ESTIMATING MANUFACTURING COSTS FOR PRE-COMMERCIAL TECHNOLOGIES

A tutorial from the U.S. Department of Energy (DOE)

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Estimating Manufacturing Costs for Pre-Commercial Technologies

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Welcome to DOE's video tutorial series on cost and environmental impact analysis for manufacturing technologies!

Heather

In this module, we will:

- Describe techniques for estimating manufacturing costs, focusing on methods that can be used to support techno-economic analysis of early-stage technologies.
- Demonstrate the techniques by working through an example.

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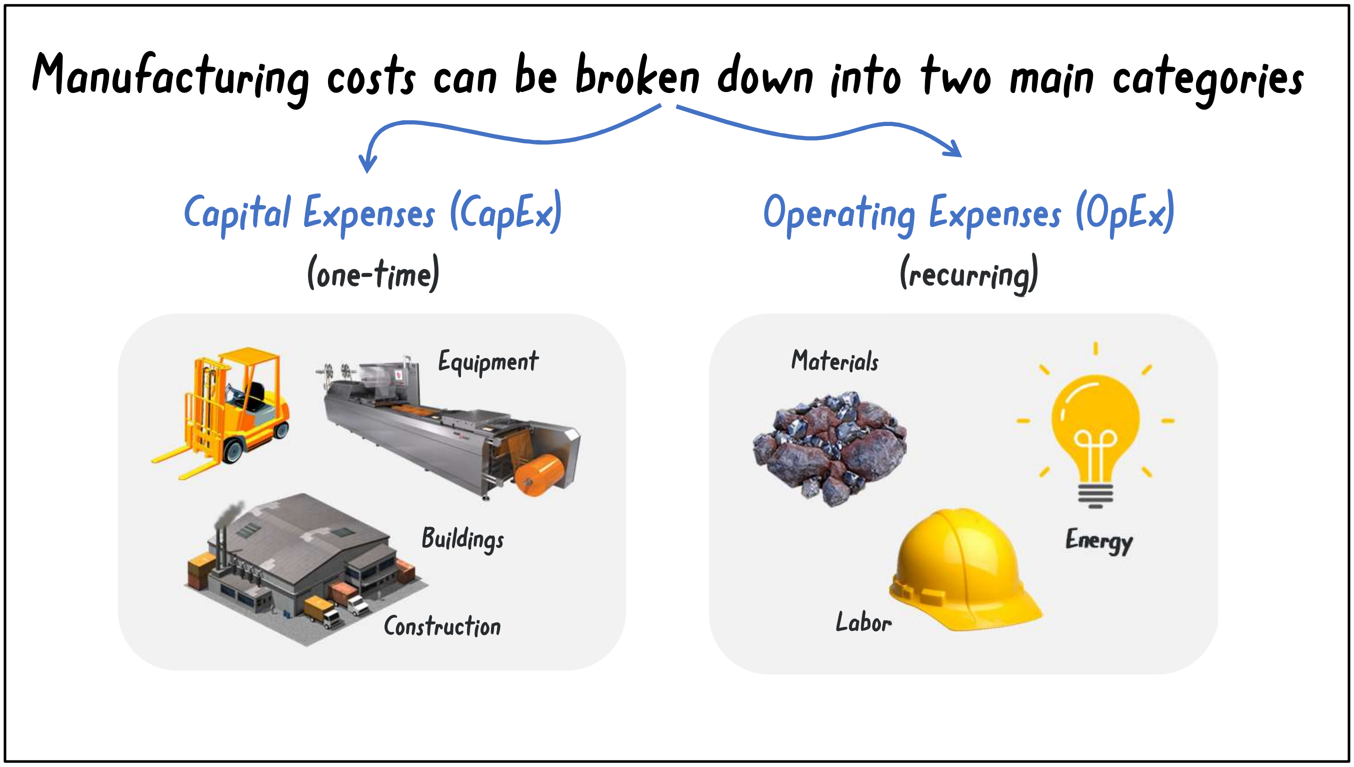
I'm Heather.

In this module, we will:

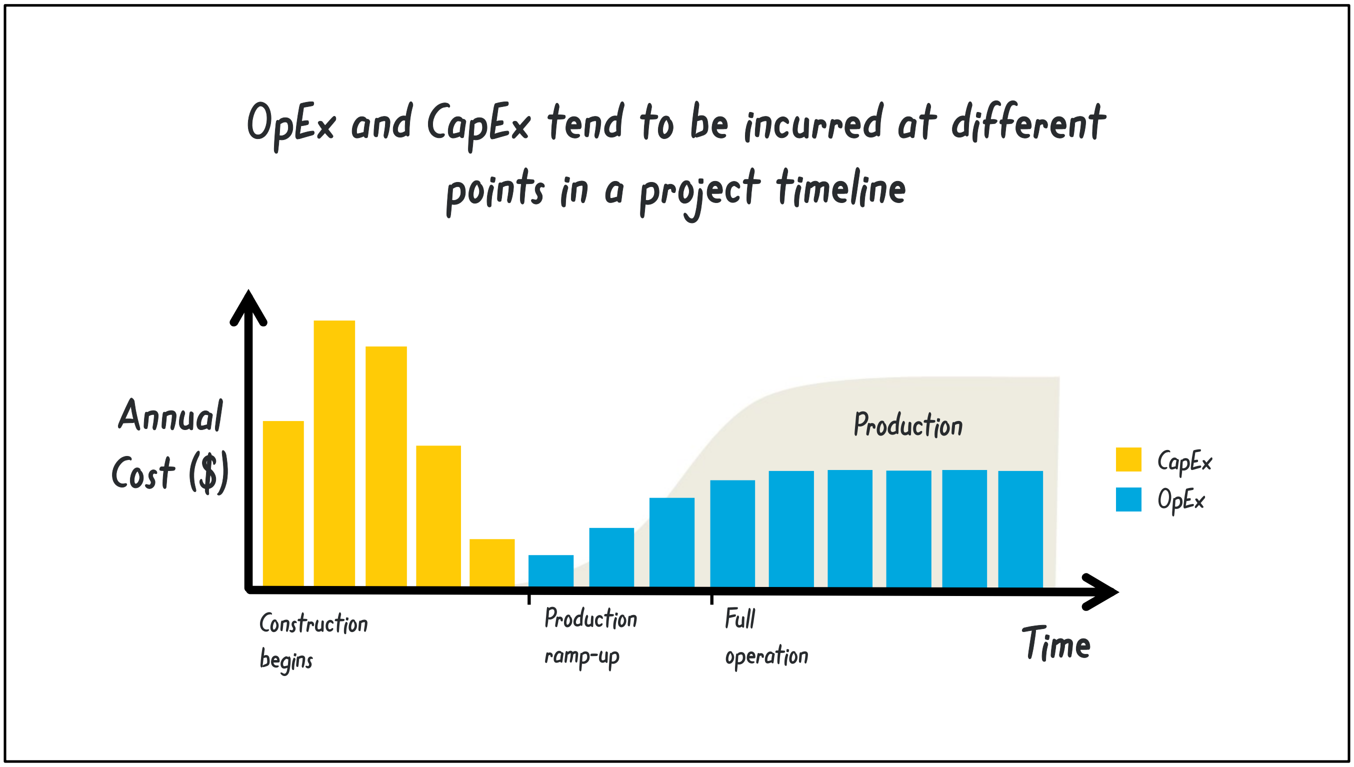
- Describe techniques for estimating manufacturing costs - focusing on methods that can be used to support techno-economic analysis of early-stage technologies.
- Demonstrate the techniques by working through an example.



As we saw in the Introduction to TEA video, manufacturing costs can be broken down into two main categories: capital expenses and operating expenses.

Capital expenses are one-time facility costs, such as equipment, buildings and construction.

Operating expenses are recurring costs, such as materials, labor, and energy.

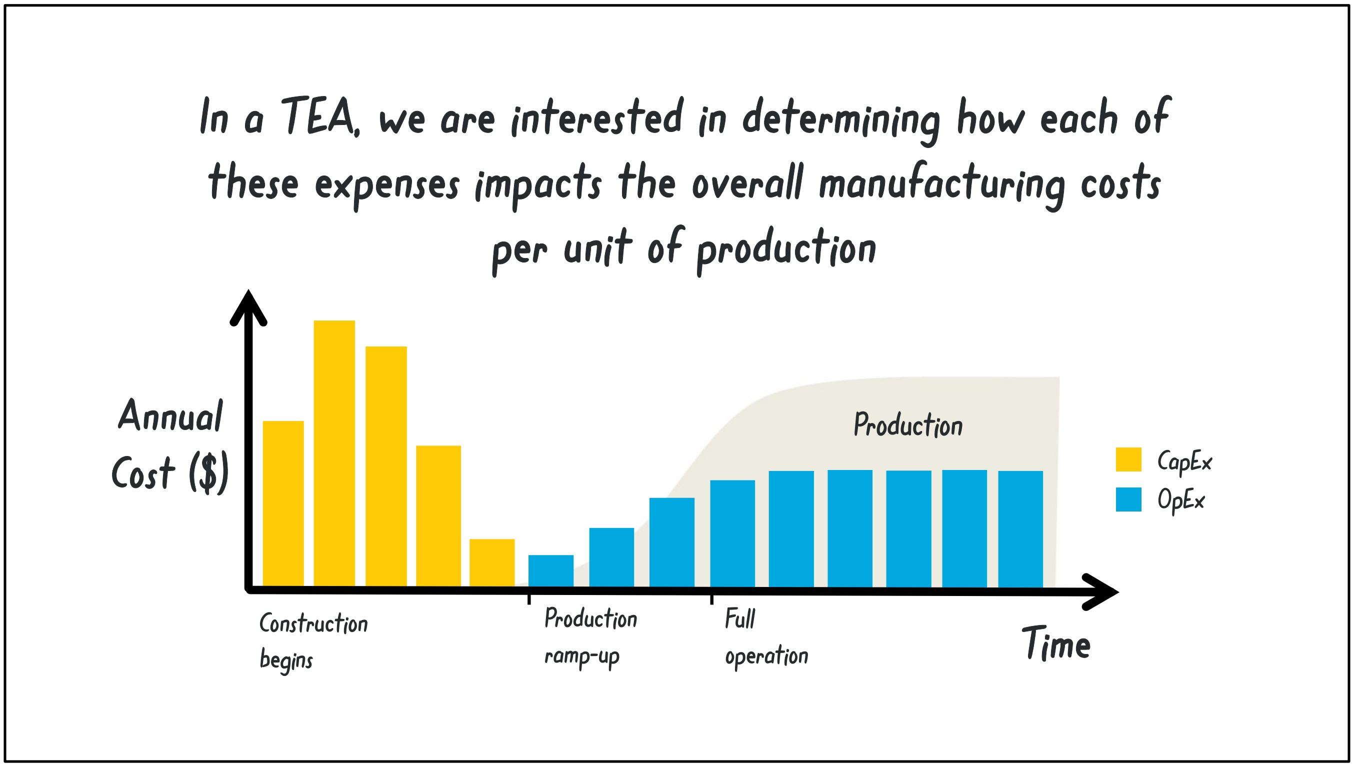


OpEx and CapEx tend to be incurred at different points in a project timeline.

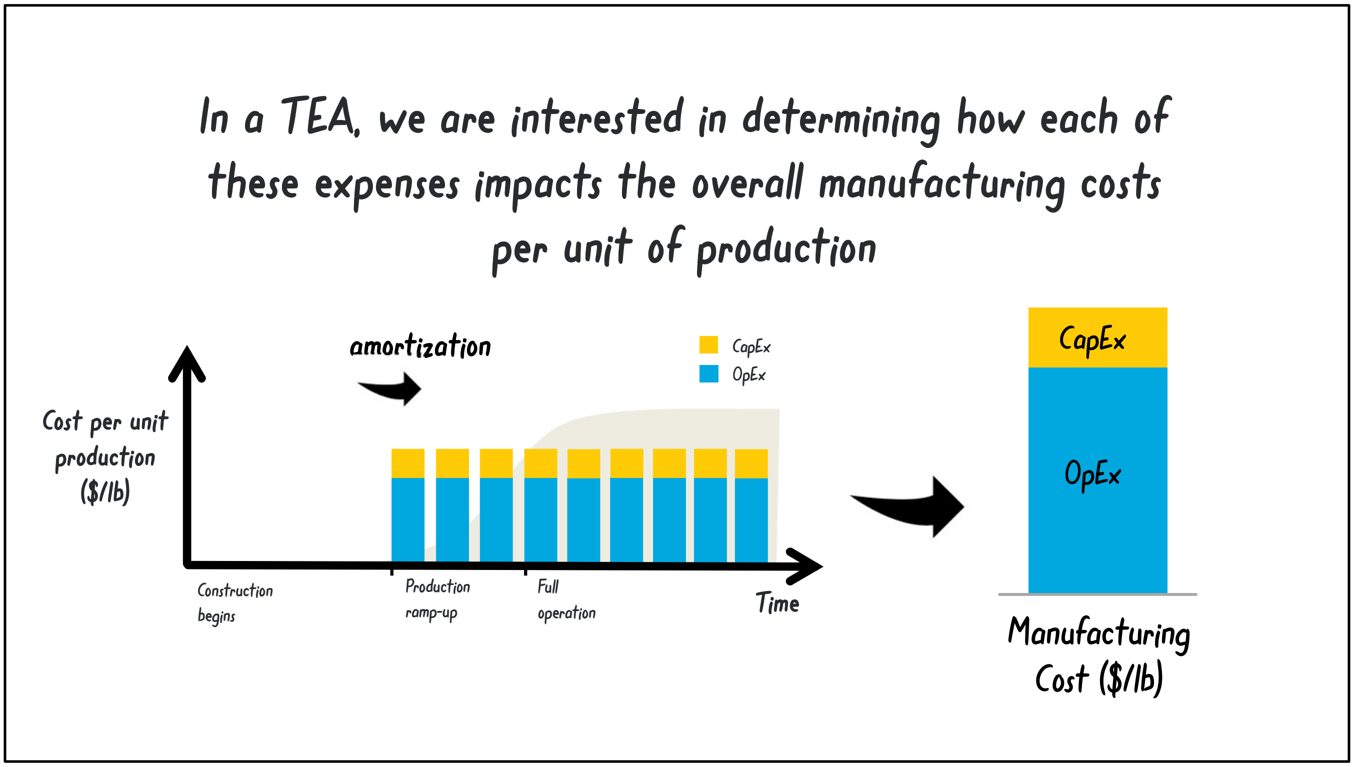
Consider the establishment of a new manufacturing line.

Capital expenses, such as costs to construct or upgrade the facility and purchase new equipment, tend to be concentrated early-on. Many of these costs will be incurred before production can begin.

Meanwhile, operating expenses, such as labor and materials, will begin to accrue as manufacturing ramps up in earnest



In a TEA, we are interested in determining how each of these expenses impacts the overall manufacturing cost per unit of production.



To calculate this, we'll amortize the capital expenses over the manufacturing production associated with the capital assets. By amortizing these costs, CapEx can be expressed as a cost per unit of production – just like OpEx.

CAPITAL EXPENSE ESTIMATION

$$\text{CapEx} = \frac{\text{Purchase Price}}{\text{Useful Lifetime}} \times \frac{1}{\text{Annual Production}}$$

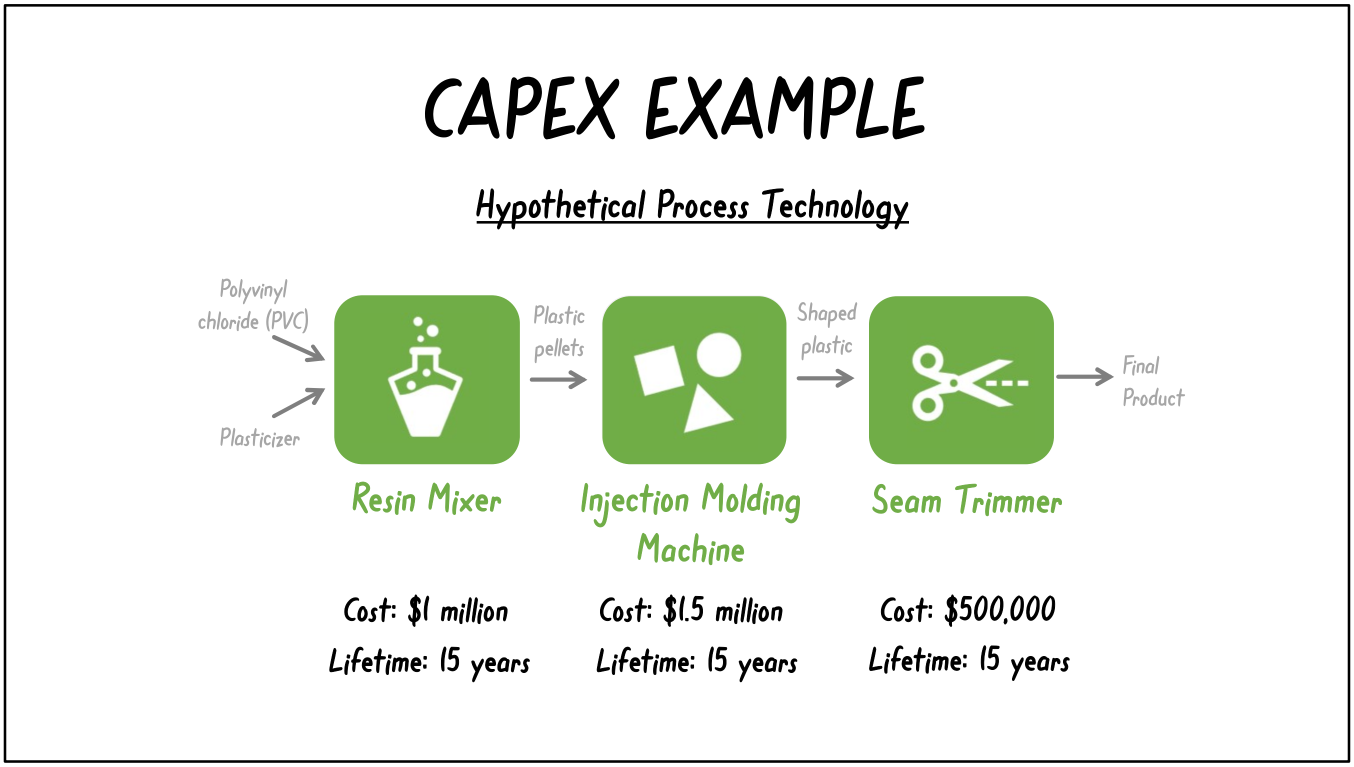
Purchase price, including installation and interest

Useful lifetime of the capital asset, in years

Average annual production volume over the asset's useful lifetime

Let's take a closer look at capital expense estimation for a major capital asset.

To amortize the cost of this asset, the purchase price (including installation and interest, if financed) is divided by the asset's useful lifetime. This gives us its annual cost, where the one-time expense is distributed evenly over the asset's lifetime. Then, to amortize by production, we divide this cost by the average annual production volume over the asset's useful lifetime. This gives us the cost of this asset per unit of production.



As an example, let's consider a hypothetical process technology that includes three pieces of major capital equipment: a resin mixer, an injection molding machine, and a seam trimmer.

At full industrial scale, and including the costs of installation and financing, the purchase price of the resin mixer is $1 million; the purchase price of the injection molding machine is $1.5 million; and the purchase price of the seam trimmer is $500,000. All three assets have an expected useful lifetime of 15 years in service.

Capital Expense	Purchase Price	Expected Lifetime
Resin Mixer	$1 million	15 years
Injection Molder	$1.5 million	15 years
Seam trimmer	$500,000	15 years

$3 million / 15 years = $200,000/year

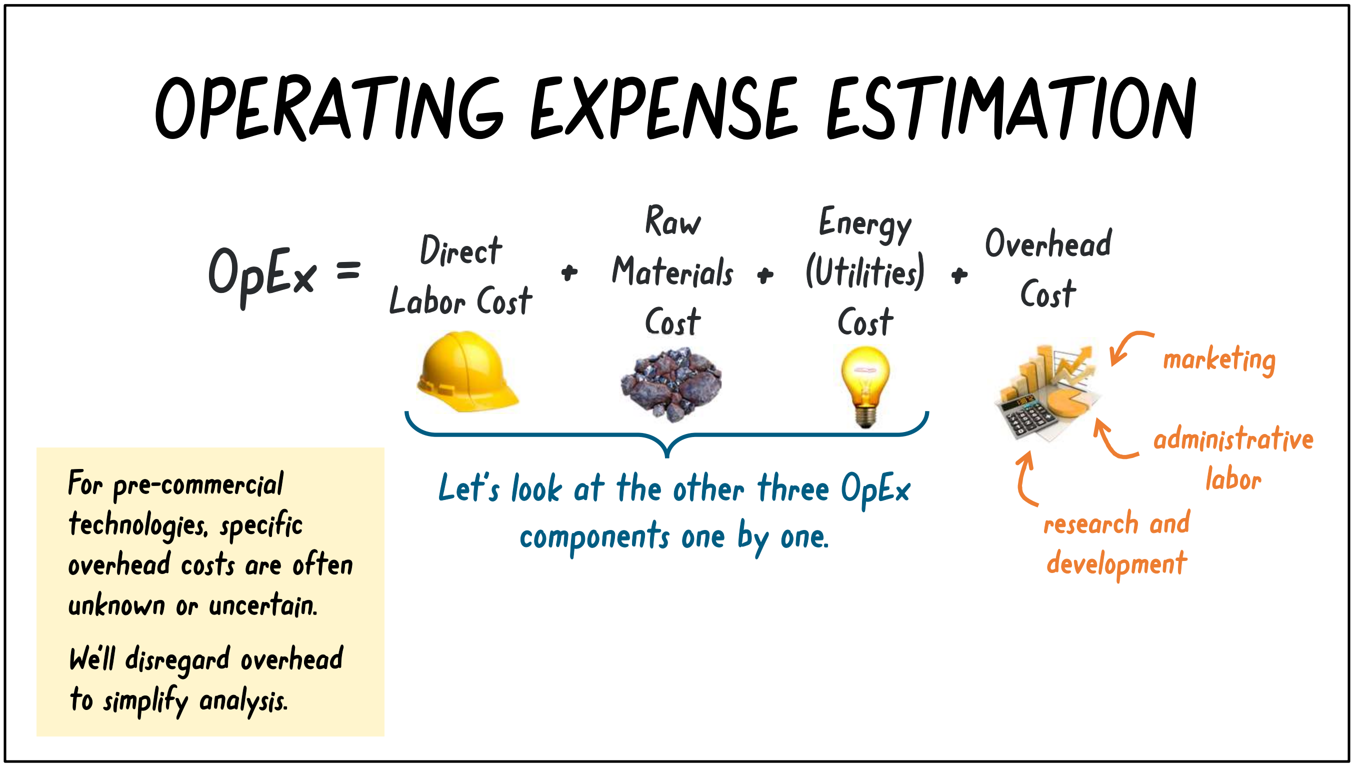
Annual production: 2 million lb per year

$$\text{Total CapEx} = \frac{\$200{,}000}{2{,}000{,}000 \text{ lb}} = \$0.10/\text{lb}$$

To calculate the capital expenses for this example, we'll apply our simple CapEx formula. Dividing the total asset costs by the expected service life, the total amortized cost of the three capital assets is $200,000 per year.

We know that the annual production for this facility is 2 million pounds.

Dividing the annual cost by the annual production, we find that the total CapEx for this technology is 10 cents per pound.



Now that we've calculated CapEx, let's look at the operating expenses. OpEx is made up of the recurring costs associated with a manufacturing operation, including:

- direct labor cost,
- raw materials cost,
- energy cost, and
- overhead cost.

Overhead can include costs like administrative labor, marketing, and R&D. For pre-commercial technologies, specific overhead costs are often unknown or uncertain. Overhead costs are not typically a major discriminator in cost comparisons of competing technologies. We'll disregard overhead to simplify this analysis.

Let's look at the other three OpEx components one by one – starting with direct labor.

Direct Labor Cost:

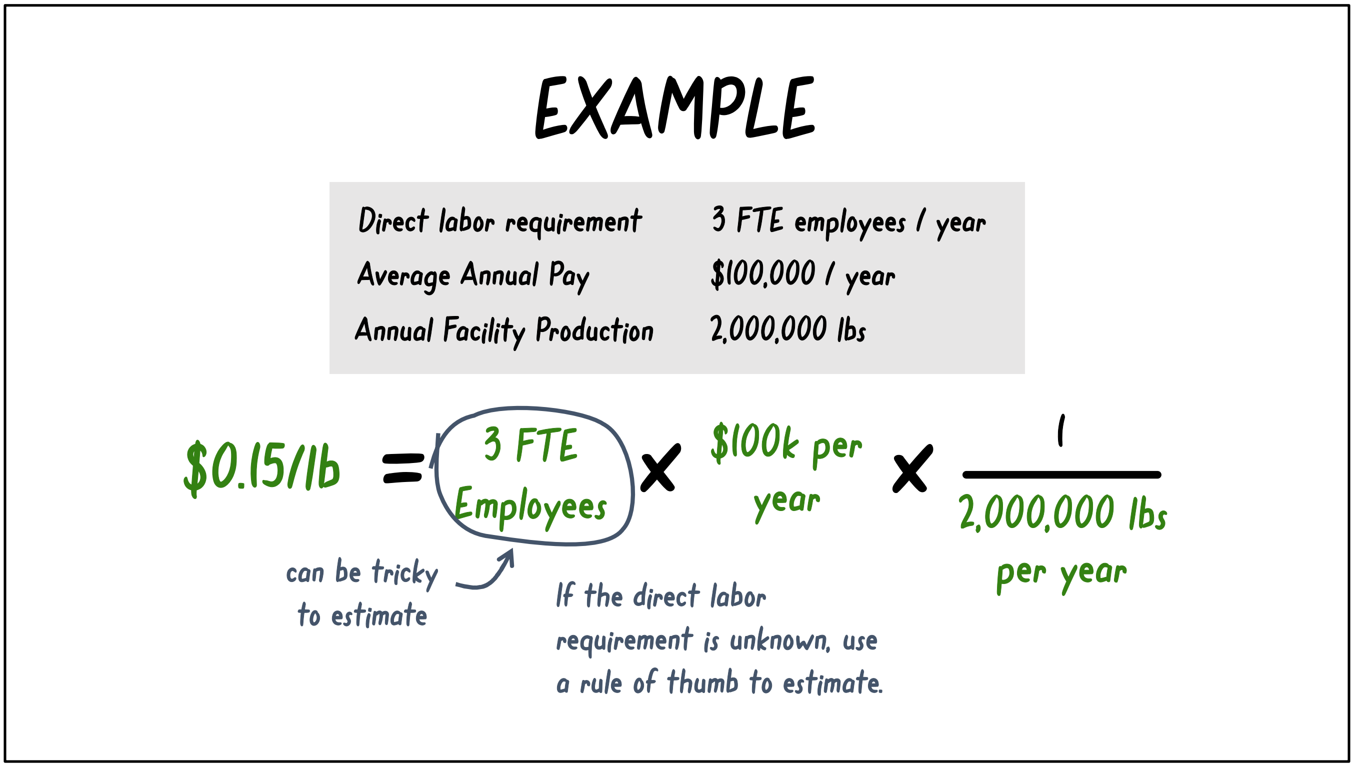
wages paid to equipment operators and supervisors

$$\text{Direct Labor Cost} = \#\text{ of FTE* Employees} \times \text{Average Annual Pay} \times \frac{1}{\text{Annual Production}}$$

*FTE = full-time-equivalent

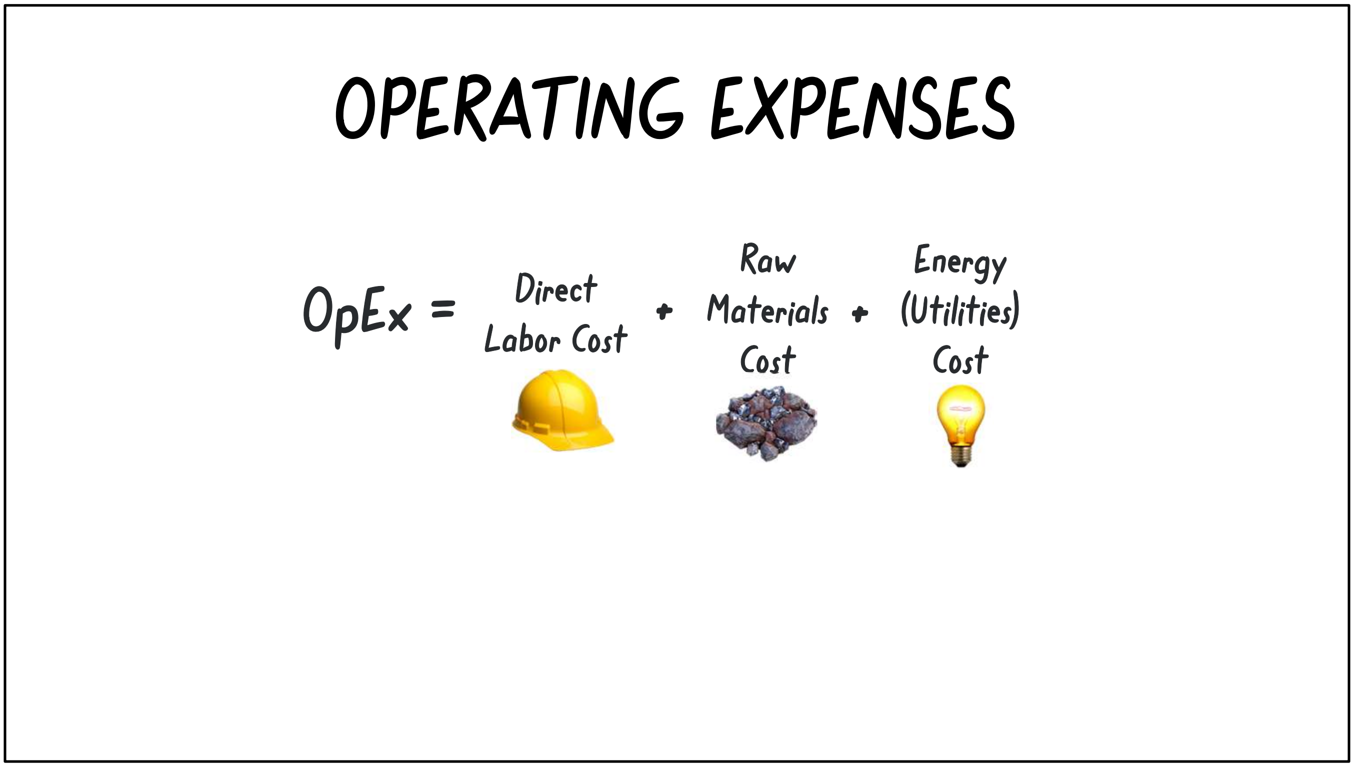
Direct labor includes wages paid to equipment operators and supervisors.

We calculate the direct labor cost by multiplying the number of full-time-equivalent employees (or FTE’s) by their average annual pay rate, including employee benefits. This gives us an annual cost. We can divide this by the annual production of the facility to calculate the direct labor cost per unit of production.

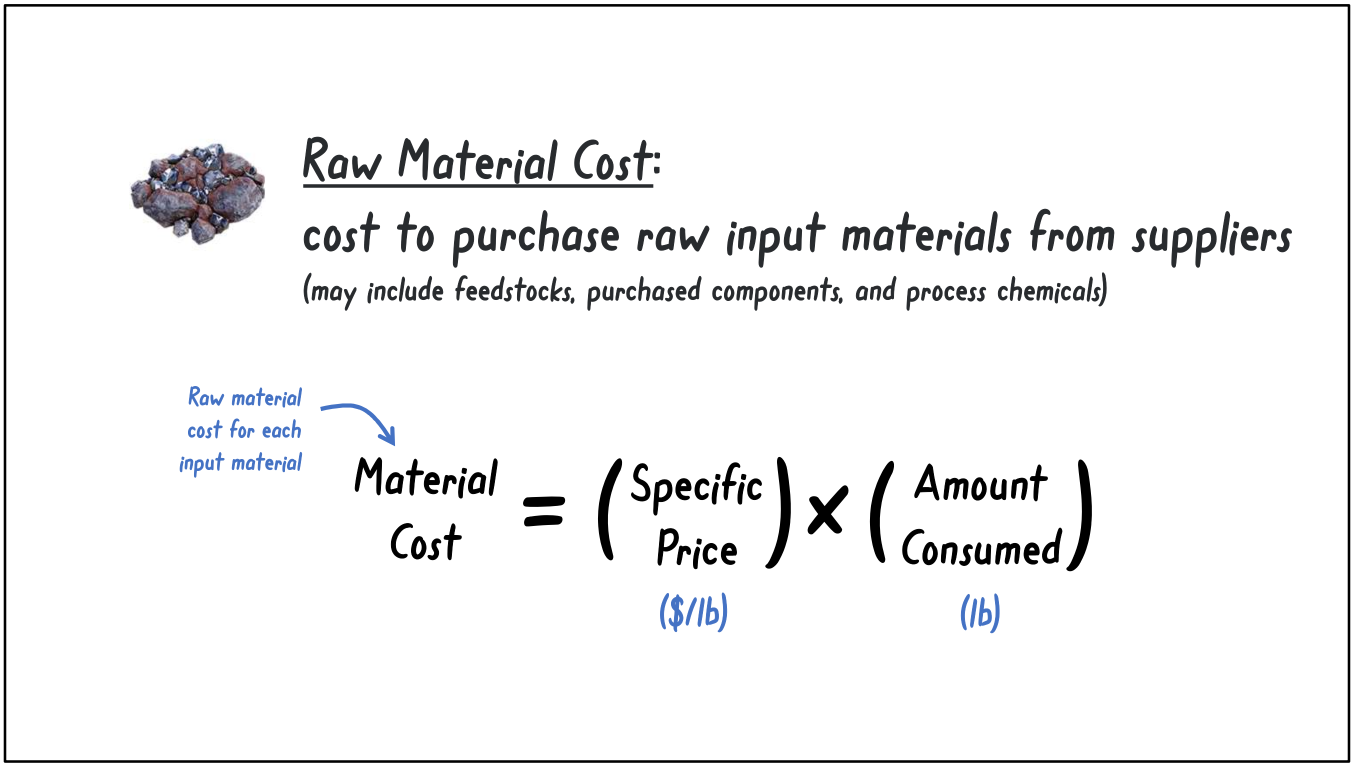


Returning to our example, let's say that we've estimated a direct labor requirement of 3 FTE employees per year for our technology. We'll assume an average annual pay rate of $100,000 per year including benefits, amounting to an annual labor cost of $300,000 per year. Dividing this by our annual production volume of 2 million pounds, the direct labor cost for this technology is 15 cents per pound.

For some technologies, it may not be obvious how many direct labor employees may be needed. If the direct labor requirement is unknown, you can use a rule of thumb to estimate it. Our team has created an Excel-based labor cost estimation tool as an example of a "rule of thumb" approach for estimating labor requirements based on process type and complexity. It is included as a resource accompanying this video.



Next, we’ll look at raw materials.



Raw material costs are the costs to purchase input materials from suppliers. This may include feedstocks, purchased components, and process chemicals.

Estimation of these costs is generally straight-forward. The raw material cost for each input material is the product of

the specific price of the material and the total amount consumed.

EXAMPLE

Bill of Materials (BOM)

Material	Specific Price	Amount
Polyvinyl chloride (PVC)	$1.50/lb	1.10 lb
Plasticizer	$10.00/lb	0.01 lb

PVC: $1.50 x 1.10 = $1.65
Plasticizer: $10.00 x 0.01 = $0.10

} Total Raw Material Cost: $1.75/lb

As an example, here is a sample Bill of Materials (or BOM) for a manufacturing process.

The BOM is the list of raw material inputs required to produce the finished product.

First, we compute the cost of each individual material by taking the product of the specific price and amount. Then, we sum the costs to find the total raw material cost.

OPERATING EXPENSES

OpEx = Direct Labor Cost + Raw Materials Cost + Energy (Utilities) Cost

Finally, let’s take a look at energy costs.

Energy Costs:

Costs to purchase energy (usually from utility providers) for process and non-process uses

Energy cost (for each source of energy used)

$$\text{Energy Cost} = \left(\text{Energy Price}\right) \times \left(\text{Amount Consumed}\right)$$

Energy Price: ($/unit) Amount Consumed: (units)

Energy costs are the costs to purchase energy, usually from utility providers, for process and non-process uses at the manufacturing facility.

Similar to the material cost calculation, the energy cost is the product of the energy price and the amount of energy consumed.

EXAMPLE

Energy Expenses

Energy Source	Energy Price	Amount
Electricity	$0.07/kWh	0.10 kWh
Natural Gas	$0.004/cf	0.05 cf

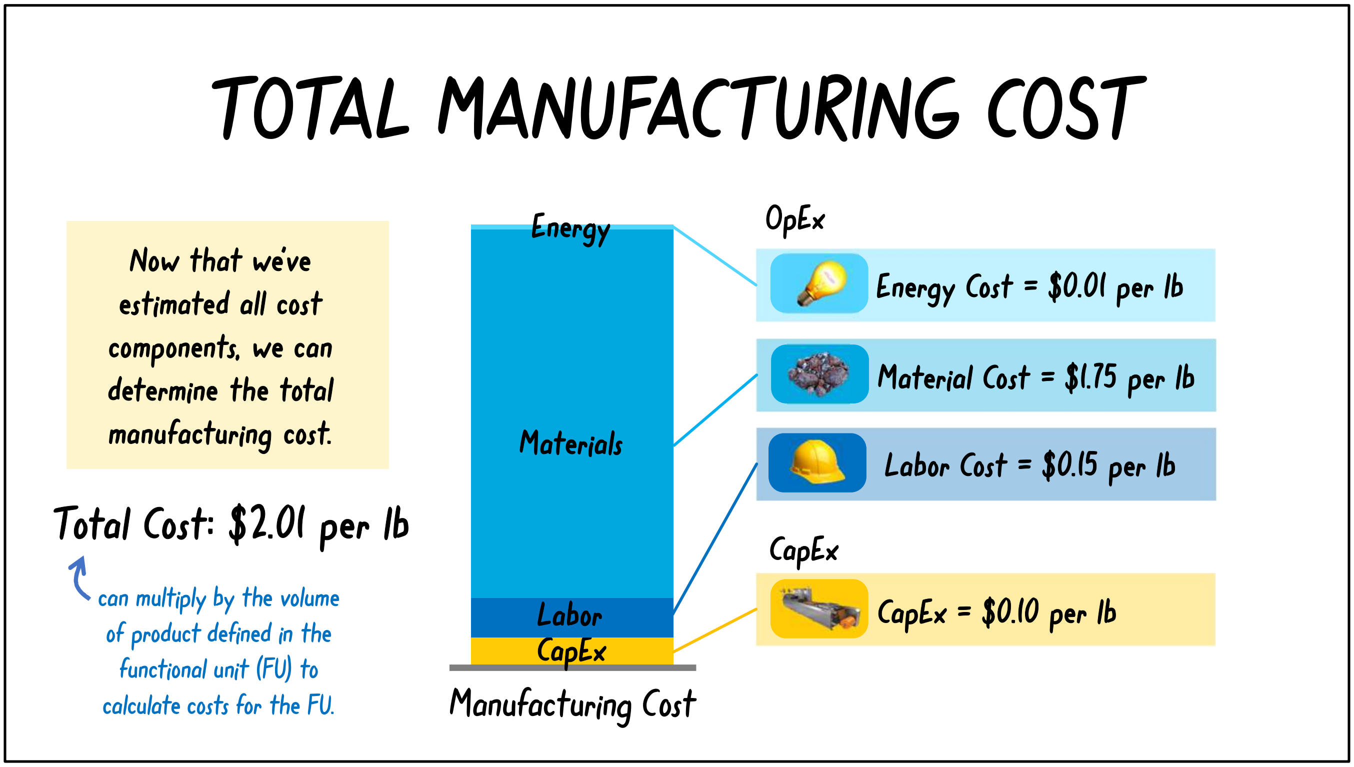
Electricity: $0.07 x 0.10 = $0.007
Natural Gas: $0.004 x 1.0 = $0.004

Total Energy Cost: $0.011/lb

For the U.S., the Energy Information Administration's Monthly Energy Review is a good source of current energy price information.

For example, let's say our manufacturing process consumes electricity and natural gas.

First, we compute the cost of electricity and natural gas individually; then we sum the costs to find the total energy cost per unit of production. For the U.S., the Energy Information Administration's Monthly Energy Review (found at https://www.eia.gov/totalenergy/data/browser/?tbl=T09.08#/?f=M) is a good source of current energy price information.



Now that we've estimated all cost components, we can determine the total manufacturing cost.

Returning to our example, we will take the sum of the non-recurring CapEx, plus OpEx including labor, materials, and energy. Summing these costs gives us the total estimated cost to manufacture a pound of product with this technology at industrial scale.

We can multiply this by the volume of product defined in our functional unit to calculate costs for the functional unit. As discussed in our tutorial on functional units, the use of a functional unit enables "apples to apples" comparisons between technologies.

Thanks for watching!

In this video, we discussed techniques for estimating manufacturing costs, including OpEx and CapEx.

For more information on tools and techniques for cost and environmental impact analysis, please check out our other videos!

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