The Case of the Life Cycle Analysis

Act I

[Slide 1: Activity Title]

[Slide 2: Title Slide of Play]

Characters

Narrator
Student 1
Student 2
Student 3
Lucia, LCA Wizard
Plastic Furniture Manager
Polypropylene Manager
Refinery Manager
Oil and Natural Gas Manager
Waste Manager

Scene 1: Home and Garden Mart

[Slide 3: Store]

Narrator: Once upon a time, three students were walking through their local Home and Garden Mart. They were there to buy outdoor dining furniture, a seemingly simple task. Little did they know that they were about to embark on the adventure of a lifetime.

Student 1: Tell me again why we're looking at dining furniture.

Student 2: Mr. [Insert principal's name]showed a lot of confidence in us when he put us in charge of finding furniture for the senior-sponsored outdoor eating areas. I don't want to let him down.

Student 3: This is our chance to leave our mark on the school. People will be sitting on this furniture way after we're gone.

Student 2: That's right, our choice will say something about who we were as a class. We need to find something stylish and comfortable.

Student 3: We also need to get something with a small carbon footprint, you know. Buy green and all that.

Student 1: [Pointing toward a furniture set] This one's green.

Student 2: Not green in color. I mean buy one that's environmentally responsible. Remember Mr/s. [Insert teacher's name]'s talk on global climate change? We all have to do our part. We're picking out furniture for the whole school here, so it's really important we consider the environmental impacts.

Student 1: And how are we supposed to know which ones are better for the environment, much less for climate change? There's all kinds of furniture here. Here's a plastic set. There's an aluminum one. And look, that one's wood. How are we supposed to choose?

Narrator: That's when they saw it—a bright light coming down from the ceiling, accompanied what for all the world sounded like harp music. Was it an alien, a ghost, an optical illusion? The three students cowered in fear and begged for mercy. [Three students cower.] Well, actually only [Student 1] cowered and begged. The others just looked curiously back and forth between the light and their frightened friend.

LCA Wizard: Do not cower mortal student. I mean you no harm. I am Lucia the Life Cycle Assessment Wizard. I am here to guide you through your decision.

Student 3: You're a wizard? You mean, like Harry Potter?

LCA Wizard [sternly]: NO!!! I am absolutely nothing like Harry Potter.

Student 1: Yea, she would be more like Hermione.

LCA Wizard: [Angrily] I'm not like her either. [Calming down] Sorry, it's just that ever since those books and movies came out, it's just been Harry Potter this and Harry Potter that. And don't even get me started about the inaccuracies in those books. J.K. Rowling meets one wizard, and suddenly she thinks she knows us as a people. It's insulting really.

Student 2: Are you going to tell us which furniture set to buy?

LCA Wizard: Yes, right, the furniture. I cannot tell you which set to pick, but I can help you to find the answer for yourselves.

Student 3: What kind of Wizard did you say you were?

LCA Wizard: A Life Cycle Assessment Wizard. It's a new position. We wizards are quite good at adjusting to the needs of the day. You see to truly understand the environmental impact of a product, we must look at its *whole* life cycle, all the way from raw materials to disposal. Only then can we truly know the full impacts of using a product. To answer your question about which type of furniture to buy, you must go on three journeys, each with its own set of dangers, but if you succeed, then you will have a better understanding of your world.

Student 2: We're mostly interested in the greenhouse gas emissions. That's what we've been learning about.

LCA Wizard: Then that is what you shall discover on your journey.

Student 3: Where are we journeying to?

LCA: You will follow the paths of the plastic, aluminum, and pine furniture on three quests and see their lives for yourself.

Student 1: Three journeys? I thought this was supposed to be quick. I've got to be home for dinner in about an hour. It's Mexican night.

LCA Wizard: I wouldn't be much of a Wizard if I didn't have some control over time and space. If you manage to stay alive, then you'll be home in plenty of time for chimichangas.

Student 1: [To friends] Wow, she's good. I never said exactly what we were having... hey wait, did she say "if" we stay alive—

Narrator: At that moment, the students heard a woosh. The floor seemed to drop from their feet as they spun through time and space. [Students spin around.]

Scene 2: Plastic Furniture Factory

[Slide 4: Furniture Factory]

Narrator: Once the students were on firm ground, they realize they were in a factory. Large machines filled the room. Plastic pellets were being dumped into large vats, and people were taking molded plastic furniture out of castings. It took a moment before they noticed the (wo)man standing in front of them. She/He seemed to be in a great hurry and had no interest in talking to the students. She/He also seemed annoyed.

Plastic Furniture Manager: Who are you? What are you doing in my factory?

Student 2: We were sent here on a quest to learn about the life cycle of outdoor dining furniture.

Plastic Furniture Manager: The life cycle? Did Lucia send you? The woman thinks I've got nothing to do all day but sit around talking with ignoramuses… No offense.

Student 1: None taken. I don't really want to be here anyway.

Student 3: Could you just tell us how the furniture is made and what kinds of greenhouse gas emissions you have as a result?

Plastic Furniture Manager: I could tell you a great deal more than that. But first you must pass a test.

Student 2: What kind of test?

Plastic Furniture Manager: A simple question: Lucia is an LCA wizard. What does LCA stand for?

[Have audience answer the question: *life cycle assessment*.]

Plastic Furniture Manager: You're smarter than you look.

Student 1: Thank you.

Plastic Furniture Manager: This furniture is made mostly of a substance called "polypropylene." Since we want a hard substance that will resist weathering and have a high degree of strength, we melt the polypropylene pellets and mix them with calcium carbonate along with a few other substances to get the right color. Then, we use a 1000-ton injection-molding machine to inject the liquid mixture into a mold shaped like a table or chair. After the piece has cooled and solidified, we take off the mold and trim away any small pieces of excess mixture.

Student 2: Are there any greenhouse gas emissions from all of this?

Plastic Furniture Manager: Of course there are. [Pretending to write them on a slip of paper] I'm going to give you the numbers for carbon dioxide, methane and nitrous oxide. Those are the main three to be concerned about. Here, these are the greenhouse gases associated with this heating, mixing, and injecting [hands a slip of paper;].

[Slide 5: Emissions from Furniture Plant]

Student 1: Great, now we can go home.

Plastic Furniture Manager: I don't think so. This is just one step in the life cycle. These numbers won't be useful to you unless you look at the other steps too. Since this furniture is made from polypropylene, you'll need to find out the emissions that result from making polypropylene resins.

Student 3: How are we supposed to find out that?

Plastic Furniture Manager: Lucia didn't even tell you how to travel? I suppose she thinks I have time to do her job. To get to the propylene plant, you need only to join hands and say "Polypropylene" in unison.

Student 1: What? That sounds like a goofy way get around.

Plastic Furniture Manager: You're three pages into a play on life cycle assessment with a Wizard, and NOW you start worrying about being goofy?

Student 3: It's a fair point. [To the other students] Come on, let's do it.

All students [joining hands]: Polypropylene.

Narrator: With a woosh, the floor again dropped from the students' feet as they were propelled through space and time.

Scene 3: Polypropylene Factory

[Slide 6: Pipes representing polypropylene factory]

Narrator: When they landed, they were in another factory. This one was filled with pipes that seemed to be crossing everywhere. At one end of the room, a constant flow of plastic pellets was being poured into large shipping containers.

Student 1: This looks like the same place.

Student 3: No, look. Those are the same plastic pellets that were being mixed together in the other factory. They must be making them here.

Polypropylene Manager: Well, well, look who thinks they know something about manufacturing polypropylene.

Narrator: The students turned in response to the voice and saw a (wo)man with clipboard standing on a platform above them.

Student 2: We don't really know anything about making polypropylene. We were sent here to learn about it.

Student 3: Especially about the greenhouse gas emissions involved.

Polypropylene Manager: Ah, I see. You've come to learn then. Well, that's different. I can tell you about making polypropylene, but you must tell me something first. What three greenhouse gas emissions are scientists most concerned about?

[Have audience answer the question: *carbon dioxide, methane, nitrous oxide.*]

Polypropylene manager: Hmm, I suppose you've managed to actually learn something. Well, here we take the refined petroleum products and put them through a process called "cracking." That means breaking up large molecules into smaller ones. To do this, we must use high pressures and temperatures—about 1000 degrees Celsius. You're interested in the polypropylene. To make that, we must first use this cracking process to create propylene. We also use this process to remove more impurities from the products we want. Once we have propylene, we have to make it into a polymer. A polymer is a large molecule made up of many smaller ones. In this case, we use chemical reactions to attach many propylene molecules together to make polypropylene. Anyone know what "poly" refers to?

Student 1: The name of a parrot?

Student 3: It means "many." Just like "polygon" is a shape with many angles.

Polypropylene Manager: That's it. A "poly-mer" has many parts. And more specifically, "poly-propylene" has many propylene molecules connected together. Polymers serve all kinds of uses. Polypropylene can be used for bottle caps, pipes, food containers, and medical applications like medical gowns, laboratory equipment, and packaging for medicines, in addition to the outdoor furniture that you're researching.

Student 2: Do greenhouse gas emissions result from this process?

Polypropylene Manager: Of course, these high temperatures and chemical reactions all require energy. Here are the emissions that result from the production of enough polypropylene to make one set of outdoor furniture [hands a slip of paper]

[Slide 7: Emissions from Polypropylene Plant]

Student 1: Now, can we go home? I'm really hungry.

Polypropylene Manager: It would be foolish to go home now. As I said, polypropylene is made from refined petroleum products. The knowledge I have is of little value until you uncover the secrets of refining and processing petroleum products.

Student 1: How do we do that? "Refining and processing petroleum products" is an awfully long thing to chant.

Polypropylene Manager: "Refinery" should do the trick. Off you go.

[The students join hands again. Students 2 and 3 say "Refinery," but Student 1 says "Chimichanga"].

Narrator: The students were again propelled through time and space before landing on solid ground.

Scene 4: Mexican Oil Refinery

[Slide 8: Oil refinery]

Student 3 [to Student 1]: Did you say "Chimichanga"?

Student 1: It was on my mind. I'm hungry.

Student 2: Nice, where do you think we ended up?

Refinery Manager: *Hola, amigos. Bienvenidos* to my refinery.

Student 1: We're in a Mexican refinery?

Refinery Manager: *Si*, one of the best in the world. Mexico is actually one of the largest oil producers in the world, and we are third after Canada and Saudi Arabia in supplying oil to your country.

Student 2: I think we were aiming for a refinery in the United States.

Refinery Manager: Ah, yes, some of the biggest refineries in the world are there, but no matter. You just want to know about the process, no? Here, there, the process is the same.

Student 3: Are the emissions the same too? We are trying to find out the greenhouse emissions that result from processing the petroleum products used to make polypropylene.

Refinery Manager: I can tell you what you came to hear, but first you must answer another question: Explain to me how greenhouse gases cause the global temperature to be higher than if we did not have those gases.

[Have audience answer the question: *Solar energy hits the earth as UV light and radiates off as heat. Molecules of greenhouse gases absorb some of that heat energy, preventing it from escaping into space.*]

Refinery Manager: Yes, most impressive. Most people do not know that without any greenhouse gases, the global temperature would be about -3 degrees Fahrenheit rather than the current average of 57 degrees. Of course, we would not want things that cold. These gases have their use as long as we do not have too much of them. But you came here to learn about oil, yes? Most of your oil (62%) is imported, with Canada, Saudi Arabia, and Mexico providing most of those imports. Another 32% comes from the lower 48 states.

Student 1: That's only 94%.

Student 2: The other 6% must come from Alaska.

Refinery Manager: *Exactamente*. Most of your country's refineries are located in the Gulf Coast states. We can use this geographical information to estimate the amount of energy it takes to move the crude oil to the refineries. Once at the refinery, the oil is put through a series of processes which produce several products that you are probably familiar with, including gasoline, diesel, and the materials that go into the plastic furniture you have been asking about.

Natural gas must be processed as well to remove impurities and convert it into several useful products. In addition to being a fuel, natural gas can produce materials needed for that furniture. These processes all take energy, and there are, of course, some emissions associated with them. Here are the amounts of greenhouse gas emissions that result from processing and refining petroleum to produce one set of furniture. [Manager hands a piece of paper to students].

[Slide 9: Emissions from Oil Refinery]

Student 1: Let me guess. We still can't go home yet.

Refinery Manager: Why would you stop now when you have almost everything that you need? But for these numbers to be useful, you must also find the emissions resulting from extracting the crude oil. To do that, you must go to the ultimate source.

Student 2: So, we're chanting "Oil well" or what?

Refinery Manager: You cannot travel to the ultimate source as you have traveled before. This journey you must make by boat.

Student 1: That's sound like it'll take even longer. You don't happen to have anything to eat around here. Do you? I'm missing chimichanga night for this.

Refinery Manager: You are in luck, *mi amigo*. My wife sent me to work with a very large lunch. [Handing Student 1 a bag] Here, this should satisfy your appetite.

Student 1: [Looking inside the bag] Wow, chimichangas. Thanks.

Scene 5: Oil Platform

[Slide 10: Oil Platform]

Narrator: And so the students boarded a boat and headed out to sea to find the ultimate source of the plastic furniture. The seas were rough, and [Student 1] spent most of the time hanging seasick over the side of the boat. Still, the students were brave, and in time, they reached their destination, an oil rig that towered above the open ocean. [During this narration, Students can act out sea adventures—rowing, swaying in the waves, etc.]

Student 3: Well, I think I've witnessed enough vomiting for a lifetime. Did you have to eat that entire bag of chimichangas before the trip?

Student 1: I told you I'd get your jacket dry-cleaned, all right.

Student 3: Can you also clean away the memory of sitting with you on that boat? Because that's what it would take for me to consider ever putting that jacket on again.

Student 2 [Looking around]: So this is the ultimate source, huh?

Oil and Natural Gas Manager [Sneaking in behind the students, startling them when s/he speaks]: You're right about that. Didn't mean to frighten you. This here's the source for all kinds of things. A bunch of prehistoric plankton dies and sinks to the bottom of the ocean. Let that set for a few hundred million years, taking care to add heat and pressure from rock piled on top, and bam, you've got yourself the stuff that makes today's world go—crude oil, and the accompanying natural gas of course. The two are often found together.

This rig over here is for pumping the crude up from deep underground, and this is where we catch the natural gas coming up with it. Most of the time, oil has water in it. We remove that before sending it on to the refineries.

Student 2: Does any of this result in greenhouse gas emissions? We're trying to find out how much greenhouse gas is emitted in order to produce a plastic outdoor furniture set.

Oil and Natural Gas Manager: Ah, I see. I can give you the information, but first you must prove to me that you are worthy of learning about these things. So, you must pass a test. Answer my three questions, and I will tell you what you want to know. Of course if you get them wrong, then I'll have to kill you.

Student 1: Kill us?

Oil and Natural Gas Manager: Yes, of course, and bury you at the bottom of the ocean so that in a few hundred million years, you too can be petroleum products.

Student 3: Ok, what are your questions?

Student 1: Are you sure we should—

Student 3: We can do this.

[Have students from the "audience" answer the questions.]

Oil and Natural Gas Manager:

[Slide 11: Question 1]

Question 1: Name the steps of the life cycle of plastic furniture. [*Oil and natural gas are extracted from the ground; they are refined and processed; some of those materials are made into polypropylene; the polypropylene is used to make furniture; the furniture is used; and the furniture is disposed of.*]

[Slide 12: Question 2]

Name two pieces of evidence that show the global temperature is increasing. [*Answers may vary, for example, increased ocean temperatures, retreating glaciers, melting polar ice.*]

[Slide 13: Question 3]

Question 3: Name two natural and two human-related causes of global climate change. [*Natural: changes in solar activity, volcanoes. Human-related: burning fossil fuels, deforestation*.]

[Continue after the class has answered the questions.]

Oil and Natural Gas Manager: Well, it seems you do know a thing or two about global climate change. Very well, I will tell you what you wish to know.

All of this pumping takes energy of course, and some methane escapes to the environment because of gaps between the rock and the pipe. As a result, some greenhouse gases are released into the atmosphere during drilling. Here are the amounts that would be released from the process of collecting petroleum products used in one set of outdoor dining furniture. [He gives the students a piece of paper.]

[Slide 14: Oil and Gas Extraction Emissions]

Student 1: Wait a second, that's it. We've gone all the way back to the beginning of the life cycle. First, crude oil and natural gas are extracted from a well. Those products are refined. Then the refined products are processed into lots of different materials, including polypropylene. And finally, that polypropylene is mixed with some other things, and injected into a furniture mold. We have the numbers for all of that. Now we can go home.

Student 3: Wait, we have all the emissions from the manufacturing part of the life cycle, but what about the emissions from using the furniture and from disposing of it? Those count too, right?

Student 1: You're kidding, right?

Student 2: I think you're right. The life cycle means everything, cradle to grave, or back to cradle.

Narrator: Just then, there was another woosh and Lucia, the LCA Wizard appeared.

LCA Wizard: Great work, my adventurous young students. Not only did you find the information I sent you to get, but you also realized you need information about other parts of the life cycle we have not yet considered.

Student 2: So, what do we do about the other stages?

LCA Wizard: Well, the maintenance on a plastic set like this is minimal. A little soap and water would be enough, so we can take those emissions to be zero. But the disposal is a different story. For that you need to go to the landfill.

Student 1: Did she just say the—

Narrator: Before [Student 1] could finish his/her question, there was another woosh sound and without much warning, the three students were transported to a landfill.

Scene 9: Landfill

[Slide 15: Landfill]

Narrator: At the landfill, yet another adventure awaited the LCA travelers.

Waste Manager: Visitors!!! Welcome! Welcome! No one ever comes here. Most people don't even like to admit that "here" exists. They simply throw things away and never think about them again. Are you here to throw something away?

Student 2: We are here to find out about greenhouse gases associated with disposing of waste.

Student 3: Specifically, a plastic outdoor furniture set.

Student 2: Yes, we've been looking into the greenhouse gas emissions for the whole life cycle of a plastic furniture set.

Student 1: Why are we even here? Can't we recycle plastics?

Waste Manager: Yes, that's true for many plastics. Unfortunately, most communities don't have the capability to recycle something like plastic furniture. So, it ends up here.

Student 1: Are you going to make us answer a question before you tell us about the emissions?

Waste Manager: I hadn't planned to. I'm just happy someone cares at all about what happens here. It matters a great deal.

Student 2: Does it matter in terms of greenhouse gases?

Waste Manager: Most certainly. There are of course, greenhouse gas emissions associated with the management of a landfill, such as collecting and compacting the waste. In addition, we have to

consider how the product decomposes, but plastic doesn't decompose much. Even over a hundred years, you're talking about only a small amount of the carbon decomposing into carbon dioxide and methane.

Student 3: Do you know how much that would be?

Waste Manager: Sure, here are the numbers you need. [Hands Student 3 a slip of paper.]

[Slide 16: Emissions from Disposal of Plastic Furniture Set]

Student 1: Does this mean we're finally done?

[LCA Wizard appears]

LCA Wizard: Yes, [Student 1], you have found everything you need to calculate the greenhouse gas emissions over the entire life cycle of a set of plastic resin furniture.

[Slide 17: Life Cycle Diagram]

Student 1: Where did you come from?

LCA Wizard: I'm the LCA Wizard, [Student 1]. I can pop in and out pretty much whenever I like. The more important question, is what do you calculate for your total emissions of carbon dioxide, methane, and nitrous oxide?

[Have students sum the emissions from each step in their LCA tables.]

[Slide 18: Total Emissions]

Student 2: It looks like the total emissions for this set of plastic furniture are ___ kilograms of carbon dioxide, _____ kilograms of methane, and ____ kilograms of nitrous oxide.

LCA Wizard: Excellent, now we need only to calculate what that amounts to in carbon dioxide equivalents.

Student 3: In what?

LCA Wizard: Not all greenhouse gases are created equal. Some can capture much more heat per molecule than others. Over a one-hundred year period, a kilogram of methane will capture 25 times the amount of energy that a kilogram of carbon dioxide would capture. That means that in the context of global warming, one kilogram of methane is equivalent to 25 kilograms of carbon dioxide.

Waste Manager: Nitrous oxide traps even more energy. One kilogram of nitrous oxide can trap as much heat as 300 kilograms of carbon dioxide.

LCA Wizard: These numbers are called the "Global Warming Potentials" of the gases. To find out how much of an impact the different emissions have, we must multiply the mass of each gas by the global warming potential.

Student 3: I get it. So then we get one number for the whole life cycle of the furniture.

[Have students calculate the greenhouse gas emissions in units of carbon dioxide equivalents.]

Student 2: Now we know that over the whole life cycle of a set of polypropylene furniture, _____ kilograms of carbon dioxide equivalents are emitted into the atmosphere.

Student 1: So what does that tell us?

LCA Wizard: It gives us a basis for comparison. Now you must find the greenhouse gas emissions associated with aluminum and wood sets of furniture.

Student 1: Now?

LCA Wizard: Oh, you wanted to get home to Mexican night, right?

Student 1: Well, I'm sort of over that for now.

LCA Wizard: I'll tell you what? You've done well here, so I'll give you a little break, but I'll be back soon to continue the adventure.

Narrator: And with that the LCA Wizard disappeared in a burst of shining light produced entirely by renewable energy.

Student 1: I've got an idea that might save us some work. My uncle once hired a private eye to do some work for him. I'll bet I could get his number. Why don't we hire that guy to find out about this life cycle stuff for us.

Student 3: I don't know, [Student 1], I think Lucia expects us to do this on our own.

Student 1: What's the problem. Next time she appears, we'll already have the information. She'll be impressed by our progress.

Student 2: It might speed things up.

Student 3: All right. How do we get a hold of this detective?

Student 1: I'll call him and we can stop by his office on the way home.

[Slide 19: Tune in Next Time…]

Act II

[In the previous act, three students were at the Home and Garden Mart picking out an outdoor dining set for their school cafeteria when they met the Life Cycle Assessment Wizard, who offered to help them identify the global warming impacts associated with three differently made sets of furniture—plastic, aluminum, and wood. The students successfully discovered the greenhouse gas emissions associated with a plastic furniture set. In Act II, they are after the emissions associated with the aluminum set.]

[Slide 20: Title Slide for Act II]

Characters:

Lucius Charles Anderson, Private Eye (Luke)
Luke's Voice Over: 1st person narration of what Luke is thinking (performed by different student)
LCA Wizard
Mining Manager
Maxine, Recycling Manager
Aluminum Factory Manager
Furniture Manufacturing Manager
Student 1
Student 2
Student 3

Scene 1: Luke's Office

[Slide 21: Detective Office]

[Lucius Charles Anderson sits, reading a newspaper, with his feet propped up on a desk. Luke continues reading or looking lost in thought while his "Voice Over" is read.]

Luke's Voice Over: It was a cold, wet night, and I was happy to be inside. I'd just finished a case, and I was looking forward to catching up on the local news. My name's Lucius Charles Anderson, but most people call me Luke. They also say I'm a private eye, but I don't care for that term myself. Let's just say, I find things for people. Finding out what most people don't know is sort of a gift of mine. I was just getting into an article on the effects of global warming when three students showed up in my office.

[Student 1, Student 2, and Student 3 enter.]

Luke's Voice Over: They had a look of longing or hunger, the kind you get when you've been zapped around the world by a wizard or maybe on a rough sea voyage, but you still need more information. You know the kind. I decided to get rid of them as quickly as I could.

Luke: You three look a little out of your element. The daycare is up the street a ways.

Student 1: We're here to hire you.

Luke: I'm not really looking for a job right now, kid.

Student 2: But it's important. We need your help tracking the emissions of outdoor furniture's life cycle.

Luke: The what?

Student 3: It's called Life Cycle Assessment. Have you heard of it?

Luke: Maybe.

Student 2: It means identifying the environmental impacts of each stage of the life cycle of a product.

Student 3: From raw materials through production, use, and then disposal.

Student 1: We need you to track the life cycle of aluminum furniture and find the amount of greenhouse gases associated with it

Luke: Greenhouse gases, huh? I was just reading about those.

Student 2: We're trying to figure out which set of outdoor furniture results in the least amount of greenhouse gases.

Luke: All right, I'll take the case, but I don't want you three crowding me. Just give me the model number of the furniture set and leave the rest to me.

Student 1: That's fine with us. We have other plans.

Luke: I hope they involve cleaning up. You smell like someone just vomited in a landfill. Or no…[smelling the air]… like someone vomited and then went to a landfill.

Student 2: Wow, he really is good.

Scene 2: Aluminum Furniture Factory

[Slide 22: Molten Aluminum]

[Luke is walking into a factory. The manager has his/her back turned to look. S/he is looking at an inventory list.]

Luke's Voice Over: For a few bills and a smile the woman at the Home and Garden Mart directed me toward Frankie's Aluminum Furniture. She said they made cast aluminum furniture there. I figured I'd go see for myself.

Luke: You Frankie?

Furniture Manufacturing Manager: Frankie owns the place, but he almost never comes out here. You'd have better luck looking for him—

Luke: I'm not looking for Frankie. I'm looking to find out about manufacturing aluminum furniture. An outdoor dining set.

Furniture Manufacturing Manager: Then why'd you ask for Frankie?

Luke: I didn't ask for Frankie. I asked if you were Frankie. It's just a way to open a convers— Nevermind. What can you tell me about manufacturing aluminum furniture?

Furniture Manufacturing Manager: I guess I could tell you just about everything there is to know. I run this place.

[They both stand there in silence for a moment looking at one another.]

Luke: So, start talking.

Furniture Manufacturing Manager: About what?

Luke: All right, tough guy, I don't have time for games.

Furniture Manufacturing Manager: If you'd like a tour of the place, all you have to do is ask.

Luke: You'd do that?

Furniture Manufacturing Manager: Sure, I'd be happy to. Come with me. This is how we get the aluminum—in 35 pound bricks called ingots. We load these into the furnace to melt them. This is pure aluminum we're talking about here, so we have to bring it up to temperatures up over 600 degrees Celsius. Once it's melted, we pour the molten aluminum into dye-cast molds like these. Those pieces are cooled and hardened, and then they are ready for assembly. We do that over here [points to a place] by welding the different molded pieces together to make all sorts of things, including tables and chairs for a dining set.

Luke: Are you telling me the whole story?

Furniture Manufacturing Manager: Well, we also make the cushions for the seats. Those are made out of a plastic resin that's made into fiber.

Luke: And all this must produce some greenhouse gases, right?

Furniture Manufacturing Manager: Sure it does. It takes a lot of energy to reach the temperatures we need to melt that aluminum.

Luke: You got those numbers handy?

Furniture Manufacturing Manager: Sure do.

[Both are silent for a moment.]

Luke: [Realizing what the manager is waiting for] I'd like to have those numbers.

Furniture Manufacturing Manager: Here you go. [Hands Luke a slip of paper]

[Slide 23: Emissions from Aluminum Furniture Manufacturing]

Furniture Manufacturing Manager: Now those are the numbers just for manufacturing the furniture itself, casting and welding and producing the cushions. They don't include the emissions from making the aluminum in the first place.

Luke: Don't start holding out on me now. Things could get ugly. Are we going to have to do this the hard way?

Furniture Manufacturing Manager: I'm not sure what you mean, but I supposed it'll be a little harder to get those numbers than you'd like. You'll have to go to an aluminum factory.

Luke: Aluminum factory, huh? All right. Do you know where I can find one?

Furniture Manufacturing Manager: Yes

Luke: (Rolling eyes) How can I get to an aluminum factory?

Scene 3: Aluminum Factory

[Slide 24: Smelting Furnace]

Luke walks slowly into aluminum factory lost in thought.

Luke's Voice Over: The furniture manufacturing manager gave me directions to an aluminum processing factory. S/he was so helpful, I felt bad about that crack about things getting ugly. I don't show gratitude well. I learned to speak mostly in short, tough sounding sentences. Maybe I'll write him/her a letter. You know, something showing my appreciation for the help.

[Luke bumps into the Aluminum Factory Manager.]

Aluminum Factory Manager: You can't be in here. This is a restricted area.

Luke: [regaining his tough-guy persona] Look here, pal. Nobody tells me where I can and can't be. I'm here for information about aluminum processing, and I've got a feeling you've got it. Now are you going to tell me what you know?

Aluminum Factory Manager: I'd be happy to, but given the temperatures of the liquids inside these vats, just a drop from them could burn a hole through your body in less time than it would take for you to say "Ouch!"

Luke: [Looking around at the vats of hot fluid and thinking] Let's talk over here.

Aluminum Factory Manager: Good idea.

[Luke and the Aluminum Factory Manager walk away from the vats.]

Aluminum Factory Manager: That's better. Now what can I help you with?

Luke: I'm tracking this set of aluminum furniture [shows a slip of paper], and I need to learn about processing aluminum. What goes into the process?

Aluminum Factory Manager: Well, we start with crushed bauxite. That's what we call aluminum ore.

Luke: Aluminum or what?

Aluminum Factory Manager: No, not or as in O-R. I mean ore as in O-R-E. The rock with high amounts of aluminum in it. You see, aluminum is one of the most common elements in the earth's crust, but usually it's part of some other chemical compound so it's very hard to isolate. In most forms, isolating aluminum wouldn't make any sense economically. It would cost more to isolate it than you could sell it for. Even with bauxite, separating pure aluminum is difficult, but at least you can still turn a profit doing it.

Luke: So what do you do with the bauxite?

Aluminum Factory Manager: The first thing we do is dissolve it in a sodium hydroxide solution. To do that we bring it up to about 3.5 atmospheres of pressure and 150 degrees Celsius. This will dissolve the alumina, but it won't dissolve impurities like bits of sand and iron.

Luke: Did you say "alumina"? Don't you mean "aluminum"?

Aluminum Factory Manager: Alumina is a form of aluminum oxide. Don't worry, we'll get to the aluminum soon enough. Anyway, those impurities settle to the bottom of the tank, and the rest is pumped on. We use a series of filters to take out the smaller impurities. Then we cool the solution to allow alumina crystals to form. Once those crystals are separated from the solution, the real fun begins.

Luke: What do you mean?

Aluminum Factory Manager: Alumina crystals have water in them. So, we need to heat them up enough to break those crystals apart and get rid of that water. That means heating things up to about 400 degrees Celsius.

Luke: And then you have aluminum?

Aluminum Factory Manager: Then we have pure alumina. Going from alumina to aluminum takes several more chemical reactions involving temperatures over 1000 degrees Celsius. Those chemical reactions produce carbon monoxide, carbon dioxide, and, of course, aluminum. After these reactions, molten aluminum collects at the bottom of the tanks where it can be separated from the other chemicals. Then, depending on what we're going to use the aluminum for, we might mix it with small amounts of other metals.

Luke: You mentioned carbon dioxide as a product of the reactions. All those operations must result in other greenhouse gas emissions too.

Aluminum Factory Manager: Yes, that's right. It also takes a lot of energy to heat rock to 1000 degrees Celsius, but we provide much of the energy for that with hydroelectric power, which reduces the greenhouse gas emissions. Here are the numbers for the greenhouse gas emissions. I've got all the numbers on that right here. [Takes a piece of paper from his pocket and gives it to Luke.]

Luke: And these include everything.

Aluminum Factory Manager: This includes the whole process for primary aluminum. Often that primary aluminum is mixed with secondary aluminum.

Luke: Secondary aluminum? What's that?

Aluminum Factory Manager: Often the primary aluminum—what we've just been talking about—is mixed with secondary aluminum from recycling operations. [Manager calls across the factory.] Hey Max, this guy's got a question about secondary aluminum.

[Max enters. Aluminum Factory Manager exits.]

Luke: You're Max?

Max: That's right. Short for Maxine. What can I help you with?

Luke: I'm looking into the aluminum that goes into this set of furniture. Your friend there tells me that you're the one to talk to about secondary aluminum.

Max: That's right. By using secondary aluminum you avoid a lot of those costly processes needed to isolate the alumina and convert it to aluminum. At this plant, the final ingots have about half primary aluminum and half secondary.

Luke: Are there greenhouse gas emissions associated with this secondary aluminum?

Max: Sure there are. First you have to collect it. And even though you avoid the most costly processing, you still have to process it to get it ready to put back into the mix. But those emissions are a small fraction of the emissions from primary aluminum. Here, give me that slip of paper. I'll write down the emissions that result from the mixture of secondary and primary aluminum so that you can compare them. [Max takes the slip of paper and pretends to write down numbers.]

Luke: [Looking at the paper] Whoa, that's a big difference! I think we'll just go with the recycling numbers since we're trying to have the least amount of emissions possible.

[Slide 25: Aluminum Processing Emissions]

Max: Also keep in mind that there's a difference in emissions for disposal as well. Here are the emissions associated with recycling aluminum and with disposing of then in a landfill. But you should just use the recycling numbers. [Hands Luke a slip of paper.]

[Slide 26: Emissions from Disposal of Aluminum]

Luke: Now, I've got numbers for both the portion of primary aluminum and secondary aluminum, but wait a minute. I never asked your friend about the greenhouse gas emissions associated with mining the bauxite in the first place.

Max: S/he's not going to tell you that.

Luke: Really? I'm pretty good at getting people to talk.

Max: Maybe so, but to find out that information, you'll have to travel awfully far. Down under.

Luke: Down under what?

Max: To Australia, I mean. They are the world's leading producer of bauxite.

Luke: Then, that's where I need to go, but I'll never be back in time to meet my clients.

Max: I could just zap you there.

Luke: "Zap" me there? What do you mean?

Max: I don't really want to go into the details, but let's just say I have a magical power or two.

Luke: If you have that kind of power over time and space, why are you working in this factory?

Max: Well, recycling is important, I love my job, and the benefits are good.

Luke: I suppose that makes sense, but how will I get back.

Max: When you're ready to return, tap your heels together three times.

Luke: Like Dorothy? I'm a hard-boiled private eye, Max, not some young kid from Kansas.

Max: That's why I'm not making you wear the red shoes.

Luke: All right. Zap away.

Scene 4: Bauxite Mine

[Slide 27: Bauxite Mine]

[Luke is sitting on the floor, dazed and holding his head.]

Mine Manager: What are ya do'in down there, mate?

Luke: Where am I?

Mine Manager: This is Dwellingup, Australia. Home of the largest bauxite mine in the world.

Luke: Wow, Max is good.

Mine Manager: How's that, mate?

Luke: [Getting up] Uh, nothing. I'm looking into the life cycle of aluminum, and I need some information about mining bauxite.

Mine Manager: Questions about the life cycle of aluminum? Do you know where you are?

Luke: You just said I was in Dwellingup, Australia.

Mine Manager: You're at the source, mate. That means you have to answer some questions for me if you want me to give you any information.

Luke: What kind of questions?

[Have students from the "audience" answer the questions.]

Mine Manager:

[Slide 28: Question 1]

Question 1: Name the steps of the life cycle of aluminum furniture. [*Aluminum ore, bauxite, is mined (or recycled aluminum is used); the aluminum is processed (a step that takes much more energy for primary aluminum than for recycled aluminum); the aluminum is cast into furniture; the furniture is used; and the furniture is disposed of*.]

[Slide 29: Question 2]

Question 2: Describe what an externality is? [*An externality is an impact on a third party caused by a decision made by a producer or consumer*.]

[Slide 30: Question 3]

Question 3: Give me one example of a positive externality and one example of a negative externality. [*Any aspect of a transaction that benefits a third party who is not directly involved with the transaction is a positive externality. For example, when a landowner decides to manage a forest sustainably, all of us benefit from the carbon sequestration achieved by that forest. In addition, the landowner's neighbors may benefit from the nice view provided by the landowner's decision not to develop the land.*

A negative externality involves a negative impact on a third party. A landowner's decision to remove a forest will result in increased greenhouse gas emissions that will affect everyone. Similar claims can be made about decisions to buy a gas-guzzling car or to opt not to conserve energy in other ways. Air and water pollution from the aluminum smelter and bauxite mining are other examples of negative externalities.]

[Continue after the class has answered the questions.]

Mine Manager: Smarter than you look, I see. OK, I'll help you. What do you want to know?

Luke: What do your operations involve?

Mine Manager: Bauxite is a pretty soft rock, really. We dig it up here in an open pit mine. Then we crush the stuff, wash it, and send it on to be processed.

Luke: How much bauxite would it take to make the aluminum for this? [Shows Manager a slip of paper.]

Mine Manager: Well, let's have a look. Thirty kilos, eh. That'd take about 150 kilos of bauxite.

Luke: And doing all of this must produce some greenhouse gas emissions.

Mine Manager: Bit o'all right there, mate.

Luke: I don't know what you're saying.

Mine Manager: Of course there's greenhouse gas emissions involved.

Luke: Could I get those numbers from you.

Mine Manager: Yea, sure, [hands Luke a slip of paper]. I hope there's not much more here. We keep up this chinwag [*chinwag* = "chat"] much longer and I'll have to take a sick day.

[Slide 31: Emissions from Bauxite Mining]

Luke: No, this is what I needed.

Mine Manager: Do you have a ride back into town?

Luke: I've got something like that, but would you mind turning around.

Mine Manager: Why?

Luke: You wouldn't believe me if I told you.

Mine Manager: [Walking away shaking head] Yanks.

[Luke taps his heels together three times.]

Scene 5: Student 1's house

[Slide 32: Dining Room]

Students 1, 2, and 3 are sitting at an empty table having just finished a large meal.

Student 2: I can't eat another bite.

Student 3: I hope not after five chimichangas. [Looking at Student 1] You sure you don't want any?

Student 1: It's tragic really. After that boat ride, I may never be able to enjoy Mexican night again.

Student 3: How do you think Detective Lucius Charles Anderson is making out?

Student 2: I hope he gets here soon. We need to give Mr. McKibben our recommendation by tomorrow.

[Luke pops up behind the table, still tapping his heels for the third time.]

Student 3: How did you get here?

Student 2: Are you working with the LCA Wizard?

Student 1: Why were you tapping your heels?

[Slide 33: Life Cycle Diagram]

Luke: Enough questions. I found out what you wanted. The process starts with mining aluminum ore, called bauxite. Once crushed and cleaned, the bauxite is taken to a processing plant where it goes through a whole series of steps before it comes out as aluminum on the other side. The aluminum from bauxite is called primary aluminum. That's mixed with recycled—or secondary—aluminum. Then the aluminum ingots are shipped to the furniture factory where they are melted down and cast into shapes for furniture. Those shapes are welded together to make tables and chairs and then sent to stores like Home and Garden Mart. I've got the greenhouse gas emissions resulting from each step.

Student 3: You found all that out in the time it took us to eat dinner?

Luke: It's what I do.

Student 2: What about emissions from the use and disposal of the furniture?

Luke: I guess I forgot about those parts.

[Lucia, the LCA Wizard appears.]

LCA Wizard: Very nice work, detective. I can help you with those last stages.

Luke: Lucia? Last time I saw you, you were tracking down Voldemort.

Student 1: [To the LCA Wizard] Wait a second, I thought you said none of that stuff was real.

LCA Wizard: Voldemort's a common name among wizards. Voldemort Jenkins works as a lounge singer in Poughkeepsie, New York. He's no dark lord, but he did owe me money. But let's get back to the task at hand. The use stage of the aluminum furniture is similar to plastic. Some simple cleaning will be sufficient maintenance throughout its use. Disposal, however, is a different story. If you take it to a landfill, you have to account for the emissions associated with managing the landfill.

Student 2: But Luke said that recycled aluminum is used too, so we wouldn't have to send it to the landfill.

LCA Wizard: Ah, excellent, [Student 2]. You are really getting the hang of this. Not only does recycling save emissions in the processing stage. It also saves in the disposal.

Student 3: [To Student 1] That's why it's so important to recycle.

Student 1: All right, all right. I'll start recycling.

Luke: Hey, Max already told me the emissions associated with collecting the recycled aluminum. We just have to connect the steps in our diagram, like this.

[Slide 34: New diagram with that closes the life cycle loop.]

LCA Wizard: You mean Maxine, the recycling Wizard?

Luke: Didn't say. She was in charge of the secondary aluminum down at the plant.

LCA Wizard: She does enjoy keeping a low profile. And yes, you are exactly right Luke. Aluminum can be used over and over again. Also, by recycling this aluminum, you are able to decrease the demand for primary aluminum.

Here, take this sealed envelope. It tells you the emissions that would be created by the same set of furniture if we didn't recycle any aluminum. Open only after you've totaled the emissions for this life cycle. [She hands Student 2 a slip of paper] By now, you know how to sum the emissions and convert them to carbon dioxide equivalents. So since you had someone else do the legwork on this one, now it's time for you three to put in some effort!

[If the class has not covered this in Act I, then the instructor will need to go over this process.]

Student 2: OK, we can do that math, but what about the third set of furniture?

LCA Wizard: That's the spirit, [Student 2]. Are you all ready for another adventure?

[In unison]
Student 1: No, not really
Student 2: Let's go!
Student 3: Absolutely!

[Slide 35: Emissions Totals with Recycling]

[Slide 36: Tune in next time…]

Act III

[Slide 37: Title slide]

[Review of first two acts: Three students, who are intent on making an environmentally responsible purchase of outdoor dining furniture, meet the Life Cycle Assessment Wizard, who introduces them to the concept of LCA and gives them the challenge of comparing the greenhouse gas emissions associated with the life cycle of three different sets of furniture: plastic, aluminum, and pine.

The three students track the life cycle of the plastic set in Act I. In Act II, the students hire a private investigator to track the life cycle of the aluminum set. As Act III begins, the students must still track the life cycle of the pine set of furniture before deciding which set to buy.]

Characters

Student 1
Student 2
Student 3
Lucia, LCA Wizard
Luke, Private Investigator
Luke's Voice Over: 1st person narration of what Luke is thinking (performed by different student)
Pine Plantation Manager
Lumber Mill Manager
Hank, Furniture Manufacturer (female)
Gruff
Waste Manager
Narrator

Scene 1: Student 1's Dining Room

[Slide 38: Dining Room]

Narrator 1: As we catch up with our three students [Student 1, Student 2, and Student 3], they are sitting around a table with Lucia, the LCA Wizard, and Luke, the private detective. They have just eaten a large meal and are discussing their next move.

Student 1: [Musingly] I wonder what the LCA of a chimichanga would entail?

Student 2: I really think we should stay focused on the furniture.

Student 3: Let's see, you've got tortillas. Made of corn, I guess.

Student 1: [Reading a package] These are made of wheat.

Student 3: Really? Well, either way, we're talking breadbasket states.

Student 1: And you've got the refried pinto beans.

Student 3: Where do those come from?

Luke: North Dakota's probably the biggest producer.

Student 3: How do you know that?

Luke: A case I had a couple years ago.

Student 1: You had a case on refried beans?

Student 2: [Frustrated] Look! I really think we should get back to the last part of our quest. We still need to find out what greenhouse gas emissions are associated with the life cycle of the wood furniture set.

Student 1: All right, all right. What's our next move?

Student 2: I guess Lucia should zap us to the furniture manufacturer.

Student 3: Wait a minute, we pretty much know how this is going to go. We'll get passed down the line until we're headed out to some forest to learn about tree cutting. Can't we just go straight to the forest?

LCA Wizard: You are right, [Student 3]. That wood set was made of southern pine, which came from a pine plantation. There's no reason not to head straight to the raw material this time. [To Luke] They could use some help on this one.

Luke's Voice Over: After being zapped half way across the world and back, I wasn't eager to do it again, but I always had a soft spot for Lucia even before she became a Life Cycle Assessment Wizard. Besides, her current work seemed pretty important, and—

Student 1: Hey, are you using voice over inside your head to decide whether or not to come?

Luke: No…Maybe…I'm a private detective. It's what we do.

Student 2: So what did your voice over tell you?

Luke: I'll come, but I'll probably be rude and a little grumpy most of the time.

Student 1: [Sarcastically] Sweet. So when do we—

Narrator: Before [Student 1] could finish the question, the floor fell away from their feet as all three students plus Luke were propelled through time and space.

Scene 2: Pine Plantation
[Slide 39: Pine Plantation]

[The three students and Luke are lying on the ground side-by-side. The Pine Plantation Manager is standing just a few feet away and looking in the opposite direction.]

Narrator: The next thing they knew, they were all lying on the ground looking up at pine trees towering above them, swaying gently in the breeze.

Student 1: I hate it when she zaps me in the middle of a question.

Student 2: Look at those trees. It's kind of nice here.

Student 3: Sort of peaceful.

Pine Plantation Manager: Timberrrrrr!!!

[As the manager says this, a tree begins to fall toward the three students and Luke. A broom handle can be used for the tree. You'll want to have a student letting it down in slow motion to give the adventurers time to get out of the way. The adventurers scramble out of the way just in time and look down at the fallen tree.]

Student 2: That thing could have killed us.

Pine Plantation Manager: Sorry about that. Where did you four come from? We checked this area thoroughly.

Student 3: I don't think you'd believe us if we told you.

Pine Plantation Manager: Did Lucia send you?

Student 1: Am I the only one who had never heard of an LCA Wizard before tonight?

Pine Plantation Manager: She really has to be more careful with her zapping.

Student 2: We're looking into the greenhouse gas emissions associated with the life cycle of a wooden set of outdoor dining furniture. We were hoping to find out about your operations here, and the greenhouse gas emissions that result from them.

Student 3: Specifically, we're looking into emissions of carbon dioxide, methane, and nitrous oxide.

Pine Plantation Manager: Yes, I can help you, but this is the *source* of wood.

Student 1 and Luke [at the same time]: Great, more questions.

Pine Plantation Manager: That's right

[Have students from the "audience" answer the questions.]

[Slide 40: Question 1]

Question 1: Name three pools of carbon. [*Examples include carbon in fossil fuels, carbon in trees, carbon in soils and ocean sediments, and carbon in the atmosphere in the form of carbon dioxide and methane.*]

[Slide 41: Question 2]

Question 2: How were fossil fuels made? [*Fossil fuels were originally the remains of prehistoric plants and animals that lived millions of years before even the dinosaurs were around. Over hundreds of millions of years of being subjected to intense heat and high pressure, those remains became fossil fuels*.]

[Continue after the class has answered the first two questions correctly.]

Pine Plantation Manager: Wow, that's pretty good. It's just that no one would guess you could answer those questions by looking at you.

Student 1: Yea, we get that a lot. Is there a third question?

Pine Plantation Manager: All right, if you're so smart, tell me this:

[Slide 42: Question 3]

Question 3: How does using secondary aluminum (rather than primary aluminum) reduce greenhouse gas emissions? [*Removing aluminum from bauxite (aluminum ore) is a very energy-intensive process that requires large amounts of fossil fuel and, therefore, produces large amounts of greenhouse gas emissions. By using secondary, or recycled, aluminum, we avoid that step*.]

Student 1: That's not fair. We didn't go on that trip.

Luke: No, wait, I think I can get this one.

[Continue after the class has answered the third question.]

Pine Plantation Manager: All right, I guess you know your stuff. Well, the first thing you should understand about our emissions numbers is that they depend on what kind of carbon dioxide you are talking about.

Luke: We don't want any tricks, pal. Carbon dioxide is carbon dioxide. C-O-2. Slap a couple of oxygen atoms onto a carbon one, and you've got yourself a greenhouse gas. That's what we're talking about.

Pine Plantation Manager: The molecule may be the same, but where it comes from matters a lot. Do you know about the carbon cycle in an ecosystem?

Luke: [Covering his ignorance] I know things.

Student 3: You mean how plants use carbon dioxide from the atmosphere during photosynthesis, store carbon as cellulose or starch, and then the carbon dioxide goes back to the atmosphere when it is oxidized in respiration or decomposition?

Luke: Yes, that's what I was going to say.

Pine Plantation Manager: Yes, exactly. We can think of it in terms of one tree. As the tree grows, it's converting atmospheric carbon dioxide into wood. Then, when it dies and decomposes, that carbon is converted back into carbon dioxide. Of course, when a tree dies, others grow to take its place. As long as there is no net loss of trees—or deforestation—then the carbon taken up by the growing trees will balance with the carbon dioxide released by a decomposing tree.

Student 2: So individual trees come and go, but the forest as a whole stores the same amount of carbon?

Luke: Assuming there's no net loss of trees.

Pine Plantation Manager: Exactly! I manage this pine plantation the same way. I make sure that we are growing trees as fast as we are harvesting them. This way, I know I'll be able to keep supplying trees to my customers, but also, it means that the carbon released when these wood products are thrown away and the wood decomposes is balanced by the carbon dioxide that the new trees are using to grow. That's why we think of the carbon dioxide from the decomposing wood as different from the carbon dioxide that result from using fossil fuels, and why wood is a "carbon neutral" energy source.

Student 2: That's right. We learned from that oil-rig manager that the fossil fuels come from plants and animals that lived hundreds of millions of years ago, so when we burn fossil fuels, we're making carbon dioxide out of ancient carbon. Fossilized carbon.

Student 3: So the carbon that comes from trees goes back into trees, but the carbon that comes from fossil fuels won't go back into fossil fuels—at least not for millions of years. But we could plant more trees to take up the carbon from fossil fuels, right?

Pine Plantation Manager: In theory yes, but the Earth doesn't actually have that much available land that will grow trees!

Student 1: Getting back to this forest, do you mean you have no greenhouse gas emissions at all?

Pine Plantation Manager: I'm not saying that. We use fossil fuels here too—fuels for cutting and trimming the trees and transporting them to the lumber mill. Even the fertilizer we use, once or twice in the trees' growth cycle to give the trees a boost, is made from fossil fuels. All of these things have to be counted when considering the greenhouse gas emissions associated with growing trees and preparing them for processing.

Student 3: So do you know what the emission numbers are?

Pine Plantation Manager: [Handing Student 2 a slip of paper] Sure! Here are the emissions based on all of these things that we need to run a pine plantation.

[Slide 43: Emissions from Sustainable Forestry]

Luke: Transport the trees to a lumber mill, huh? [To the students] Then that's where we have to go next.

Student 2: Lucia didn't say this time how we're supposed to travel.

Luke: We could probably just tap our heels together.

Student 1: You mean, like Dorothy?

Luke: That's what I said too, but it worked before.

Student 2: That sounds ridiculous.

Luke: How did you three travel through the plastic life cycle?

Student 3: We put our hands together and chanted the destination.

Student 1: Sometimes we used a magic clipboard.

Luke: Oh right! That doesn't sound ridiculous at all.

Pine Plantation Manager: You could also catch a ride with one of our truck drivers. It's not far from here.

Student 2: Well, sure, I guess that sounds reasonable.

[Luke, Student 2, and Student 3 walk off with the Pine Plantation Manager to find a truck. Student 1 lags behind while s/he tries tapping his/her heels together just to see what happens. Nothing does.]

Student 1: Hey guys, wait up. [Runs to catch the others.]

Scene 3: Lumber Mill
[Slide 44: Lumber Mill]

[Luke and the students walk on. Student 1 is limping as if s/he just finished a long horse ride.]

Student 1: I can't believe you guys made me ride on the logs.

Student 2: There wasn't any more room in the cab.

Student 3: And you were the last one to the truck.

[Luke moves away from the others and observes the area.]

Luke Voice Over: As we followed the logs into the building, we were met with the shrieking of saws that seemed to come from every direction. The logs were being sorted by size and then fed into a machine with large spiked wheels that looked like a giant pencil sharpener.

Student 1: Are you doing that thinking out loud to yourself thing again?

Luke: No, I—… Maybe

Student 1: Well, quit it. We don't need any extra narration right now. All this noise is deafening.

Student 2: This thing looks like a giant pencil sharpener.

[Lumber Mill Manager walks up from behind as the other characters look at the machine.]

Lumber Mill Manager: That there's a debarker.

Student 3: A what?

Lumber Mill Manager: We use it to take the bark off the logs when they come in. Then we send them on to the sawyer to be cut.

Student 2; Are you the manager here?

Lumber Mill Manager: That's right. I heard you kids were on your way. Looking into greenhouse gas emissions as I understand it.

Student 3: That furnace over there must produce a lot of emissions.

Lumber Mill Manager: Actually, it doesn't, and it isn't a furnace. After the wood is cut, we dry it in that kiln, but the heat is produced from the bark chips and sawdust produced during the earlier steps. Scientists typically don't count the carbon from burning wood as greenhouse gas emissions—

Student 1: Because the carbon from that wood would go into the atmosphere anyway when the tree decomposed.

Student 2: You were actually paying attention back there?

Student 1: I have my moments.

Student 3: So what happens after the kiln?

Lumber Mill Manager: The wood is planed to make sure that each piece is straight and sized correctly. We mark it, sort it, and let it sit in that pile until we sell it.

Luke: And that's it? That's the whole story?

Lumber Mill Manager: Yes, sir, that about sums it up. Here are the numbers for the greenhouse gas emissions associated with that process [hands Student 2 a slip of paper], but I understand that you folks are interested in wood for outdoor furniture.

[Slide 45: Emissions from Lumber Production]

Luke: That's right. What's that mean to you?

Lumber Mill Manager: It means you'll be wanting to talk to Gruff about pressure treating wood. Wood for outdoor use is treated to protect it from insects, fungus, and moisture.

Luke: Gruff, huh? [To the others] Maybe we can zap there this time.

Lumber Mill Manager: I don't know about that, but if you walk over yonder about five minutes, you'll see him/her. That's where they do all the pressure treating for outdoor wood products.

Luke: All right, that's what we'll do, but I wouldn't go far if I were you, in case we have any more questions.

Student 3: Thank you for your help.

[The students and Luke start walking away from the Lumber Mill Manager.]

Student 3: [To Luke] You know, you might try being a little less stern with people. You act like everyone is keeping secrets from you.

Luke: In my line of work, they usually are.

Student 2: Everyone we've been talking to has been very helpful.

Student 1: Yea, after we pass their tests.

Student 2: I'm just saying that Luke could try being a little nicer to people when we get information.

Luke: Listen and listen good, [Student 2], you do things your way, and I'll do things mine. Sometimes people need to be pushed into giving up information, and there's no one better at doing that pushing than me. You got that?

Student 2: Than I.

Luke: What?

Student 2: You should say, "There's no one better at doing that pushing than I." Grammatically, I mean.

Luke: Just stay out of my way. [Walks off on his own.]

Luke Voice Over: I didn't like to admit it, but the kid had a point. Maybe I could change my style to fit the situation. It wouldn't hurt to—

Student 1: Luke, enough with your inner dialogue. We found Gruff.

[Slide 46: Cut lumber]

[Luke walks over to the three students who are now standing with Gruff.]

Luke: So, you're Gruff, huh.

Gruff: That's right,

Luke: And you're in charge of pressure treating the wood for outdoor use? [Stumbling over his words to be nice.] I'm Lucius Charles Anderson, Private Detective. It's…it's nice to meet you.

[Luke looks at Student 2 who gives him a thumbs up of approval for his show of courtesy.]

Gruff: Mmm.

Student 3: We were hoping you could tell us about the greenhouse gas emissions associate with pressure-treating wood.

Gruff: I suppose I could.

[They wait for Gruff to explain more, but s/he doesn't.]

Student 2: Pressure treatment. I suppose that means high pressures are involved?

Gruff: That's right.

Student 3: I suppose the high pressure could help to force the preservative chemicals farther into the wood.

Gruff: Yep, that's right.

Student 2: I guess it's done in that big tank behind you.

Gruff: Sure is.

Student 1: Do you know the amount of greenhouse gases it takes to produce the preservative chemicals and put the wood through this process?

Student 3: And could you please tell us?

Gruff: Got them right here. [Hands Student 1 a slip of paper.]

[Slide 47: Emissions from Pressure Treatment Process]

Luke: You have been very helpful, Mr./Ms. Gruff. Thank you very much for your assistance.

[The students and Luke walk away from Gruff.]

Luke: [To Student 2] That was nice, right?

Student 2: I don't know, Luke. It sounded more sarcastic than nice. Gruff wasn't all that helpful.

Student 1: S/he gave us the numbers we needed about greenhouse gas emissions.

Student 3: You're right, that's the important thing. Now we have to figure out how to get to a furniture factory.

[Student 1 taps his/her heels together three times.]

Student 3: I really don't think that'll work, [Student 1].

Student 1: It was worth a shot. A few hours ago, I didn't believe in fairies either.

Student 2: [Pointing off into the distance] Is that a sign for a furniture place over there?

Luke: Looks like it says "Hank's Outdoor Furniture."

Student 3: Great, let's go see what Hank has to say about greenhouse gas emissions.

Scene 4: Hank's Outdoor Furniture
[Slide 48: Hank's Outdoor Furniture Sign]

[Hank, a woman, is sanding a chair down when Luke and the students approach.]

Luke: [To Hank] We're looking for Hank. You know where we can find him?

Hank: I've got a pretty good idea. You're looking at her.

Luke: We don't have times for games here, lady. We're working on—

Student 2: Luke. Be nice.

Hank: Name's Henrietta, but people around here have been calling me Hank ever since I was a kid. Guess my dad wanted a son.

Luke: I see, uh, pretty name.

Student 3: We're trying to find out about the greenhouse gas emissions associated with the life cycle of outdoor furniture. We've been tracking the pine set from the pine plantation, to the mill and the pressure treating.

Hank: And now you've come to where we make the stuff.

Student 1: Do you think you can help us?

Hank: I'd be happy to. Most of the emissions at this step come from the use of power tools—saws and sanders. Then, there's the emissions that result from making the stain and finish that I put on the wood.

Student 2: Stain and finish?

Hank: To give the wood the desired color and protect it from the elements. Here are the emissions numbers [Hands Student 2 a piece of paper]. That also includes the emissions that resulted from making the stainless steel fasteners.

Student 1: How do you know those numbers too?

Hank: You're not the only ones curious about LCA.

[Slide 49: Emissions from Furniture Manufacturing]

Student 1: All right, that means we're done.

[Lucia, the LCA Wizard appears, startling the others and causing Student 1 to cower behind Luke.]

LCA Wizard: Not exactly

Student 1: [Standing up straight again] I'll never get used to that.

Student 2: We still have to figure in maintenance and disposal.

LCA Wizard: That's right. Unlike the other two sets, the wood set will require some maintenance during the time it's in use. When calculating life cycle figures, we often look at them on a per year basis. For example, if the usable lifetime of a product was 20 years, then we would divide the amount of greenhouse gases emitted during the production, upkeep, and disposal of an item by 20. The usable life is often dictated by how quickly an item will wear out.

Student 1: But [Student 2's] furniture isn't really worn out. It's just so outdated.

LCA Wizard: Yes, with things like clothing or furniture, the usable lifetime is more often a matter of taste than wear. Often, people don't change their furniture because it is no longer functional, but because they want something new.

Student 3: That may be true for personal use, but our school seems pretty comfortable with hanging onto things long after they've gone out of style.

LCA Wizard: And they should be congratulated for that. So, let's assume the usable life of this next set will be fifteen years also. To keep the surface looking good, the pine would need to be sealed at least twice over its lifetime. Here are the maintenance emissions to account for those [Hands Student 3 a slip of paper.]

Now, who's ready for another trip to the landfill? That's where we need to head for the disposal information.

[Slide 50: Emissions from Use and Maintenance]

Student 1: [To Student 2] I'm not going to ask a question this time because I'll only get—

Narrator: As the floor fell away, Luke and the students were hurtled once again through space and time.

Scene 5: Landfill
[Slide 51: Landfill]

[The Waste Manager is sitting and staring off into space when the three students, Luke, and Lucia appear in a landfill.]

Student 1: —interrupted when Lucia zaps us to the landfill.

Student 2: What were you saying?

Student 1: It doesn't matter.

Waste Manager: You're back! Welcome, welcome! It's always so good to have visitors. Nobody ever comes out here to the landfill. Most prefer not to think about what happens to the waste that they create. Are you here to talk about plastic again?

LCA Wizard: Not this time. Now they are researching wood.

Student 1: I thought that the emissions from the wood decomposing didn't need to be included in our results since the same decomposition would happen naturally with trees in a forest.

LCA Wizard: That's true, but because of the chemicals added during pressure treatment, the pressure-treated wood must be disposed of in a landfill rather than allowed to decompose under more natural conditions.

Student 2: What difference does it make, it still decomposes, right?

Waste Manager: When wood decomposes in a forest, it does so aerobically, which means that oxygen is present. The product of that aerobic decomposition is carbon dioxide. But when it decomposes in a landfill, no oxygen is present. That means it goes through what is called "anaerobic decomposition." One of the products of anaerobic decomposition is methane.

Student 3: And we've learned that methane traps more heat per mass than carbon dioxide does.

LCA Wizard: Exactly! Since the methane would not be produced outside of the landfill, we must include those methane emissions in our calculations.

Luke: [To Waste Manager] Allow me to introduce myself. Lucius Charles Anderson, Private Detective.

[Luke looks over at Student 2 for approval of his courtesy. Student 2 gives an approving nod.]

Luke: [To the Waste Manager] Are you saying that because the wood must decompose without oxygen in a landfill, some of the carbon in the wood becomes methane instead of carbon dioxide? So, the carbon dioxide emissions from this don't have to be included, but the methane emissions do. Is that right?

Waste Manager: Yes, exactly. Some of that methane is recaptured at the landfill before it ever reaches the atmosphere, but the rest must be included in your calculations. And then there are also the emissions associated with the general production and management of the landfill. Here are the numbers that include both the methane emitted from decomposition and the other emissions from running the landfill [Hands Student 2 a slip of paper.]

[Slide 52: Emissions from Disposal]

Student 1: Now are we done?

LCA Wizard: That is a fine job of identifying all the stages of the life cycle.

[Slide 53: Life Cycle Diagram]

Student 3: We still have to sum these and convert them to carbon dioxide equivalents.

LCA Wizard: And then you'll be ready to compare the three sets of furniture.

[Slide 54: Total Emissions]

Student 2: But we need ten sets of furniture to fill up the outdoor eating area. So, if we want to know the total emissions, we need to multiply each of these values by ten.

Luke: I suppose that finishes things up for me.

Student 1: How much do we owe you?

Luke: Don't worry about that. I've learned a lot on this case.

Student 3: That's true for all of us, I guess. We learned more about global climate change, and we also learned how to perform life cycle assessments.

Student 2: I'll never be able to look at a product again without thinking about the raw materials and energy requirements for making it, using it, and getting rid of it.

Student 1: I never realized that something as boring as outdoor dining furniture could involve so many different people and places.

Luke: That's all true, but I was referring more to what [Student 2] taught me. I've also learned that being mean and tough with people is only appropriate some of the time.

Student 2: That's not quite what I meant, Detective Luke, but I suppose it's progress.

Narrator: With that, Lucia, the LCA Wizard zapped Luke back to his office and the three students back to the Home and Garden Mart. There, the students made their final calculations and chose a furniture set just minutes before the store closed.

In the morning, they told Principal [Insert principal's name] about their adventures. S/He didn't believe most of it, but s/he was quite interested in what they found out about the greenhouse gas

emissions.

Which furniture do you think they bought?

[Slide 55: The End]

[Slide 56: Comparison of Emissions]