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Chapter 14: Recycling – HINTS

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Exercise 14.1 Take stock of your five favourite personal belongings. How do you think they will eventually be recycled, if at all? And what about the last five disposable products you have encountered (e.g. packaging, coffee cups)?

Hint 14.1: whatever you may think, products like your phone or computer – if those are among your favourites, of course – will *not* be recycled by careful disassembly, and the material losses will be substantial. Disposable products, especially if collected along with household refuse, will most likely be burnt for energy, and material loss will be virtually complete.

Exercise 14.2 Assume we have an average 1% (EU) versus 9% (China) annual market growth, and assume full recovery during recycling (impossible, as we shall see later). How much of the demand for new materials can be met by recycling, for product life spans of 5, 10 and 20 years, assuming that the amounts of materials used for individual products remains the same?

Hint 14.2: this will be straightforward.

Exercise 14.3 Think of design strategies that facilitate the (separate) collection of end-of-life products, such as labels or electronic markers. Then consider the viability of laws to achieve the same objective. What is your conclusion regarding design for recycling?

Hint 14.3: considering that design can only suggest certain behaviour that laws can easily make mandatory (although enforcing such laws may be another matter), you should not be surprised to conclude that when it comes to collection, design for recycling will in fact have only limited potential.

Exercise 14.4 The smaller the chunks, the greater the chance that they contain only a single material (i.e. they are fully liberated); conversely, larger chunks tend to be a mix of materials (i.e. they are not fully liberated). Why not shred everything into small chunks directly?

Hint 14.4: the key word here is ‘cost’.

Exercise 14.5 Search the Internet for illustrations of the three types of separators shown in Figure 14.2. What are their typical dimensions? Hint: also use ‘sorting’ as a search key word (e.g. ’eddy-current sorting’).

Hint 14.5: this will be easy. Note that along the way you are likely to find many illustrations of process schematics, which may also be worth a closer look.

Exercise 14.6 Why can magnetic separation be used to separate austenitic stainless steels from plain carbon steels?

Hint 14.6: you might like to consider the magnetic properties of both materials.

Exercise 14.7 Which material properties could in principle be used to automatically sort plastics?

Hint 14.7: many possibilities. Some key options include dielectric properties, optical properties (i.e. transparency, colour, either with respect to visible light or to infrared light) and density, although the latter will require very sensitive equipment as the densities of most commodity plastics are very similar.
Exercise 14.8   From Chapters 3 to 11, select three different manufacturing principles. For each one, describe what the production scrap typically looks like.

Hint 14.8: if necessary, re-read the appropriate chapters. With *very* few exceptions, all methods generate production scrap.

Exercise 14.9   By weight, copper wire contains some 70% copper and 30% PVC. Suppose we process one ton of wire per hour into a copper fraction weighing 0.74 ton/hour, of which 0.69 is copper and 0.05 is PVC. What is the weight and composition of the tailing? And what are the grade and recovery of the copper?

Hint 14.9: you should find that the recovery is very high (not surprising, given the value of copper) and the grade somewhat lower, but still quite high.

Exercise 14.10   How would extra-fine shredding of end-of-life products affect the grade and recovery of the product recycling process? What would be the extra costs?

Hint 14.10: again, a nice example of the manufacturing triangle and its trade-offs in action.

Exercise 14.11   Imagine we design a car structure combining steel with aluminium (as several of today's cars already have). Assuming it will be shredded during recycling, what would be better: a few large fasteners, or many small ones?

Hint 14.11: whatever you may be thinking, you do not have to fear for the shredder, which will have no difficulty breaking up even large fasteners.

Exercise 14.12   What is the total potential recoverable value of the materials in one coffee maker in Euros (use the data in Table 14.2, and give a range for your Hint)?

Hint 14.12: simply run the numbers. Your answer should be less than 2 Euro.

Exercise 14.13   Estimate how many coffee makers are discarded in your country every year. Assume a 10 year product lifespan and one coffee maker (similar to the Braun) per four inhabitants. What is the size of this waste coffee maker stream in tons/year?

Hint 14.13: again, just run the numbers.

Exercise 14.14   Assume collection is done for free (e.g. people handing in the coffee makers voluntarily) except for transport costs. If we can use 10% of the material value to pay for transport, then what is the maximum transport distance we can afford?

Hint 14.4: considering the relatively low density of this material stream, you should assume a cost of transport of about 0.40 euro/(ton.km). Running the number should get you in the neighbourhood of 320 km.

Exercise 14.15 Full disassembly may take around 30 seconds per coffee maker. How does the cost of this step compare against the material value, assuming all-inclusive labour costs of 10-20 euro/hour?

Hint 14.15: again, a straightforward calculation – but very instructive to make!

Exercise 14.16 Now assume full shredding. What is the cost per coffee maker?

Hint 14.16: this would constitute 'fine shredding', the cost of which can be found in the section on recycling economics.

Exercise 14.17 How many such coffee makers would be needed to make setting up a dedicated coffee maker recycling facility economically attractive? How does this compare to your answer to Exercise 14.13?

Hint 14.17: this would be a facility involving shredding and automated separation of fractions. Unless you have made an error somewhere along the way, this facility will consume more coffee makers than you will have available in a certain region.

Exercise 14.18 Adding up the results from the previous six exercises, does it make economic sense to have one or more national recycling plants fully dedicated to discarded coffee makers? Would such a plant involve mainly manual disassembly or mainly shredding?

Hint 14.18: in an indirect way, the section on best practice case studies provides the answer.

Exercise 14.19 Revisit Exercises 14.1 and 14.3. What are your answers now?

Hint 14.19: just re-think the exercises in the light of the example you have just studied.

Exercise 14.20 Expressed as a percentage, how much reduction in energy does recycling offer as compared to 'virgin' production for the five materials in Table 14.2?

Hint 14.20: this should be easy. Recycling can save up to 90% of the energy.

Exercise 14.21 Which other environmental impacts can we consider, apart from energy and carbon emissions, when we compare primary and secondary material production?

Hint 14.21: many possibilities, such as emission of SOx and NOx gases, land use and water consumption. Even noise hindrance could be included here: shredders tend to be noisy.

Exercise 14.22 Composite materials (e.g. used in the BMW i3 electric city car) are not compatible at all with today's car recycling infrastructure. Nonetheless, composite car structures save weight and hence, energy. Does an 85% recycling target for a composite car make sense?

Hint 14.22: it does, but only if you take a very limited view of things. More comprehensive analysis would trade off the car's reduced recyclability against its lower weight (and possibly, longer lifespan), and would certainly include the sizable energy savings thanks to the lower fuel consumption (with the fuel for the i3 not going into the car directly, but into the electric power plant). Such analysis may not be directly useful for politicians, but does point at the complexity of sustainable transport and advanced materials.

Exercise 14.23   See if you can find analyses of the energy benefits of lightweight vehicle design, compared to the extra energy expended in making the lighter materials (which may or may not be partially recovered during recycling). What are the main factors that determine the trade-off between the two?

Hint 14.23: key factors in such analyses would certainly include the car's lifespan (in km driven) and the energy savings as compared to a suitable benchmark vehicle – which in turn depend on the weight savings (in the car structure as well as in its engine, suspension etc.).

Exercise 14.24   How do the overall recoveries compare for the three process routes described above? How can you explain the relatively high recoveries for arguably the most complex product of them all, the car?

Hint 14.24: simply list the factors; as for the car, recall that politics can strongly shape the environment in which recycling as a business takes place.

Exercise 14.25   The heat of combustion of PP is 46 MJ/kg. How does this compare to its GER? What if we also factor in the 25% efficiency: how 'good' is 'thermal recycling' in this case?

Hint 14.25: if your answer is not in the range of 10-15% you have made an error somewhere. 'Good' is of course not very good at all in this case.