

Problem 1 (35 pts)

The owner of a pulp and paper mill wants to hire your engineering design firm. At an initial meeting to discuss the needs of the mill, the owner says: "I need to dam the Red River to provide cheap, renewable power for my pulp and paper mill."

The following additional information is known: The pulp and paper mill was constructed 50 years ago on the Red River to provide ready access to fresh water needed for the mill. It has been modernized over the years and now the mill uses 25 MW of electric power. Upstream of the mill, the geology of the river valley is well suited for the construction of a small, 40-m high dam. The average flow of the Red River is 75 m³/s. You may assume that the density of water is approximately 1,000 kg/m³, that the acceleration due to gravity is 9.81 m/s², and that the following equation provides the maximum power that can be generated at 100% efficiency.

$$\text{Power (W)} = \left(\frac{\text{mass (kg)}}{\text{time (s)}} \right) \times \text{acceleration} \left(\frac{\text{m}}{\text{s}^2} \right) \times \text{height (m)}$$

- Identify at least 6 stakeholders for the dam and their stake (i.e., why they care) (10 pts)
- Identify at least 6 constraints for this project and classify them into one of the four broad areas of constraints (15 pts)
- Rewrite the client statement into objectives and functions that clearly define the problem and consider both the stakeholders and constraints. You may use bullet point form. (10 pts)

Problem 2 (45 pts)

"ZipZap" is a carbonated, highly caffeinated soft drink sold in aluminum cans that is popular with 1st year engineering students in December and April. The manufacturers of "ZipZap" have hired you to reduce their costs and improve their product's environmental image. You have prepared the product life cycle shown in the attached figure. Using that life cycle:

- Describe how to conduct the inventory analysis for this life cycle. (10 pts)
- Long answer question (up to 2 pages):* Conduct an environmental impact analysis for this life cycle. Specifically, identify the points in the life cycle that cause environmental impact, discuss the expected environmental impacts and how they can be determined at those points, and consider how to compare these impacts across the life cycle. (25 pts)
- Identify 2 specific opportunities to apply the principles of industrial ecology to this life cycle and describe how each opportunity will reduce both environmental impacts and internal costs. (10 pts)

Problem 3 (25 pts)

The Lewiston Water Pollution Control Center (LWPCC) is so happy with their two 30-kW microturbines for producing electricity from biogas that they want to increase their on-site electricity generation capacity. The question LWPCC has is whether to buy another 30-kW microturbine or to buy one 40-kW fuel cell instead. The following information is available:

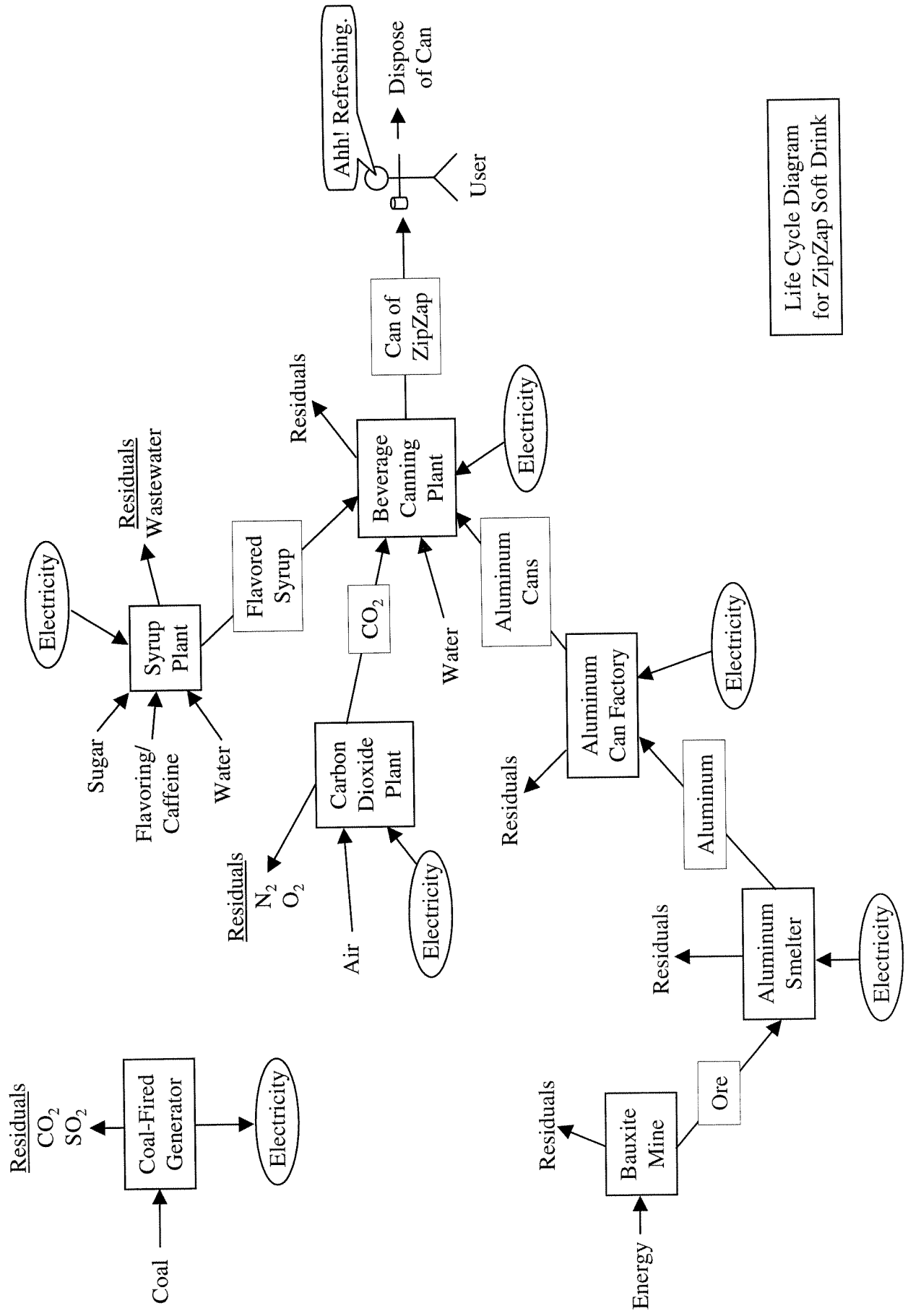
1. The plant requires on average 123 kW of power (1.08 million kWh per year).
2. The electricity not produced on-site from biogas is purchased from the New York State Power Authority at \$0.12/kWh. Note that in both options, LWPCC will continue to use their existing microturbines.
3. The capital cost for installing microturbines that operate on biogas is \$3,750/kW
4. The operating cost of the microturbines is \$0.013/kWh
5. The capital cost for installing a fuel cell that operates on biogas is \$4,000/kW
6. The operating cost of the fuel cell is \$0.005/kWh
7. The microturbines and fuel cell will produce, on average, 90% of their rated capacity.
8. Every kWh of electricity produced at the LWPCC provides CO₂ emission credit that can be sold to produce a revenue of \$0.012/kWh produced.
9. Assume that $i = 5\%$, $N = 5$ years and $(P|A, i, N) = \frac{(1+i)^N - 1}{i \cdot (1+i)^N}$
10. There are 8,760 hr/yr. There are 3,600 kJ/kWh. And recall that $1 \text{ W} = 1 \text{ J/s}$
11. $\text{LCC} = \text{Initial Capital Costs} + \text{Annual Operating Costs} \times \text{PIA} - \text{Annual Revenue} \times \text{PIA}$

Determine the life cycle cost of both options and recommend the most economical alternative. Show all of your work!

Problem 4 (45 pts)

In the design of Hawaii Interstate Highway H-3 many factors were considered in addition to the purely technical factors required to ensure that the highway will not collapse under the weight of the traffic or wash away during a tropical storm. Many of these factors are common across all highways. Assume that the objective of a highway is to move vehicles from one place to another and answer the following questions.

- a) Identify 4 human factors issues related to the design of an automobile. (10 pts)
- b) Identify 4 human factors issues related to the design of a highway. (10pts)
- c) Identify 3 social impacts related to either automobile or highway design or both (3 impacts total). (10 pts)
- d) Explain, with examples, why ethical issues will arise for design engineers if either highway owners or automobile manufacturers (choose one or the other) consider internal costs to be their most important constraint. (15pts)



Life Cycle Diagram
for ZipZap Soft Drink