



United Nations Environment Programme
Division of Technology, Industry and Economics

Profiting from Cleaner Production

**Strategies and Mechanisms
For Promoting
Cleaner Production
Investments
In Developing Countries**



Profiting From Cleaner Production

Solutions to the exercises



The United Nations Environment Programme
Division of Technology, Industry and Economics
Production and Consumption Branch

Presents a Training Series

**Strategies and Mechanisms for Promoting
Cleaner Production in Developing Countries**

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Small Group Exercise SOLUTION

“Classifying Environmental Management Options”

Question 1: Flowpipe and Fitting, Inc. (FPF)

Environmental Management Hierarchy Categories	Option #
Cleaner Production , including the following:	
• Good housekeeping	#3, #6
• Input substitution	#3
• Better process control	#1
• Equipment modification	
• Technology change	
• Product modification	
• Energy efficiency	#7
• On-site recycling/reuse	#4
Off-site Recycling/Reuse	
Pollution Control/Treatment	#2
Waste Disposal	#5

The following table presents the options actually implemented by FPF:

Option	Initial Investment	Annual Savings	Payback	Environmental and other Benefits
#1 (modify smelting parameters)	One-time action, minimal up-front cost	US\$2,250	immediate	<ul style="list-style-type: none"> • Reduced smoke • Reduced fuel use & air emissions from fuel use • Reduced operating time
#3 (inspect scrap used as raw material and segregate out low quality material)	Minimal up-front cost	US\$1,870	immediate	<ul style="list-style-type: none"> • Reduced smoke • Improved product quality
#4 (washing & reusing sand)	US\$ 75	US\$2,630	1.5 weeks	<ul style="list-style-type: none"> • Reduced waste sand & sand bonding materials
#6 (employee training for improved casting)	US\$ 470	US\$6,400	4 weeks	<ul style="list-style-type: none"> • Reduced solid waste • Reduced fuel use & air emissions from fuel use
#7 (equipment to reduce electricity losses)	US\$5,850	US\$5,630	1.05 years	<ul style="list-style-type: none"> • Reduced electricity use • Reduced equipment wear
TOTAL	\$6,395	18,780	4.1 months	

Question 2: The PLS Company

Environmental Management Hierarchy Categories	Option #
Cleaner Production , including the following:	
• Good housekeeping	#7
• Input substitution	#9
• Better process control	#3
• Equipment modification	
• Technology change	#3
• Product modification	
• Energy efficiency	
• On-site recycling/reuse	#4, #6
On-site Recycling/Reuse	#1, #8
Pollution Control/Treatment	#2
Waste Disposal	#5

The PLS company has traditionally handled solid scrap waste by a combination of incineration and landfilling. More recently, PLS had implemented two Cleaner Production options to reduce the volume of solid scrap, as shown in the table below. At the time this case study was conducted, PLS was considering others in the list above. We will be learning much more about this company and its Cleaner Production efforts later in this training course.

Option	Initial Investment	Annual Savings	Payback	Environmental Benefits
#3 (quality control camera)	US\$105,000	US\$38,400	2.73 years	• Reduced scrap from full print runs by 40%
#6 (reuse scrap in start-up runs)	Minimal	US\$58,500	immediate	• Reduced scrap from start-up runs by 50%



Small Group Exercise

SOLUTION

“Cost Identification at the PLS Company”

Question 1

List all costs associated with the printing step or with the management of solid scrap waste from the printing step. Use the table below to record your answers. Use only the first column of this table to answer Question 1— the other columns will be used to answer Question 2 later.

Answer:

There are many different types of costs. However, costs can be broken down into three broad categories to make them easier to remember:

- The cost of manufacturing inputs, *e.g., raw materials, energy, water, labour, and capital*
- The cost of waste management, *such as the cost of: regulatory compliance; on-site waste handling, recycling, & treatment; and off-site treatment and disposal*
- Less tangible costs, *such as the cost of: reduced production reliability and quality; negative company image; and potential environmental liability.*

See the handout entitled “The Investment Decision Cost/Savings Checklist – (Detailed)” for a checklist of the various cost items that are included in these three categories. The relative significance of the different components of these costs will vary between industry sectors, individual companies, specific manufacturing processes, and different waste streams.

For example, the costs due to air emissions of solvent fumes at the PLS Company would include some cost components that are not relevant for the generation of solid scrap. An example might be the cost of worker sick days due to exposure to solvent fumes.

Taking a closer look at the PLS Company’s print step and the management of waste from the print step as a specific example, the costs in the following table seem potentially relevant.

Use this table for recording your answers to both Questions 1 & 2

USE THIS COLUMN FOR QUESTION 1	USE FOR QUESTION 2 ONLY	
<p>In the column below, list any costs that you think are associated with the existing printing step or with management of solid scrap waste from the printing step</p>	<p>If the new system is adopted, would this cost <i>increase?</i> <i>decrease?</i> <i>stay the same?</i></p>	<p>Which of these might be the most Significant for project profitability?</p>
<i>The cost of manufacturing inputs</i>		
plastic film	D	X
Ink	D	X
energy to run the printing equipment	D	
direct labour to run the printing equipment	D	
maintenance of printing equipment	D	
depreciation costs for the printing equipment	S	
other indirect inputs (e.g., indirect labour, materials, energy, etc.)	D	
<i>The cost of waste management</i>		
on-site handling of solid scrap (e.g., moving scrap from production area to incinerator)	D	
labour to operate incinerator	D	X
maintenance of incinerator	D	
incinerator depreciation	S	
electrical power for incinerator operation	D	
incinerator fuel and fuel additive	D	X
water for the incinerator scrubber (e.g., pumping it from the deep well)	D	
incinerator ash disposal to off-site landfill (e.g., trucking costs, landfill fee)	D	
labour to operate wastewater treatment plant	S	
maintenance of wastewater treatment plant	S	
wastewater treatment plant depreciation	S	
wastewater treatment chemicals	D	
wastewater treatment operating energy (e.g., for mechanical agitation and mixing)	D	
wastewater treatment sludge disposal to off-site landfill (e.g., trucking costs, landfill fee)	D	
regulatory compliance costs related to incinerator and wastewater treatment plant (e.g., monitor incinerator smoke, test treated water quality, obtain operating permits, etc.)	S	
<i>Less tangible costs</i>		
production throughput (i.e., profit)	S	
insurance costs (e.g., due to the presence of an incinerator on site)	S	
potential liability (e.g., non-compliance fines when wastewater exceeds regulatory limits)	S	
potential future regulatory costs (e.g., possible future ban on incineration)	D	* future WWTP upgrade
company image costs (e.g., as landfill space becomes more scarce)	D	

You may not have generated the exact same list of costs for the PLS print step as shown above. This is not surprising— different companies and individuals often have different perceptions of what should be included in estimating costs. Some companies know that raw material costs are significant, but tend to neglect rising waste treatment costs in business decision-making. In contrast, some companies tend to think of “environmental” costs as including only waste management costs, without realising that the value of lost raw materials can be quite high.

Question 2

The largest waste stream at the PLS Company is solid scrap, and the largest amount of solid scrap is generated by the printing step. In order to address this significant source of waste, the PLS Company has proposed to purchase a quality control (QC) camera system. This automated camera system would be used on the print line to detect print errors earlier than was possible without the camera. The result would be a significant reduction in the amount of solid scrap generated by the printing step.

Question 2a: If adopted, how will the QC camera impact the costs associated with the printing step or with the management of solid scrap waste from the printing step, i.e., the costs you listed in Question 1? Which costs might increase? Which might decrease? Which might stay the same? In answering this question, assume that the total amount of product coming out of the printing step (i.e., printed film) does not change.

Answer:

It is important to determine which costs might be reduced by your CP efforts. For some costs, such as raw materials use, the potential for cost reduction may be clear. For other costs, the potential for cost reduction may not be as clear. For example, will incinerator operating costs decrease if the amount of scrap being burned decreases? Perhaps — perhaps not. Some incinerators may require constant operation regardless of the total amount of waste being burned. Thus, the costs that are actually variable and can be reduced via CP will be different from situation to situation. You need to discuss the potential for cost reductions with knowledgeable people at your facility to ensure an accurate analysis.

See the table above for an illustration of which costs were expected to increase or decrease if the QC camera project is implemented. Note that fewer wastewater treatment costs decreased than you may have expected. This is because the incinerator scrubber water makes up only a small portion of the total facility wastewater going to the treatment plant.

Question 2b: Can you think of any new costs that might be relevant for the QC camera?

Answer:

The following are some completely new costs that might be relevant:

- Purchase and installation of the camera system
- Ongoing training in the use of the camera
- Camera energy use
- Camera maintenance and repairs
- Camera insurance

Question 2c: Of the costs that would change upon adoption of the proposed QC camera system, which might be the most significant for project profitability?

Answer:

It is an important component of cost identification to identify the potentially most significant items in your list. Sometimes this is difficult to determine until more actual data are gathered.

See the table above. Again, you may not have chosen the same items shown. The relative significance of the different types of costs will vary between industry sectors, individual companies, manufacturing processes, waste streams, and investment projects. You may be able to guess which costs are likely to be the most significant but try to do rough estimates of costs you are not sure about, to be sure you do not miss something important.

The goal, of course, is to identify all the relevant components of cost for a particular situation, to estimate which costs are quantitatively the most significant, and then spend your valuable time focusing on reducing those! The goal is not to “waste” your time getting quantitative estimates of every single item on your initial list!



Small Group Exercise

SOLUTION

"Cost Estimation at the PLS Company"

Question 1

As a first step, try to estimate *the total purchase value of plastic and aluminium film that are lost as scrap* at the PLS Company, using the data given below. PLS does not measure the waste generation rates for solid scrap but you can calculate the scrap amounts from information found in the accounting records.

Use the given data from the PLS accounting records to estimate the total lost purchase value of plastic and aluminium film from all three manufacturing steps at PLS. In order to make the data easier to understand, it would be a good idea to record the film input and output data on the PLS materials flow map, i.e., record the data for each manufacturing step at that step on the map. This will help you visualise how to calculate the scrap amounts. You will need to re-read the description of the PLS Company's Manufacturing Steps carefully in order to do this exercise.

Answer:

The accounting records gave the amounts of virgin plastic and virgin aluminium film used for each step of production, the flows of intermediate product between production steps, and the amount of final slit product. This information, in combination with the written description of the manufacturing steps and the materials flow map for the manufacturing steps should have allowed you to calculate the solid scrap rates using a materials balance approach.

A materials balance basically says: what comes in must come out – somewhere. So, if you bring a raw material into the facility, it eventually comes out, either in the form of product or of waste. In the absence of chemical reactions, the general formula for a materials balance over a given time period is:

$$\text{Input} + \text{Initial Inventory} = \text{Output} + \text{Final Inventory}$$

The input term includes raw materials, and the output term includes both intended products and unintended wastes. The inventory terms could include inventories of raw materials or final product in the stockroom, or inventories of waste, e.g., a pile of solid scrap waiting to be incinerated.

If the manufacturing process involves chemical reactions, which convert raw material to something else entirely, then you would probably need a chemist or engineer to help with the materials balance. However, in the case of PLS, no chemical reactions affect the solid plastic and aluminium films, so doing a materials balance is fairly easy. In addition, we can assume that no raw material or scrap is “inventoried” in the production area at PLS. So our materials balance equations for this exercise is quite simple:

$$\text{Input} = \text{Output}$$

In other words, for each manufacturing step, the amount of film that goes in must come out – either as product or as scrap.

$$\text{Virgin material input} = \text{Finished Products} + \text{Waste Scrap}$$

See the Figure 1 entitled “Materials Balance for Estimation of Solid Scrap Amounts at the PLS Company”. This looks very similar to the materials flow map that you have seen before, but is different in that it shows the actual km/yr of virgin and processed films that were given to you for this exercise. It also shows the amounts of solid scrap waste that were calculated using the given data, and the composition of the solid scrap streams from each manufacturing step.

The first calculation, which is partly given to you on the data table, is to convert the 71,934 km/yr slit width final product from the slitting process to the same full width basis in which all the other data are given. The written description of PLS’ operations tells you that the full width film is slit into 3 equal width strips during the slitting process. So dividing by three gives:

$$(71,934 \text{ km/yr slit width})/3 = 23,978 \text{ km/yr full width final product}$$

The amount of solid scrap being generated by the slitting step can be calculated as the difference between the film input and the film output of that step, both on a full width basis:

$$\text{Slitting: } 24,154 \text{ km/yr input} - 23,978 \text{ km/yr output} = 176 \text{ km/yr solid scrap}$$

The amounts of solid scrap being generated by laminating and printing are calculated similarly:

$$\text{Laminating: } 24,496 \text{ km/yr input} - 24,154 \text{ km/yr output} = 342 \text{ km/yr solid scrap}$$

$$\text{Printing: } 26,016 \text{ km/yr input} - 24,496 \text{ km/yr output} = 1520 \text{ km/yr solid scrap}$$

The written description of PLS’ operations also allows you to calculate the respective amounts of plastic and aluminium film that make up each solid scrap stream. Since only plastic film is used as input for the printing step, the solid waste scrap from printing also consists only of plastic film. In contrast, the printed plastic film that goes from printing to laminating is combined with equal lengths of both virgin plastic and virgin aluminium film

for the lamination step. The solid scrap waste from the lamination step thus contains 2 layers of plastic film and 1 layer of aluminium film along the length of the laminated scrap. The same is true of scrap produced by the slitting step, which uses no new virgin film materials. The calculations of the composition of the solid scrap waste from each manufacturing step is shown in the table below.

Manufacturing Step	Amount of solid scrap	Solid scrap composition	Amount of plastic film	Amount of aluminium film
Printing	1520 km/yr	1 plastic layer no aluminium	1520 km/yr	0 km/yr
Lamination	342 km/yr	2 plastic layers 1 aluminium layer	342 x 2 = 684 km/yr	342 km/yr
Slitting	176 km/yr	2 plastic layers 1 aluminium layer	176 x 2 = 352 km/yr	176 km/yr
Subtotals			2,556 km/yr	518 km/yr

The subtotals given in the table above along with the unit film costs given in the exercise statement allow calculation of the lost purchase value of raw materials:

Plastic film: 2,556 km/yr * US\$34/km = US\$86,904 /yr

Aluminium film: 518 km/yr * US\$66/km = US\$34,188 /yr

Total lost purchase value = US\$121,092/yr

You could also calculate the lost purchase value for each individual manufacturing step:

Manufacturing Step	Virgin Plastic Film as Scrap (US\$)	Virgin Aluminium Film Input as Scrap (US\$)	Total
Printing	1,520 km * \$34/km = \$51,680	0	\$51,680
Lamination	684 km * \$34/km = \$23,256	342 km * \$66/km = \$22,572	\$45,828
Slitting	352 km * \$34/km = \$11,968	176 km * \$66/km = \$11,616	\$23,584

Question 2

Waste management costs are not as easy to find in the PLS accounting system as direct manufacturing costs. For example, it is known that a number of different PLS employees spend at least part of their time on activities related to the handling, treatment, and disposal of solid scrap at the facility, as well as related regulatory compliance activities. However, the accounting records at PLS do not specify which employees.

Even for employees who obviously spend time on waste management activities, such as the pollution control officer (PCO), the accounting records do not specify the amount of time spent on solid scrap activities vs. unrelated activities (e.g., handling hazardous waste ink or monitoring solvent air emissions at the facility.)

Question 2a: In addition to the PCO, who else would probably be involved in waste management activities related to solid scrap at PLS?

Answer:

You would probably have to talk to your colleagues to answer this question. You might start with the PCO, who would be the most familiar with waste management operations at the facility. From the PCO, you find out that the following PLS staff are involved in waste management activities related to solid scrap, and whether those people work full-time or part-time in helping to manage solid scrap.

PCO: part-time

The PCO spends part of his time on environmental management related to solid scrap and part of his time on environmental management related to solvent air emissions, hazardous ink waste, and other environmental issues at the facility.

Incinerator operator: full-time

Incinerator operation is a full-time job because PLS has a huge pile of solid scrap at the back of the facility that accumulated between the time that PLS stopped landfilling the material but before the incinerator was installed. PLS has the incinerator only for the purpose of burning solid scrap, so all the operator's time can be attributed to solid scrap management at PLS.

Wastewater treatment plant operator: part-time

Wastewater treatment plant operation is also a full-time job, but only part of the wastewater entering the plant comes from the incinerator scrubber, and therefore is due to solid scrap management. The remainder of the water comes from other parts of the facility and is not related to solid scrap management.

Maintenance workers: part-time

Maintenance workers spend most of their time doing maintenance on production equipment, and only a smaller portion of their time doing maintenance on the incinerator and wastewater treatment plant.

Plant Manager: part-time

The plant manager only gets involved when the DENR comes to inspect the facility. The manager accompanies the PCO and the DENR staff on the inspection tour to indicate the company's commitment to sound environmental management and regulatory compliance, and discuss any potential problems. Much of the inspection tours focus on incinerator and wastewater treatment plant operations, and can thus be attributed to solid scrap management.

Question 2b: What systematic approach would you use to identify all of the various types of waste management activities related to solid scrap?

Answer:

Again, you would probably interview each of the colleagues identified in part 2a. For example, you might ask them to list all of their solid scrap management activities, using the “Cost of Waste” checklist to remind them of all the possible activities that they should include.

You could also ask your colleagues to help you draw an “activities map” of their waste management activities. This would be similar to a materials flow map, but would show waste management activities in the boxes on the map. It’s a visual way of organising information on waste management activities that is easier to look at and understand than a list.

As example, think about the PCO’s waste management activities related to solid scrap at PLS. Using the “Cost of Waste” checklist as a reminder, the PCO identified activities as shown in the following table.

Waste Disposal Activities	<ul style="list-style-type: none"> • The PCO supervises hauling of the incinerator ash and wastewater treatment plant sludge to a landfill on a as needed basis
Recycle/Rework Activities	<ul style="list-style-type: none"> • Prior to Cleaner Production at PLS, there were no solid scrap recycle/rework activities
Waste Treatment	<ul style="list-style-type: none"> • The PCO supervises the operation of both the incinerator and the wastewater treatment plant, which includes daily visits to each • The PCO trains the operators of the incinerator and the wastewater treatment plant on proper operation of the equipment • The PCO works with the maintenance manager to schedule maintenance and repairs of the incinerator and wastewater treatment plant • The PCO is working with a vendor to plan a wastewater treatment plant upgrade • The PCO responds to community complaints about black smoke from the incinerator
Waste Handling & Regulatory Compliance	<ul style="list-style-type: none"> • The PCO obtains annual permits from DENR to operate the incinerator and the wastewater treatment plant • The PCO takes water samples from the wastewater treatment plant and air samples from the incinerator exit and has them analysed (by an outside laboratory) to confirm regulatory compliance • The PCO keeps records on incinerator and wastewater treatment plant operations to show DENR during inspection visits, and to support permit applications • The PCO organises and guides the DENR inspection visits • The PCO reports on solid scrap environmental management issues to upper management

Question 2c: How would you actually estimate the associated labour costs?

Answer:

For anyone who only works part-time on solid scrap management, you could ask them to estimate what percentage of their time each week is spent on solid scrap activities vs. other activities. The list or map of activities they have generated should help them with this estimate. If someone has a difficult time remembering the average amount of time spent on a given activity, they could keep a time log during a typical week, both to provide corrections for the activities list or map they generated earlier and to provide labour time estimates for the different activities.

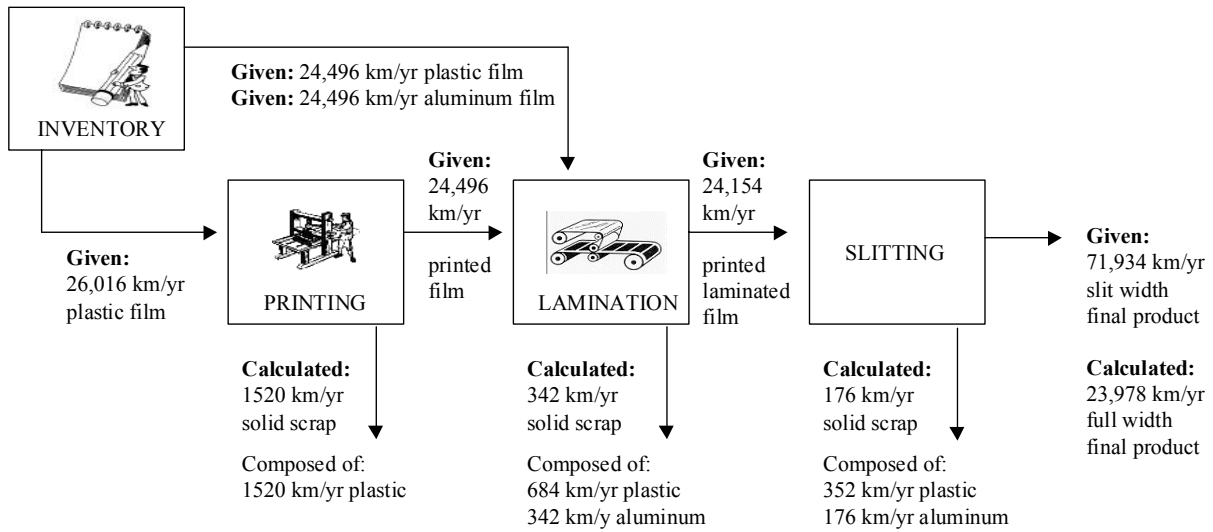
Once you know the amount of time spent by each person on solid scrap management activities, you can use salary and benefits information from the accounting records to calculate total solid scrap management labour costs.

In addition, the more detailed information from the activities list and maps may help you to estimate other costs of solid scrap management. For example, a summary of incinerator and wastewater treatment plant maintenance activities may help you estimate not only maintenance labour costs but also the cost of maintenance materials and spare parts.

Final Note:

In the case of a company that does not wish to eliminate any job positions, are labour costs variable costs that can be reduced by CP, or fixed costs that can not be reduced? There are differing opinions on this. We suggest that you view labour costs as “opportunity costs”. In other words, if facility employees did not have to spend so much time on waste management activities, they could spend that time more productively for the company, such as by working part-time in production areas or by planning and implementing profitable CP projects! Do your cost analysis both with and without labour costs to show how significant these “opportunity costs” might be.

Figure 1: Materials Balance for Estimation of Solid Scrap Amounts at the PLS Company





Small Group Exercise SOLUTION

"Profitability Assessment at the PLS Company: Part I Cash Flows and Simple Payback"

Question 1: Calculation of annual operating costs.

Use the materials balance information and the Cash Flow Worksheet [in the original assignment] to calculate the “before” and “after” operating costs for the project. At the bottom of the worksheet, calculate the total annual operating costs “before” and “after” installation of the QC camera. Finally, calculate the total savings for the project, i.e., the total reduction in operating costs.

Answer: The completed Cost Savings Worksheet is shown on the following page. Sample calculations are shown below:

Cost of manufacturing inputs (use “Virgin film input” values)

Direct labor — before the camera: 26,016 km/yr * \$2.50/km = \$65,040

Direct labor — After the camera: 25,742 km/yr * \$2.50/km = \$64,355

(similarly perform calculations for direct energy, ink, and plastic film)

Cost of incineration operation (use “Full-run scrap rate” values)

Fuel — before the camera: 684 km/yr * \$3.00/km = \$2,052

Fuel — after the camera: 410 km/yr * \$3.00/km = \$1,230

(similarly perform calculations for fuel additive, labor, and trucking ash to landfill)

Cost of wastewater treatment plant operation (use “Full-run scrap rate” values)

Chemicals — before the camera: 684 km/yr * \$0.30/km = \$205

Chemicals — after the camera: 410 km/yr * \$0.30/km = \$123

(similarly perform calculations for electric power, labor, and trucking sludge to landfill)

The total value for the annual costs **before** the QC camera project = \$2,933,204

The total value for the annual costs **after** the QC camera project = \$2,894,741

The annual savings is calculated to be the difference between the before and after costs:

$$\$2,933,204 - \$2,894,741 = \underline{\$38,463}$$

Cost Savings Worksheet SOLUTION

Cost of manufacturing inputs			
Cost Item	Unit Cost (US\$ /km virgin film used)	Business As Usual (US\$ /yr)	With QC Camera (US\$ /yr)
Direct labor	\$2.50	\$65,040	\$64,355
Direct energy	\$4.25	\$110,568	\$109,404
Ink	\$71.00	\$1,847,136	\$1,827,682
Plastic film	\$34.25	\$891,048	\$881,664
SUBTOTAL (manufacturing inputs)	\$112.00/km	\$2,913,792	\$2,883,105
Cost of incinerator operation			
Cost Item	Unit Cost (US\$ /km scrap burned)	Business As Usual (US\$ /yr)	With QC Camera (US\$ /yr)
Fuel	\$3.00	\$2,052	\$1,230
fuel additive	\$6.50	\$4,446	\$2,665
Labor	\$14.20	\$9,713	\$5,822
Trucking ash to landfill	\$0.70	\$479	\$287
SUBTOTAL (incineration)	\$24.40/km	\$16,690	\$10,004
Cost of wastewater treatment plant operation			
Cost Item	Unit Cost (US\$ /km scrap burned)	Business As Usual (US\$ /yr)	With QC Camera (US\$ /yr)
Chemicals	\$0.30	\$205	\$123
Electric power	\$1.30	\$889	\$533
Labor	\$2.30	\$1,573	\$943
Trucking sludge to landfill	\$0.08	\$55	\$33
SUBTOTAL (wastewater treatment)	\$3.98/km	\$2,722	\$1,632
TOTAL = (manufacturing inputs + incineration + wastewater treatment)		\$2,933,204 Before	\$2,894,741 After
Annual Savings (Before - After):		= \$38,463	

Question 2: Calculation of Simple Payback to evaluate profitability.

Question: The total initial investment cost for the QC camera system (for purchase, installation, and employee training, etc.) is US\$ 105,000. Use the annual savings calculated in Question 1 above to calculate Simple Payback for this project.

Answer: The Simple Payback calculation is shown:

$$\text{Simple Payback} = \frac{\text{Initial Investment}}{\text{Annual Savings}} = \frac{\$105,000}{\$38,463} = 2.7 \text{ years}$$

Question: PLS uses a Simple Payback hurdle rate of three years. In other words, if the Simple Payback for a project is less than three years, then PLS considers the project to be profitable. Based on the Simple Payback you calculated, is the QC camera project profitable or not?

Answer: Based on the simple payback calculation, the investment is considered profitable because the project payback is less than the hurdle rate of 3 years.



Small Group Exercise SOLUTION

“Profitability Assessment at the PLS Company: Part II Net Present Value”

Question 3: Calculation of Net Present Value (NPV) to evaluate profitability.

Question: The average discount rate for investment projects at the PLS company is 15%. Use this discount rate to calculate NPV₃ for the QC camera project.

Answer: Using the Present Value table accompanying this exercise, factors for a discount rate of 15% for years 1, 2, and 3 are obtained:

Present Value Factors @ 15% discount rate

Year 1: 0.8696

Year 2: 0.7561

Year 3: 0.6575

The following shows the NPV calculation for this problem:

Year	Yearly Savings	Present Value Factor (15%)	Present Value
1	\$38,463	x 0.8696 =	\$33,447
2	\$38,463	x 0.7561 =	\$29,082
3	\$38,463	x 0.6575 =	<u>\$25,289</u>
			\$87,818
	less: initial investment		- \$105,000
	equals: Net Present Value		- \$17,182

Question: Based on the NPV you calculated, would you say that the QC camera project is profitable by the end of three years? Or not profitable?

Answer: Based on the NPV calculation, the investment is not profitable because it demonstrates a negative NPV after three years.

Question 4: Compare Simple Payback and NPV

You have now calculated both Simple Payback and NPV₃ for the QC camera project. Record your results in the table below, and compare the results from the two indicators. What do you think about the relative value of Simple Payback and NPV as profitability indicators?

Answer: Based on the simple payback calculation, the investment is considered profitable because it is less than the hurdle rate of 3 years. However, based on the NPV calculation, the project is considered NOT to be profitable because the project NPV is less than zero. The reason for the difference is that payback does not take into account the time value of money.

However, NPV has the advantage of taking into account the “time value of money” as well as any cash flows occurring after the first year, both of which are neglected by Simple Payback. Thus, NPV can be a more reliable and accurate profitability indicator than Simple Payback.

Profitability indicators for the QC camera project

Profitability Indicator	The Value you Calculated	Hurdle Rate	Profitable or not?
Simple Payback (yrs)	2.7 years	3 years	Yes
NPV ₃ (US\$)	-\$17,182	zero	No

Sensitivity Analysis:

In order to demonstrate the sensitivity of the profitability calculations performed in this exercise, an additional cost savings item that will impact the profitability of the QC camera project is introduced. This cost savings item is discussed below followed by a re-calculation of the Simple Payback and NPV.

The environmental manager at the PLS company realizes that new, stricter environmental regulations will require PLS to upgrade its wastewater treatment plant (WWTP) in about 3 years. In the business as usual scenario, this WWTP upgrade would cost about US\$150,000. However, if the QC camera project is implemented, and scrap volumes from the printing step are reduced accordingly, then the WWTP upgrade will not be so expensive — US\$ 95,000. The one-time savings, then, is US\$55,000.

Reduced scrap volumes result in reduced incineration, which results in reduced scrubber water from the incinerator, which results in reduced wastewater to be treated. The cost savings associated with this reduced WWTP upgrade in year 3 can now be included in the analysis.

Simple Payback

Because the cost savings does not occur until year three, and simple payback, by definition, uses the savings that occur in year 1, the calculation of simple payback remains the same— 2.7 years. In other words, simple payback is not capable of taking this future year savings into account at all.

Net Present Value

The calculation of net present value including this new cost savings in year 3 is very similar to the calculation done for Question 3a. The only change is that the yearly savings for year three is now:

$$\text{Year 3 savings} = \$38,463 + \$55,000 = \$93,463$$

Year	Yearly Savings	Present Value Factor (15%)	Present Value
1	\$38,463	x 0.8696 =	\$33,447
2	\$38,463	x 0.7561 =	\$29,082
3	\$93,463	x 0.6575 =	<u>\$61,452</u>
			\$123,981
	less: initial investment		- \$105,000
	equals: Net Present Value		+\$18,981

The QC camera project is now considered a profitable investment! A comparison of these results with those calculated in Question 3a are shown in the following table. This sensitivity analysis for the project demonstrates the importance of including all cost savings associated with the project in order for the analysis to demonstrate a realistic profitability of the project.

Profitability indicators for each scenario

Profitability Indicator	Hurdle Rate	<u>Scenario 1</u> Includes reduced manufacturing inputs and waste management cost savings	Profitable or not?	<u>Scenario 2</u> Also Includes reduced WWTP upgrade cost in year 3	Profitable or not?
Simple Payback (yrs)	3 years	2.7 years	Yes	2.7 years	Yes
NPV (US\$)	Zero	-\$17,182	No	+\$18,981	Yes

You also can do a sensitivity analysis for any cost estimation that you feel is uncertain. For example, if you know that landfill disposal costs are going to rise significantly in the future, at a rate much higher than typical inflation, you can repeat the profitability calculations using different values for the cost that is uncertain. This will illustrate the impact of the cost uncertainty on project profitability.