

DEFINING FUNCTIONAL UNITS FOR LCA AND TEA

produced by the DOE Advanced Manufacturing Office (AMO)



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



Defining Functional Units for LCA and TEA

A tutorial produced by the DOE Advanced Manufacturing Office.

*Welcome to the AMO video
tutorial series on cost and
environmental impact analysis!*



Heather

In this module, we will:

- *Describe the purpose of a functional unit in life cycle assessment (LCA) and techno-economic analysis (TEA)*
- *Show examples of functional units for different products and technologies*
- *Discuss considerations for selecting the best functional unit to use.*

Welcome to the AMO video tutorial series on cost and environmental impact analysis.

I'm Heather.

In this module, we will:

- Describe the purpose of a functional unit in life cycle assessment and techno-economic analysis;
- Show examples of functional units for different products and technologies; and
- Discuss considerations for selecting the best functional unit to use.

WHAT IS A FUNCTIONAL UNIT?



A functional unit describes a quantity of a product or product system on the basis of the performance it delivers in its end-use application.

- *Functional units are foundational to LCA and TEA, as they enable objective comparisons across different products or systems that serve the same final function.*
- *Since the functional unit will serve as the reference quantity throughout our analyses, we will want to choose a convenient and physically meaningful quantity with practical relevance to the final application.*

Let's begin by defining what we mean by a functional unit.

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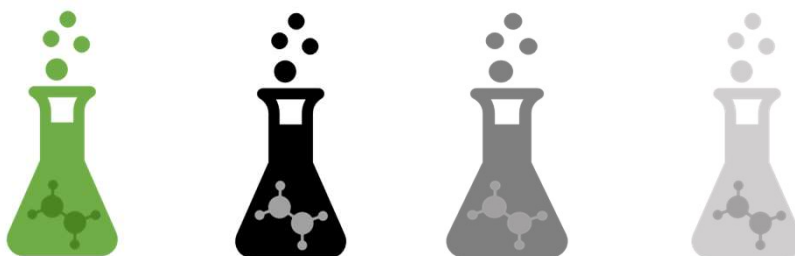
Data we collect - such as amounts of input materials, energy consumption, and manufacturing costs - will all be expressed in terms of the functional unit.

Since the functional unit will serve as the reference quantity throughout our analyses, we will want to choose a convenient and physically meaningful quantity with practical relevance to the final application.

Let's take a look at a few examples.

EXAMPLE #1

CATALYST FOR ETHYLENE MANUFACTURING



Functional Unit: ~~One ton of catalyst~~

↪ Does not account for the amount of catalyst required to produce a given quantity of ethylene

First, suppose we are analyzing a new catalyst for ethylene manufacturing. We would like to compare this new catalyst to other catalyst options. Our first step will be to identify an appropriate functional unit that will enable us to compare catalysts objectively. Let's walk through how we might think about and choose a functional unit for this example.

We know the functional unit will need to specify an unambiguous quantity of catalyst. This catalyst is typically measured in units of tons, so we might think to start with one ton of catalyst.

However, something is missing. This functional unit does not capture the performance of the catalyst. We don't know that one ton of this catalyst will be directly comparable to one ton of other catalyst options. Specifically, this mass-based quantity does not account for the amount of catalyst required to produce a given quantity of ethylene.

So this won't be a suitable functional unit as it's written.

EXAMPLE #1

CATALYST FOR ETHYLENE MANUFACTURING



Functional Unit: *The quantity of catalyst (in tons)
required to manufacture one
million tons of ethylene*

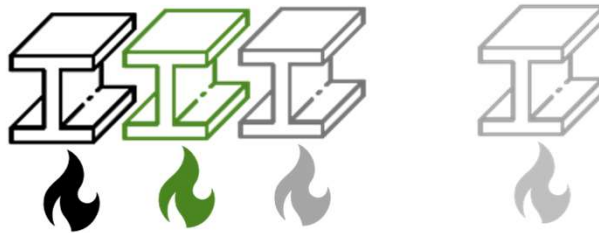


To properly account for this catalyst's performance, the functional unit should account for performance factors like the catalyst's longevity before it needs to be replaced or recharged, its selectivity, and the resulting ethylene yield. A functional unit that captures these attributes is the quantity of catalyst, in tons, required to manufacture 1 million tons of ethylene.

Now we have a functional unit that is interchangeable across catalysts – even if they have dissimilar properties or different lifetimes. We can use this functional unit as a reference quantity to compare catalysts objectively in terms of cost, environmental impacts, or other metrics.

EXAMPLE #2

MATERIAL PROCESSING TECHNIQUE FOR AUTOMOTIVE STEEL



Functional Unit: *The amount of steel, in pounds, needed to produce an automotive B-pillar that meets all relevant structural and safety requirements over a vehicle lifetime of 200,000 miles traveled.*



Let's try another example. Imagine we are analyzing a new material processing technique for automotive steel. This new technique enhances the strength of the steel, which will be used in lightweight vehicles. We'd like to be able to compare the high strength steel produced using this technique to other lightweight materials. steel produced using conventional methods.

To do this correctly, we'll need to consider design constraints for an automotive application of interest. In this case, let's say we're comparing materials for an automotive B pillar.

In this example, a good choice for the functional unit could be the amount of steel, in pounds, needed to produce an automotive B-pillar that meets all relevant structural and safety requirements over a vehicle lifetime of 200,000 miles traveled.

Notice that functional units are application specific! If we decide to consider this material for a different application, benefits and tradeoffs will likely shift – so if we change the application, we'd need to update our functional unit, even if the materials we're considering remain the same.

EXAMPLE #3

SORBENT FOR CARBON CAPTURE



Functional Unit: *The amount of sorbent material, in pounds, needed to capture one million tons of CO₂ per year from a flue gas stream containing 5% CO₂.*



Let's try another.

Consider a sorbent for carbon capture that will be used to capture carbon dioxide from a waste gas stream at a manufacturing facility.

We would like to be able to compare a new sorbent material to other sorbent options.

To do this, it makes sense to think about this sorbent's performance in terms of the quantity of CO₂ captured – taking into account the sorbent's lifetime and regeneration process. This will allow us to compare the new technology across a wide range of carbon capture solutions, not necessarily just those in the same material family as this one.

For this example, our functional unit could be the amount of sorbent material, in pounds, needed to capture one million tons of CO₂ per year from a flue gas stream containing 5% CO₂ by volume.

EXAMPLE #4

BATTERY FOR LAPTOP COMPUTER



Key Performance Attributes:



Energy capacity
(Watt-hours)



Charge capacity
(milliamp-hours)



Battery longevity
(years)



Battery weight
(pounds)

Let's try one more.

Imagine we are interested in comparing different battery technologies for a laptop computer,

For a laptop battery, performance attributes we may care about include energy capacity (Watt-hours), electric charge capacity (milliamp-hours), longevity of the battery (years), or even the battery's weight (pounds). We'll want to integrate into our functional unit those factors that we think are essential for an apples-to-apples comparison across batteries. In our case, perhaps we think the charge capacity and overall longevity are the most important.

EXAMPLE #4

BATTERY FOR LAPTOP COMPUTER



Functional Unit: *A battery sized to provide 5,000 mAh of capacity over a minimum service life of four years of daily use*



Additional performance consideration: battery weight

We might write our functional unit as a battery sized to provide 5,000 milliamp hours of capacity over a minimum service life of four years of daily use.

If there are additional noteworthy tradeoffs between battery systems not captured in this functional unit – battery weight, for example – we can always note those separately as additional considerations.

FUNCTIONAL UNIT ATTRIBUTES

A good functional unit is:



*Quantitative
and precise*



*Expressed in terms of
application-specific
performance requirements*



*Defined broadly
enough to encompass
competing technologies*

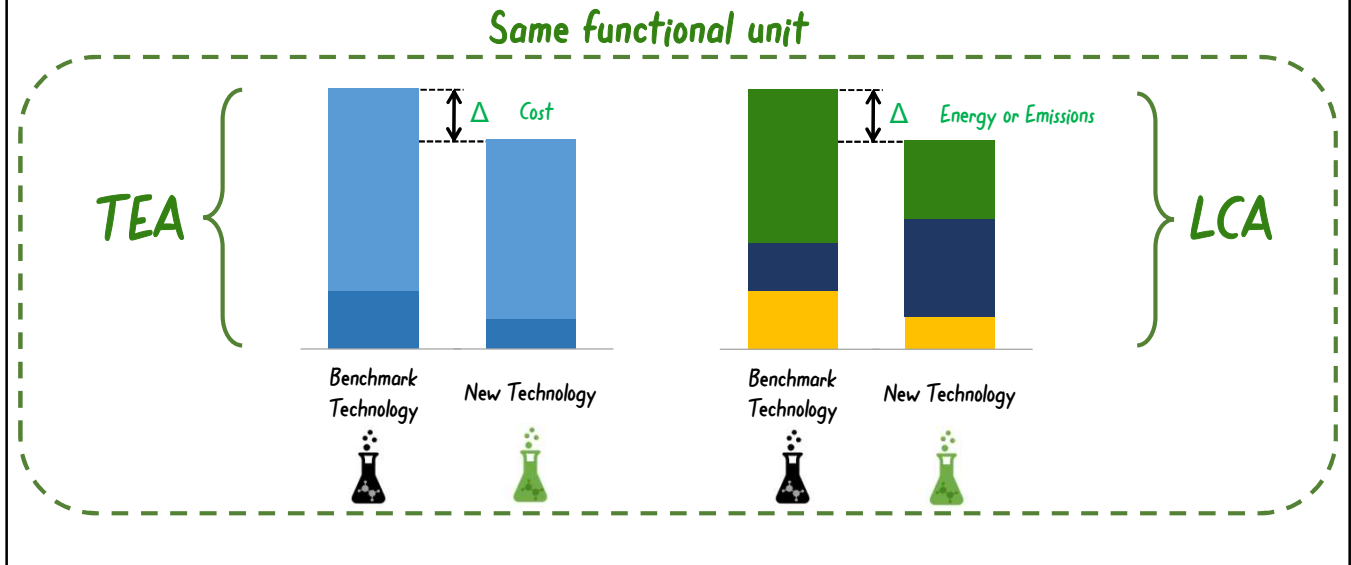
Functional units enable objective comparisons across disparate products and technologies.

As we've seen in these examples, functional units share a few key attributes that we can highlight here.

- A good functional unit is quantitative and precise. It should specify an unambiguous amount of a product.
- Second, it should be expressed in terms of application-specific performance requirements.
- And finally, the functional unit should be defined broadly enough to encompass competing technologies in the same functional unit definition.

The main advantage of using a functional unit as the basis for an analysis, rather than a reference volume or weight, is that functional units enable objective comparisons across disparate products and technologies. As a result, choosing the right functional unit is an essential first step for LCA or TEA analysis.

COMPARING TECHNOLOGIES



For any given application, we can leverage the functional unit to compare technologies:

on the basis of cost, by applying it in techno-economic analysis;

And on the basis of environmental metrics, by applying it in life cycle assessment.

Using the same functional unit for both TEA and LCA allows us to generate an integrated, holistic assessment of potential cost and environmental impacts for a technology.

*Thanks for
watching!*

In this module, we discussed things to consider when choosing a suitable functional unit for LCA and TEA analysis.

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



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