cleaning and coating operations are often toxic to aquatic organisms
400 and render water unfit for human use.

401

402 • Halogenated organics (0.00g/l): Organic compounds of chlorine, bromine and
403 fluorine are classed as halogenated organics. Most are now produced
404 unintentionally, such as by chlorine bleaching of paper, with regulation of
405 PCB's, CFC's, PCP's and DDT. Some are still used in cleaning and
406 degreasing operations and as wood preservatives. Most are highly toxic to
407 aquatic life and humans, are highly persistent and will accumulate in the food
408 chain.

409

410 • Chlorides (inorganic) (0.00g/l): Inorganic chlorides in the form of salts are
411 used in brine operations, for ice control and many other industrial processes.
412 If released they will alter the salinity of freshwater ecosystems killing
413 organisms and rendering the water unfit for use. They are difficult to treat.

414

415 The final categories of emissions to water included will be determined from the
416 data provided and will be grouped by effect (e.g. those which deplete oxygen and those
417 contain toxic organics and metals).

418 **2.2.4 Emissions to Land**

419 Emissions to land are defined as any solid by-products (solid wastes) of any
420 manufacturing stage which have no purpose in the process, or in other processes, and
421 which must be stored, land-filled or otherwise disposed. Solid wastes may include
422 particulates that have been collected from gas streams and dewatered solids and sludge
423 from treated effluent. Items that are wood waste are those returned to the land for
424 disposal in wood form; do not include bark, sawdust, etc. that becomes hog fuel and is
425 converted to energy. The ash from the burning may be an emission to land.

426 The final categories of solid waste will be determined by the characterization of
427 solid wastes reported by the relevant industries. The following are typical of the types of
428 solid waste that should be considered.

- 429 • Mining/extraction waste
 - 430 ➤ mine overburden
 - 431 ➤ spilled ore
 - 432 ➤ settling pond fines (not reused)
 - 433 ➤ log bucking ends
 - 434 ➤ stripped tree branches
 - 435 ➤ lost logs
- 436 • Beneficiation waste
 - 437 ➤ unusable ore extractions
 - 438 ➤ sintering waste
 - 439 ➤ oversize rock
 - 440 ➤ settling pond fines (not reused)
- 441 • Primary processing waste
 - 442 ➤ furnace slag
 - 443 ➤ lime fines

- 444 ➤ scale
- 445 ➤ collected dusts (not reused)
- 446 ➤ bark, slabs, trimmings, sawdust (not reused)
- 447 ➤ ash, collected fly ash (not reused)
- 448 ➤ settling pond fines (not reused)
- 449 ➤ waste treatment sludge
- 450 ➤ packing materials, pallets (not reused)
- 451 • Secondary processing waste
- 452 ➤ trimmings (not reused)
- 453 ➤ collected sanding, grinding dusts (not reused)
- 454 ➤ glue waste, paint shop waste
- 455 ➤ packing materials, pallets (not reused)
- 456 ➤ unused concrete

457

458 A brief description of the content of each solid waste type should be included for
459 each industry. The key characteristics which should be included are inert, inorganic
460 contents, soluble /leachable mineral and metal contents, organic contents including toxic
461 materials and nutrient contents (i.e. nitrogen and phosphorous).

462 Where there is any doubt about the potential for sale, recycling or reuse of any
463 material, it should be included as a potential emission to land, or solid waste, with a brief
464 description of the reuse or recycling potential.

465 The final categories of solid wastes to be included will be determined from the
466 characterization provided and will be grouped by effect (i.e. those which are leachable,
467 contain toxic metals etc.).

468 **2.3 SECONDARY COMPONENTS AND ASSEMBLIES**

469 *Secondary components* are those which are manufactured and shipped, ready to
470 install, and that require some degree of processing after the primary (or secondary)
471 industry. Examples are steel bar joists, wood trusses and composite joists and pre-cast
472 concrete (see Section 4.1). These products are not fundamentally different in kind from

473 many secondary products, such as glue laminated wood beams, but are typically stocked
474 in standard sections and may contain several materials.

475 *Secondary assemblies* are comprised of materials assembled on site and for which
476 the component materials or products can be easily predicted. For example, a concrete
477 block, steel frame or wood frame wall assembly can be readily converted from wall area
478 into required quantities of concrete blocks, mortar and steel reinforcement, steel or wood
479 studs and fasteners etc.

480 Industry studies will be expected to provide the following information for those
481 secondary components and secondary assemblies most closely allied to their primary
482 industry:

- 483 • composition of the assembly or component by primary/secondary material type
484 using the units of measurement determined by the industry; and
- 485 • estimates of the energy use and emissions of the secondary industry producing
486 the components using the measurement units for the component (i.e. MJ per
487 linear meter of bar joist).

488

489 Energy use, solid wastes and other emissions incurred on the construction site will
490 be contained in a separate database and should not be included in the industry estimates.

491 **3. DATA SOURCES AND VERIFICATION**

492 There are numerous types of data that can be acquired for estimating unit factors,
493 all of which have been used to some degree by other researchers. However, it is
494 important to distinguish between primary and secondary data. Primary data are those
495 collected using CORRIM inventory data collection rules and typically are obtained from
496 specific facilities. Secondary data are those included in the product system life-cycle
497 inventory but which have been obtained from secondary sources such as literature, other
498 LCI studies, etc. Depending on the source and method of data collection, all data should
499 be identified as being either primary or secondary.

500 One common method is to use aggregated statistics from national sources such as
501 US Department of Commerce Census of Manufacturers. Two major shortcomings of
502 methods using national statistics are that the units are often not relevant to environmental
503 LCI analysis, and the methods of compiling and aggregating are often not relevant to the
504 building industries.

505 For example, a good deal of national industrial data is in dollar value terms
506 because it is intended for economic and trade uses. To convert dollar values to physical
507 units is an unwieldy and unreliable exercise at best. Furthermore, data on several
508 products used in buildings, such as different steel components, may be lumped together
509 for convenience making it difficult to distinguish between what may be quite different
510 choices from a design or environmental cost accounting perspective.

511 Most national statistical data is compiled from individual industry or company
512 submissions and each compilation step can add errors. Because CORRIM includes direct
513 industry participation, CORRIM has two more appropriate data sources for estimating
514 unit factors:

- 515 • actual industry data; and
- 516 • process studies.

517 **3.1 ACTUAL INDUSTRY DATA**

518 Actual industry data for plants and entire industries is the preferred data source
519 for this project. Such data may include estimates or extrapolations, but should be based
520 on measured values. Records of actual raw material inputs, measured stack and outfall
521 emissions and energy purchases by fuel type are examples of this type of data. Because
522 this data reflects actual conditions and efficiencies it is considered the most accurate.

523 However, there may be some difficulties with this type of data. One difficulty
524 may be incomplete measurement and record keeping for some emission categories.
525 Another may be that industries producing several products from the same plant have
526 difficulty assigning energy use and emissions to individual products. Process studies are
527 helpful in resolving these kinds of problems.

528 **3.2 PROCESS STUDIES (INPUT-OUTPUT MODELS)**

529 A process study is a physical/chemical analysis of what occurs within a process
530 under ideal conditions. Data is generated from physical/chemical models of processes
531 (often called input-output process models) such as mass-balance equations, energy
532 analyses, chemical analyses (stoichiometry) and process engineering studies.

533 Process study data may be used when measured quantities are not available, and
534 could be an important adjunct in resolving some of the problems encountered with actual
535 industry data. Estimates generated from process models should be adjusted for expected
536 efficiencies of actual plants.

537 **3.3 DATA REQUIREMENTS**

538 *Origins*

539 Industry data should be designated as measured or derived. The actual sources
540 should be indicated except where it is sensitive internal information.

541 *Dates of Data*

542 The most recent data should be used for unit factor calculations and the dates
543 should be noted. Significant trends in an industry, such as significant energy efficiency
544 improvements or shifts to a different process, feedstock or pollution control device
545 should be indicated in note form.

546 *Units of Measure*

547 Data should be collected in the customary units of the industry under
548 investigation (eg. MBF lumber, MSF 3/8 basis veneer & plywood, etc.). The units of
549 measure should be carefully defined and noted for each piece of information. It will also
550 be helpful to note species and moisture contents. CORRIM will develop appropriate
551 factors for conversion to standard metric units (see for example, Briggs 1994), typically
552 oven-dry tons for materials and megajoules for energy (See Section 3.5).

553 *Level of Plant Detail (Machine Center)*

554 Ideally, each major step in the process under investigation will be treated as a
555 separate unit (“machine center”) for data collection. For example, at a minimum, a
556 sawmill operation would consist of the following unit operations (machine centers): log
557 yard, debarking and bucking, primary breakdown of logs into trimmed, green lumber;
558 kiln drying, planer mill, and grading and packaging (Appendix B). This level of detail
559 provides recognition of various product grades and joint products from each center that
560 may be sold to other industries without further processing. It also recognizes alternative
561 pathways of primary material through the mill (green lumber to grading & packaging
562 versus green lumber to kiln drying). There are many variations on each of these unit
563 operations and some can be studied in greater detail. By performing data collection at the
564 unit operation level, many potential issues with respect to co-product allocation can be
565 resolved, and it will be possible to combine different machine center technologies into
566 new configurations as part of sensitivity analyses.

567 *Data Range*

568 Data for individual machine centers and facilities will vary by plant age and type,
569 and factors such as transportation distances will also vary by region. It will be useful to
570 get a sense of the degree of variation normally experienced. The estimates used in
571 modeling by CORRIM will most often be industry averages of machine centers and
572 facilities, with regional breakdowns where feasible. However, it will be useful to
573 statistically summarize data in a way that provides the range, median, mode and
574 upper/lower quartiles. This will permit analyses that can focus on the sensitivity of
575 outcomes to advances in adoption of technology such as “What happens as the industry
576 gradually improves so the average moves up to the current upper quartile?” As noted in
577 Section 2.2, researchers are required to make clear how industry averages or typical plant
578 estimates were derived.

579 *Categories of Data*

580 For each industry, researchers will be expected to select relevant categories of
581 raw material, energy, products and emissions, and to collect the data accordingly. The
582 figures may be compiled or aggregated, based on the requirements of the industry, but the
583 maximum number of reporting categories should be maintained.

584 For example, where two products are made for a similar use but have significant
585 differences in the way they are produced, the data should be kept separate (see Section
586 5.4). Similarly, where methane emissions can be estimated they should be indicated as
587 methane and not be included in volatile organics.

588 Whereas some categories such as carbon dioxide are distinct, others such as stack
589 particulates are very broad. For those broad categories, some further characterization
590 should be provided. For example, stack particulates could be described as 78% mineral
591 fly-ash containing alumina, carbon, and manganese, 18% silicates, and 4% other
592 materials.

593 **3.4 VERIFICATION OF DATA**

594 All data will be evaluated and compared with published data, where available, to
595 ensure uniformity of approach and consistency with international work. Given a
596 reasonable allowance for small errors and variations of method, any data that appear
597 inconsistent with published data will be referred to the CORRIM Panel on Data,
598 Standards and Procedures for judgment.

599 **3.5 TABLES OF STANDARD FACTORS**

600 Examples of conversion factors and standard tables have been provided in
601 Appendix A for various calculations, such as:

- 602 • calculating CO₂ emissions directly from fuel consumption;
- 603 • calculating energy inputs to processes which use petroleum as feedstocks;
- 604 • estimating emissions associated with raw material transportation by rail, road or
605 water; and
- 606 • estimating energy consumption per metric ton-kilometer by transportation mode.

607
608 A more comprehensive set of conversions for wood products is published
609 elsewhere (Briggs 1994) and additional research will be undertaken to regionalize the
610 factors where appropriate.

611

4. ANALYSIS SCOPE

612 4.1 STAGES OF ANALYSIS

613 Five main stages of production will be recognized and kept separate in analyses
614 (1) forest growth and extraction/beneficiation of raw materials, (2) primary and
615 secondary manufacturing, (3) construction of structures, (4) service life and use, and (5)
616 recycling and disposal.(Figure 1). Typical examples are:

- 617 • Forest Growth and Extraction/beneficiation
 - 618 ➤ nursery stock production and planting
 - 619 ➤ silviculture (thinning, fertilizing, pruning, etc.)
 - 620 ➤ timber harvesting
 - 621 ➤ mineral mining and concentrating
- 622 • Manufacturing processes
 - 623 ➤ timber milling, kiln drying, veneer production
 - 624 ➤ metal smelting and rolling
 - 625 ➤ mineral calcining, cement production
 - 626 ➤ laminated product manufacturing, truss manufacturing
 - 627 ➤ metal plating, metal joist manufacturing
 - 628 ➤ ready-mixed concrete production, concrete products manufacturing.
- 629 • Construction of Structures
 - 630 ➤ assembly of walls, floors, roof framework
 - 631 ➤ application of roofing & siding materials
 - 632 ➤ installation of windows & doors
- 633 • Service Life and Use
 - 634 ➤ life of structure
 - 635 ➤ maintenance activities over the life of the structure
 - 636 ➤ replacement cycles
- 637 • Recycling and Disposal
 - 638 ➤ demolition and de-construction
 - 639 ➤ segregation of materials

640

641 At each stage, transportation values will be assessed for movement to the next
642 stage. Transportation details should include:

- 643 • mode of transport - road, rail, water; and
- 644 • typical haulage distances.

645

646 Forest harvesting will include transportation of logs to roadside for pick-up.
647 Transportation of logs from roadside landing to a log yard will be a transportation
648 activity.

649 See Section 4.5 for a more detailed discussion of transportation activities.

650 **4.2 SYSTEM BOUNDARIES AND LIMITS**

651

652 The derivation of unit factors requires an analysis of the *Gross System Inputs and*
653 *Outputs* for each distinct product.

- 654 • *Gross System Inputs* are defined as the raw material, and water and energy
655 inputs from natural sources required to maintain the system in production.
656 Gross system inputs include the energy content of petroleum fuels, coal or
657 other materials commonly used as fuels in the applicable jurisdiction, and used
658 as feedstocks or for non-energy purposes in a process under study. The energy
659 content is equal to the energy value of a material if it is burned as a fuel (ie. the
660 opportunity cost of using these energy resources for a non-energy purpose).
- 661 • *Gross System Outputs* are defined as the products, co-products and by-
662 products, including gaseous, liquid and solid wastes, released by a system in
663 production.

664

665 Each stage in a production process must be limited by an imagined boundary
666 drawn around it. The boundary serves to include all of the essential information while
667 excluding externalities that would not significantly increase the accuracy of the estimates.

668 Once the boundary is determined then inputs are defined as:

669 *Any material or energy flow which enters the boundary of the process.*

670 Outputs are defined as:

671 *Products and emissions which exit the boundary of the process.*

672 Estimates must be based on practical and appropriate limits of analysis. The limits set for
673 this project are similar to a Level II analysis determined by the I.F.I.A.S. (*International*
674 *Federation of Institutes of Advanced Studies, 1974*) for energy analysis. These limits
675 typically capture about 90% to 95% of the full impacts of an industry (Boustead &
676 Hancock 1979).

677 The limits include:

- 678 • acquisition, beneficiation, storage and transfer of raw materials, including
679 dedicated road and bridge building, utility construction and earth-moving
680 which must be done to gain access to a raw material;
- 681 • acquisition, storage and transfer of energy which will be calculated from
682 standard Resource Utilization Factors for US or Canadian energy as
683 appropriate;
- 684 • processing of raw materials into primary products (i.e. steel, sawn lumber,
685 Portland cement);
- 686 • processing of primary products into secondary products, where applicable (i.e.
687 steel joists, wood trusses, ready mixed concrete);
- 688 • combining primary and secondary products into sub-assemblies and
689 assemblies in producing a completed structure;
- 690 • energy consumed during consumption and use
- 691 • processing of materials to manufacture repair and replacement products
692 installed on regular maintenance schedules;
- 693 • deconstruction, demolition, and sorting at end of service life
- 694 • transportation of products at all stages;
- 695 • allocated energy requirements of, and waste accumulation from, pollution
696 control processes that are not an integral part of the industrial processes under
697 study (e.g. a central waste water treatment plant); and

- 698 • environmental restoration costs such as reforestation and mine site
699 reclamation.

700

701 The limits *do not* include:

- 702 • construction of plants, vehicles or other machinery used for any phase of
703 production;
704 • maintenance and administration of plants or equipment; or
705 • transportation of people to work or other "social costs".

706 **4.3 LEVEL OF DETAIL: ANCILLARY MATERIALS**

707 Within the defined boundary of a process, the level of detail of the analysis should
708 be sufficient to reveal all significant environmental effects. Effort need not be spent on
709 developing data for materials of negligible significance. For the purpose of establishing a
710 guideline for the level of analysis detail, **ancillary materials** to a process are defined to
711 be those which do not appear to be major contributors to the total product assessment.
712 Examples are fluxes and lime used in the steel industry and paints and waxes used in the
713 lumber industry for marking and protecting milled wood.

714 The methodology to ensure that all inputs to a process that are important to
715 environmental performance are included is as follows:

- 716 1. Identify all intermediate and final products that account for at least 95% of the mass
717 of output flows from the process.
- 718 2. Perform a mass balance for the subsystems being analyzed and normalize to the
719 primary output for the system
- 720 3. Materials that will be included in the scope of analysis are classified as being of
721 primary, secondary, or negligible importance based on their contribution to the total
722 mass of the system, the total energy of the system and their environmental relevance
723 to the system. Specifically,
- 724 a. All materials that have a cumulative mass contribution of up to 95% of the
725 product system are considered primary and will require primary data sources

726 within the data collection activities. The additional materials that bring the total
727 cumulative mass up to 98% of the product system are considered secondary and
728 require secondary data sources to quantify their life-cycle contribution.

729 b. Any input, regardless of mass or energy contribution is considered primary if any
730 of its environmental releases during its life cycle, up to and including its use in
731 the product system under study, contribute more than 15% to an environmental
732 release data category in the summary profile.

733 Furthermore, any material, no matter how small its mass contribution, which has
734 extraordinary effects in its extraction, use or disposal, is highly toxic or classed as
735 hazardous waste should also be accounted for if it is an integral part of the product or
736 essential to its production. For example, glues used in the manufacture of plywood are
737 integral to the product and would be included even if they accounted for less than 2% of
738 inputs (by mass). But paints used to mark lumber are not integral to the product and
739 would not be included unless they accounted for at least 2% of inputs.

740 Care should be taken to verify the ancillary material status of any input in the
741 context of the analysis boundaries. For example, a basic oxygen furnace makes steel
742 from molten pig iron with essentially no additional energy or material inputs other than
743 oxygen. When the furnace is isolated from the pig iron making process its input
744 requirements are very low. In this case the contribution of fluxes and lime are
745 significant, even though they would be classed as ancillary materials in the context of the
746 total steel-making process.

747 **4.4 GEOGRAPHIC DIVISION**

748 **4.4.1 ELECTRICITY GENERATION REGIONS**

749 At least four main geographic divisions will be used for purposes of assigning electricity
750 requirements to specific grids. More detailed geographic sub-divisions, focused on
751 specific cities chosen for analyses of structures, will be used as appropriate for grouping
752 plants in terms of production technologies and distribution areas, and for estimating
753 transportation distances for raw materials and products (see Section 4.5).

754 **4.4.2 PRODUCT MANUFACTURING REGIONS:**

755 The ability to develop unit factor estimates on a regional basis varies among
756 industries. Researchers may need to approach regionalization somewhat differently
757 depending on geographic location of facilities and possible differences in manufacturing
758 processes.

759 Steel:

760 In Canada, the integrated steel industry is concentrated in Ontario, and the
761 average integrated plant profile was developed for that region only, with transportation
762 factors reflecting the environmental implications of moving raw resources and products
763 from or to other regions. But steel mini-mills are located in all regions of the country and
764 estimates for production from those plants reflect that fact. There is a need to compare
765 these estimates with the situation in the US and change as needed.

766 Cement:

767 In the case of cement production in Canada, unit factors were developed using
768 weighted averages to take account of the significant regional differences in the mix of
769 cement production processes. But concrete is produced in all regions and cities, with so
770 many plants of various sizes that the development of weighted averages is not practical.
771 Estimates for concrete products may need to be developed for each city of interest
772 assuming cement would come from within the region using a typical or average
773 transportation mode/distance combination.

774 Forest Resources and Wood Products:

775 Wood products are especially problematic from a regional-perspective because of
776 the very large number of plants of different sizes that draw on different resources and
777 produce a wide range of products at different levels of efficiency. As a result, the
778 procedures applied to the regional aspect of estimating wood product unit factors provide
779 a good example of how regional problems can be handled. Specific procedures for wood
780 products are:

- 781 • regional average recovery (efficiency) factors will be used for all lumber
782 production with a separation of softwood versus hardwood as needed.
783
- 784 • all wood products used in a construction area or city will be identified by source
785 region with transportation distances estimated accordingly; the result will be a
786 weighted average of each material for that construction area or city. As an
787 example, if Hartford, Conn. were chosen as a study city, the portions of lumber
788 from Canada, the US South, US West, etc. would be estimated and a weighted
789 average calculated for transportation distance and for all LCI characteristics. In
790 some cases specific sizes/grades may be sourced from one region while others are
791 sourced from another.
792
- 793 • electrical energy used in producing each wood product will be assumed to come
794 from the relevant regional grid in which the production facility is located;
795

796 **4.4.3 HOUSING REGIONS AND REPRESENTATIVE CITIES**

797

798 While the specifics may change from industry to industry, the basic approaches to
799 regionalization should be consistent with these examples. All reports should contain a
800 clear description of the adopted approach and a full explanation of the rationale.

801 **4.5 TRANSPORTATION FACTORS**

802 Transportation factors for raw material inputs should be expressed in metric tons-
803 kilometer per unit of material, by mode of transport. CORRIM participants will develop
804 a full set of energy and emission factors associated with these movements using standard
805 tables of transportation energy use and emissions, by type of fuel. Appendix A, Tables 5
806 and 6, are examples for Canada; CORRIM will verify if these are applicable for the US.
807 When estimating transportation energy use, researchers should:

- 808 • include only combustion energy (exclude pre-combustion energy, see 2.2.2);
809 • exclude maintenance energy such as lubricants and hydraulic oils; and

- 810 • take account of empty back hauls.

811

812 Transport distances for the movement of products to markets should be expressed
813 in kilometers by mode of transport for average haul distances from the plant locations
814 that would typically serve the destination cities identified in section 4.4.3. Energy and
815 emissions associated with transportation will be separately assigned using the factors
816 shown in Appendix A, Tables 5 and 6.

817 **4.6 RESOURCE EXTRACTION FACTORS**

818 Energy use and associated emissions for off-road vehicles and wheeled or tracked
819 equipment used in mining, quarrying, timber harvesting and other resource extraction
820 activities will be estimated by CORRIM using the energy emission factors shown in
821 Appendix A, Table 5. In the absence of more precise information, the use of diesel fuel
822 will be assumed for this component.

823 **5. STANDARD CONVENTIONS**

824 A number of difficult methodological issues that occur in life cycle assessment
825 have been discussed elsewhere in this guideline, by other researchers, and in guidelines
826 by national or international standards organizations (ISO 1997). A body of standard
827 conventions is steadily emerging to ensure a degree of comparability among studies. It is
828 critical that individual studies conform to these conventions to the maximum extent
829 possible. If it is necessary to deviate from the conventions, the reasons for and nature of
830 the deviation should be clearly explained. Key conventions that have been established by
831 CORRIM are discussed in the remainder of this section.

832 **5.1 NON-DOMESTIC PRODUCTION**

833

834 Researchers will not be required to trace the full energy and environmental costs
835 of non-domestic production of raw resources or components to the countries of origin. If
836 such data is available, it will be used with appropriate citations. For example, ATHENA

837 has developed information on wood, steel, and concrete products produced in Canada and
838 their data would be used for Canadian products consumed in the US. In other cases, such
839 as plywood from Indonesia, or steel from Korea, where good LCI data may be
840 unavailable, all materials and components will be assumed to be produced by technology
841 and processes equivalent to US plants. Factors for imported materials will not be
842 separately reported, but will be combined with those for domestic products based on the
843 relative amount of each consumed.

844 Transportation energy and associated emissions will be included for imports
845 based on the actual location of production, hauling distances and typical modes of
846 transportation.

847 **5.2 PROCESS FEEDSTOCKS**

848 The energy value of fossil hydrocarbons used as process feedstocks will be
849 included in the gross energy figures for the product as if they were burned as fuels. No
850 feedstock value will be assigned textiles, biomass materials or other combustibles unless
851 those materials are in widespread use as an energy source and would have otherwise been
852 harvested or collected for energy purposes. In other words, the test for adding an energy
853 value for process feedstocks will be whether or not there is an energy opportunity cost
854 associated with the use of the material as a feedstock. Since wood products derived from
855 industrial logs are not intended to be used for energy, wood products will not be charged
856 their inherent fuel value.

857 **5.3 COPRODUCT ALLOCATION**

858 Where several products are derived from one plant or process, and data cannot be
859 readily disaggregated, the procedure will be as follows:

- 860 • where differences in product processes are relatively minor (e.g. a steel mill
861 producing several hot rolled shapes), the energy and emissions will be
862 allocated either on a mass or volume basis, whichever is the convention in that
863 industry;

864

- 865 • in product processes (e.g. zinc coated and bare steel products) where the
866 difference exceed 10% of the gross figures for raw material, energy or
867 emissions, the separate sub-processes should be investigated and energy and
868 emissions allocated on the basis of estimates of the energy and emissions for
869 the different steps required for each product.

870

871 It is recommended that data on wood manufacturing processes be gathered at the
872 machine center level of detail (Section 3.3 and Appendix B) to minimize co-product
873 allocation issues. The machine center approach allows for a more realistic assignment of
874 energy use and emissions to the environment than does whole mill data. The example
875 shown in Appendix B illustrates this and shows which of the products and wastes from
876 each machine center will carry energy and environmental emissions with them.

877 **5.4 COMPOSITE PRODUCTS**

878 Composite components, such as structural members made from wood and steel,
879 will be assessed by the industry that is the usual manufacturer of the component (i.e.
880 where a wood manufacturer utilizes steel components, the wood industry will be
881 considered the manufacturer). The assessment will entail estimates of the material
882 contents of the components and of the energy and emissions associated with secondary
883 manufacturing.

884 Composite components or assemblies containing major or essential materials not
885 on the list of assessed materials will not be included at this time. For example, panel
886 systems which contain rigid insulation as a structural stiffener, or which would not
887 reasonably be made without insulation, will not be included in CORRIM studies until
888 LCI research is completed on the insulation industries. The same applies for systems
889 relying on non-ferrous metals, fiberglass or plastic panels, or other materials.

890 Associated materials, such as glues, paints and concrete admixtures, will be
891 evaluated by those most closely allied with their use in construction products. Where
892 adequate data is not readily available within the industry, estimates from published data
893 may be used for these materials with appropriate citations.

894 Fire retardant treatments of structural components will be treated as a separate
895 item from the component, even where its application is required by code. There will be a
896 notation to the effect that when the building finishing phases are added to the model at a
897 later date the choice of finishes will have to include fire retardant requirements (i.e. a fire
898 retardant covering will be a "minimum finish" requirement where mandated by code).

899 **5.5 BY-PRODUCTS, WASTES AND RECYCLING**

900 The approach to waste management and recycling conforms to other guidelines
901 (CSA 1994, ISO 1997) for life cycle assessment. However, many use the term "waste"
902 loosely to refer to anything other than the primary product under investigation. CORRIM
903 will use the following definitions:

- 904 • internal by-products produced and recycled within an industrial process or within
905 the system boundaries;
- 906 • industrial by-products material from another industry that becomes feedstock to a
907 process being studied;
- 908 • industrial waste; and
- 909 • post-consumer waste.

910 **Internal By-Products**

911 Recycling of internal mill or plant waste, such as reuse of metal scrap in a steel
912 mill, use of sawdust or wood chips in a wood products mill or use of collected process
913 dust in a mineral industry will not be credited separately. This type of recycling of useful
914 process waste within an industry is considered good housekeeping and will appear as
915 higher conversion efficiency (the ratio of inputs to "useful product") and lower waste in
916 the process material balance. In practice, this means the energy use and other
917 environmental effects associated with production of the internal scrap in the first instance
918 is implicitly attributed to the final products made using that scrap as one of the material
919 inputs.

920 **Industrial By-Products**

921 Industrial by-products, such as trim scraps, off-spec materials, sawdust and
922 shavings are defined by the following criteria:

- 923 • the by-product has value;
- 924 • it is produced as an integral part of a manufacturing process;
- 925 • it has never been used in a final consumer product or as originally intended when
926 manufactured; and
- 927 • it is collected and used as input material for other manufacturing processes.²

928

929 An industrial by-product is treated as a co-product (Section 5.3) at the point
930 where it is produced and its allocated share of original manufacturing energy and
931 environmental effects carried forward to the next use.³ All energy or other environmental
932 costs incurred in the collection, transportation and processing of an industrial by-product
933 to make it suitable for use as a feedstock material will also be attributed to the product(s)
934 made from the by-product.

935 In the case where the process under investigation is receiving a by-product from a
936 process outside the study boundaries, we require allocation of only the inputs and outputs
937 associated with the original manufacturing process. Transportation, process energy or
938 other inputs and outputs related to the process creating the by-product will be implicitly
939 allocated entirely to the final products of that process.

940

² FOOTNOTE?

³ When industrial waste has been manufactured from material that has already been frequently recycled (i.e. previous generations of industrial and/or post-consumer waste), the allocation of original manufacturing (i.e. from virgin raw resources) inputs and outputs may be insignificant in terms of any one generation of product made from that waste. It can be argued that the analysis should therefore be simplified by taking the waste into the next generation of use free of any 'embodied' effects other than those associated with its collection, transportation and further processing. However, we have found it very difficult, if not impossible, to properly trace the origins of industrial wastes recycled in the industries studied to date (wood, steel, concrete and gypsum board). The data we have examined suggests less frequent recycling than might be supposed. Also, the products of concern to the ATHENA™ project are typically very long lived so that the relevant manufacturing processes are generally very close to, if not at, the end of a recycling sequence for all practical purposes. We have therefore adopted the specified coproduct allocation guideline as a pragmatic decision rule which we will reassess as we study new industries.

941

942 Industrial Waste

943 The term industrial waste is restricted to those materials that fail the internal and
944 industrial by-product tests. These are any materials that are not the primary product, co-
945 products, by-products, used internally for energy or sold to energy facilities. Industrial
946 waste is material that is discarded and typically sent to some type of disposal facility.
947 Industrial wastes may be a small percentage of the overall material balance of the process
948 producing them, and they will receive no allocation of the generating process energy or
949 emissions. They will, however, incur a transportation energy to the disposal facility and
950 will create environmental effects in the disposal process. Examples for a sawmill can be
951 found in Appendix B.

952 Post-consumer Waste

953 Post consumer waste is defined as material that has already served a purpose as a
954 consumer item and has been discarded. All energy or other environmental costs (inputs
955 and outputs) associated with the original processing or manufacturing of post-consumer
956 waste will be considered to have been ‘paid’ during its previous use.⁴ Only
957 transportation energy and other inputs and outputs required for its collection,
958 transportation and further processing to make it suitable for use in the new production
959 process will be counted and attributed to the product(s) under study.

960 Decision Requirements and Documentation

⁴ In principle, the original resource, energy and other environmental costs of producing a product that is recycled after use should be allocated to the successive generations of products produced from the original material. As in the case of industrial waste, it can argued the original environmental costs that would be allocated to any one generation of products could be insignificant relative to the transportation and other costs associated with the recycling process itself. But if a product is recycled after one generation into a long-lived product, then the original resource, energy and other environmental costs may be significant when allocated to each of the two generations. But there is the practical problem of tracing the origins of post-consumer waste and making a reasonable allocations to successive generations of products. There is also the problem that some post-consumer waste will be from products made a very long time ago at much greater environmental cost than is incurred with modern technology. It does not seem reasonable that the waste carry a full proportional allocation of such original manufacturing effects, even if we could readily determine those effects. So we have again taken a pragmatic approach when developing this guideline.

961 Researchers are likely to encounter situations where co-product allocation to
962 certain by-products or wastes is questionable. For example, some gypsum board
963 manufacturers use waste gypsum board from construction sites as feedstock material.
964 Similarly, some particleboard manufacturers obtain wood particles made from waste
965 wood from demolition projects. In the case of gypsum, a decision was made within
966 ATHENA that the waste should not carry a full co-product allocation as specified for
967 industrial wastes. Only the waste collection, transportation and processing effects were
968 attributed to the new gypsum board made from those wastes. The reasons were as
969 follows:

- 970 • the waste accounts for a very small percentage of the feedstock for the new board
971 manufacturing processes;
- 972 • it is questionable whether the waste meets the value criterion; and
- 973 • it can be debated that the waste is part of the end use process (i.e. the installer is
974 really the consumer and the waste results from its use) thereby violating the third
975 criteria.

976 Another example is fly ash from coal burning utilities that is used in cement
977 making. In the study of cement/concrete products by ATHENA, waste was not allocated
978 any of the original resource-use, energy or pollution burdens except those incurred in
979 processes to make it suitable for use, to transport it to the point of reuse, and in the
980 second production process. Again, the value argument weighs heavily as does the fact
981 that fly ash is extracted to prevent pollution and not as an integral part of the process of
982 making electricity.

983 It is critical that all such decisions be fully documented. Also, data should be
984 compiled and maintained in a form that allows a different allocation rule to be applied if
985 a decision should be found unacceptable during the review process.

986 **6. DATA PRESENTATION AND REPORTS**

987 Reports on individual LCA studies will be prepared as stand-alone documents
988 suitable for publication and written to meet the needs of more technically oriented

989 audiences. In addition to providing a basic overview and understanding of the relevant
990 industry, reports should emphasize specific methods, data sources, calculations and
991 reasons for analytical decisions.

992 **6.1 UNITS AND SIGNIFICANT DIGITS**

993 The units of measure used for raw materials, primary products and finished
994 components will be those most commonly used in the individual industry and by
995 professional quantity surveyors and suppliers in the building construction sector (e.g.
996 mass for steel, area or volume for wood products, and volume for concrete).

997 For secondary components such as masonry units, framed assemblies,
998 manufactured trusses etc., the units should be linear, piece count, or area covered. The
999 purpose is to make actual structure comparisons using the units commonly recognized in
1000 the building industry.

1001 The units used for energy, air emissions, liquid effluents and solid wastes are
1002 shown in the relevant category lists in Section 2. These are the Standard International
1003 Metric units that are widely accepted in scientific fields. The scale of these units has
1004 been selected to make them manageable for each category.

1005 The number of significant digits should normally reflect the confidence in the
1006 measurement or estimate. However, researchers are asked to lean toward including more
1007 rather than fewer digits on the understanding that final rounding will be made when
1008 structuring databases for use.

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APPENDIX A: CONVERSION FACTORS

TABLE 1
VOLUME AND MASS

VOLUME	cubic inch	ml	Liters	U.S. fl. oz.	U.S. gallons*	U.S. barrels	cubic feet
cubic inch	x	16.387	0.0164	0.554	4.329×10^{-3}	1.374×10^{-4}	5.787×10^{-4}
ml	0.0610	x	0.001	0.03381	2.642×10^{-4}	8.387×10^{-6}	3.532×10^{-5}
Liters	61.024	1000	X	33.815	0.264	8.387×10^{-3}	0.0353
U.S.fl. oz.	1.805	29.573	0.0296	x	7.812×10^{-3}	2.48×10^{-4}	1.044×10^{-3}
U.S. gallons*	231	3785	3.785	128	x	0.0317	0.134
U.S. barrels	7276.5	1.192×10^5	119.237	4032.0	31.5	X	4.21
Cubic feet	1728	2.832×10^4	28.316	957.568	7.481	0.2374	x

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MASS	grams	kilograms	ounces	pounds	grains	tons	milligrams
Grams	x	0.001	3.527×10^{-2}	2.205×10^{-3}	15.432	1.102×10^{-6}	1000
Kilograms	1000	X	35.274	2.205	15432	1.102×10^{-3}	1×10^6
Ounces	28.350	0.28	x	0.0625	437.5	3.125×10^{-5}	2.835×10^4
Pounds	453.59	0.453	16.0	x	7000	5.0×10^{-4}	4.536×10^5
Grains	0.065	6.480×10^{-5}	2.286×10^{-3}	1.429×10^{-4}	x	7.142×10^{-8}	64.799
Tons	9.072×10^5	907.19	3.200×10^4	2000	1.4×10^7	x	9.072×10^8
Milligrams	0.001	1×10^{-4}	3.527×10^{-5}	2.205×10^{-6}	0.0154	1.102×10^{-9}	x

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*NOTE: U.S. gallon = 0.80 Imperial gallons (Source: U.S National Technical Information Services)

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To convert from	to	multiply by
Grams / cu ft	Milligrams / cu m	35.315×10^3
Pounds / 1000 cu ft	Milligrams / cu m	16.018×10^3
Barrels Imp (petroleum)	liters	158.98
Btu's	joules	1054
Cubic yards	liters	764.534
Feet	meters	0.305
Gallons (British)	liters	4.546
Gallons (U. S.)	liters	3.785
Inches (in)	meters	0.025
Kilowatt - hours (kWh)	Mega joules	3.6
Miles (statute)	kilometers	1.609
Ounces (avdp)	kilograms	0.028
Pounds	kilograms	0.454
Square feet	square meters	0.093
Tons (short)	kilograms	907.185
Watts	joules / sec	1
Yards	meters	0.914
Pounds	metric ton	0.0004
Acres	hectares	0.405
Square miles	hectares	259
Cubic feet (ft ³)	cubic meters (m ³)	0.028
Cubic inches (in ³)	cubic centimeters (cm ³)	16.393
Watt/sec	joule	1
Calories (cal)	joules	4.105
Gram - calorie	joules	4.184
Watt - years	joules	3.15×10^7

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Sources: 1. Starr, C. *Energy & Power*. Scientific American , 1971.

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2. Handbook of Industrial Energy Analysis.

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1052**TABLE 2**
DENSITIES

Material	kg/m ³
Douglas Fir	513
Balsam Fir	400
Hemlock	465
Southern Pine	641
Cement	1483
Concrete	2373
Dry packed gravel	1600-1920
Wet gravel	2020
Calcined gypsum	880-960
Pebble lime	850-1025

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1057**TABLE 3**
ENERGY CONTENT AND EMISSION FACTORS

Fuel Type	Energy Content	Carbon Dioxide
	MJ	g/MJ
natural gas	37.82/m ³	49.7
motor gasoline	34.66/L	68.0
Kerosene	37.68/L	67.7
Propane	25.53/L	59.8
diesel oil	38.68/L	70.7
spent pulping liquor	14.00/kg	107.4
Coke	28.83/kg	86.0
coke oven gas	18.61/kg	86.0
light oil	38.68/L	73.1
heavy oil	41.73/L	74.0
petroleum coke	42.38/L	100.0
wood waste	18.00/kg	81.5

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Sources 1. Statistics Canada, *Quarterly report on Energy Supply-Demand in Canada*: 1987-IV pg. vii
2. Environment Canada, Energy Mines and Resources

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TABLE 4
ENERGY CONTENT AND CO2 EMISSION FACTORS
OF CANADIAN COALS

ENERGY CONTENT

	Nova Scotia	N. B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.
Anthracite			27.7					
Bituminous:								
Canadian	27.2	26.9	27.2	27.5	27.5 ¹		16.0 ²	18.5 ¹
Imported								
- Power				29.1				
- Steel				30.1				
- Industry			29.1	29.1				
Sub-Bituminous							18.4	
Lignite				15.9	16.0	14.3		

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¹ Estimated. Volumes are small.

² Represents waste coals used in one plant. Values are variable.

Source: EMR Coal Division.

October 30, 1990

CARBON DIOXIDE EMISSION FACTORS

	Nova Scotia	N. B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.
Anthracite			86.2					
Bituminous:								
Canadian	84.5	83.0	84.5	91.6	91.6		94.3	94.3
Imported								
- Power				85.9				
- Steel				81.6				
- Industry			85.9	85.9				
Sub-Bituminous							94.3	
Lignite				93.8	95.0	93.8		

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Source: EMR Coal Division and Statistics Canada, 57-202.

October 30, 1990

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TABLE 5
TRANSPORTATION ENERGY EMISSIONS

Fuel	CO₂	VOCs	CH₄	NO_x	CO	SO₂
	Metric tons/TJ	Metric tons /PJ				
Gasoline	68.0	434.0	43.4	321.0	3805.0	11.7
Diesel						80.0
- Road	70.7	86.9	21.7	807.0	443.0	-
- Rail	70.7	70.0	7.8	1400.0	57.0	-
- Marine	70.7	390.0	45.0	240.0	180.0	-
HFO - Marine	74.0	360.0	40.0	200.0	7.4	450.0

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Notes: Road (gasoline and diesel) VOCs, CH₄, NO_x and CO figures are for 1992.

Road CH₄ figures calculated as per EMR instructions in source document.

N₂O estimates omitted because EMR estimates are only approximation and because combustion sources of N₂O are considered relatively insignificant.

SO₂ figures are the simple average for the three regions cited in the source.

Source: Ad Hoc Committee on Emission Factors, EMR; *Emission Factors for Greenhouse and Other Gases: An Inventory*, December 1990.

Table 6
TRANSPORTATION COMBUSTION ENERGY REQUIREMENTS
(MJ/tonne-kilometer)

MODE	FUEL	ENERGY CONSUMED
Truck	Diesel	1.18
Rail	Diesel	0.49
Ocean	Residual Fuel Oil	0.12

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Source: Franklin Associates, Ltd.

Appendix B

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1097 **Example Material Balances and Co-product Allocation Decisions**

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1099 **1. Balance on Log Harvest**

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1101 Typically, when a timber stand is harvested several different types of logs with
 1102 very different end-use destinations will be jointly produced. The forest growing and
 1103 harvest activities to place the logs at roadside will be allocated among these log co-
 1104 products according to the mass of the barky logs. In some log categories, there may be
 1105 several sub-varieties that will go to different destinations, some of which may be outside
 1106 the study boundary.

1107

1108 **IMPUT: Trees grown according to some management regime**

Material	Use Destination	Material Balance, % od mass	Included in Co- product allocation
Export Logs			Yes
Poles			Yes
Sawmill logs	To large log sawmill To small log sawmill To pallet mill		Yes
Veneer logs	To plywood To LVL		Yes
Logs for Pulp			Yes
Total		100%	

1109

1110 **2. Balance on Sawmill**

1111

1112 The following set of “machine centers” is intended primarily to illustrate the types
 1113 of joint products that occur at each of these centers, their various destinations and
 1114 decisions as to whether they will be included in co-product allocations.

1115 **a. Log yard**

1116

1117 **INPUT:** Logs delivered from forest harvesting that were designated for sawmill use.

Material	Use Destination	Material Balance, % of mass	Included in Co- product allocation
Logs	Sorted & sold		Yes
	To sawmill		Yes
	On-site chipper		Yes
Yard scrap	To hog fuel		Yes
	To landfill (waste)		No
Total		100%	

1118

1119 **b. Debarking & Bucking**

1120

1121 **INPUT:** Woods length logs, not debarked

Material	Use Destination	Material Balance, % of mass	Included in Co- product allocation
Debarked Logs	To sawmill		Yes
Debarked logs	To chipper		Yes
Bark	To hog fuel		Yes
	To landscape, etc.		No
	To landfill (waste)		No
Sawdust	To hog fuel		Yes
	To landscape, etc		No
	To waste		No
Clean-up waste	To hog fuel		No
	To landfill (waste)		No
Total		100%	

1122

1123 **c. Green Lumber Manufacture**

1124

1125 **INPUT:** debarked logs

Material	Use Destination	Material Balance, % of mass	Included in Co- product allocation
Green lumber sold unplaned	To grade & package		Yes
Green Lumber sold planed	To planer		Yes
Green Lumber to kiln	To kiln		Yes
Green scrap wood	To chips/pulpmill		Yes
	To fingerjoint, etc.		Yes
Sawdust	To pulpmill		Yes
	To boiler		Yes
	To bedding, mulch		No
	To waste		No
Total		100%	

1126

1127 **d. Kiln Drying**

1128

1129 **INPUT:** The portion of green lumber designated for drying

Material	Use Destination	Material Balance, % of mass	Included in Co- product allocation
Kiln Dry Lumber, not planed	To grade & package		Yes
Kiln Dry Lumber to planer	To planer		Yes
Collected waste	To landfill		No
Total		100%	

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1132 **e. Planer**

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1134 **INPUT:** The portion of green lumber and kiln dry lumber designated for planing

Material	Use Destination	Material Balance, % of mass	Included in Co- product allocation
Planed Lumber	To grade & package		Yes
Planer shavings	To pulp		Yes
	To particleboard		Yes
	To hog fuel		Yes
	To bedding		No
Sawdust	To particleboard		Yes
	To hog fuel		Yes
	To bedding		No
Dry Scrap wood	To pulp chips		Yes
	To fingerjoint, etc.		Yes
Dirty mill waste	To hog fuel		No
	To disposal		No
Total		100%	

1135

1136 **f. Grading & Packaging**

1137

1138 **INPUT:** Lumber, banding & packaging materials

Material	Use Destination	Material Balance, % of mass	Included in Co- product allocation
Banded, packaged lumber	To structural		Yes
	To other		Yes
Scrap banding & packaging	To recycle		No
	To disposal		No
Total		100%	

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