Agricultural Sciences
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Life Cycle Assessment

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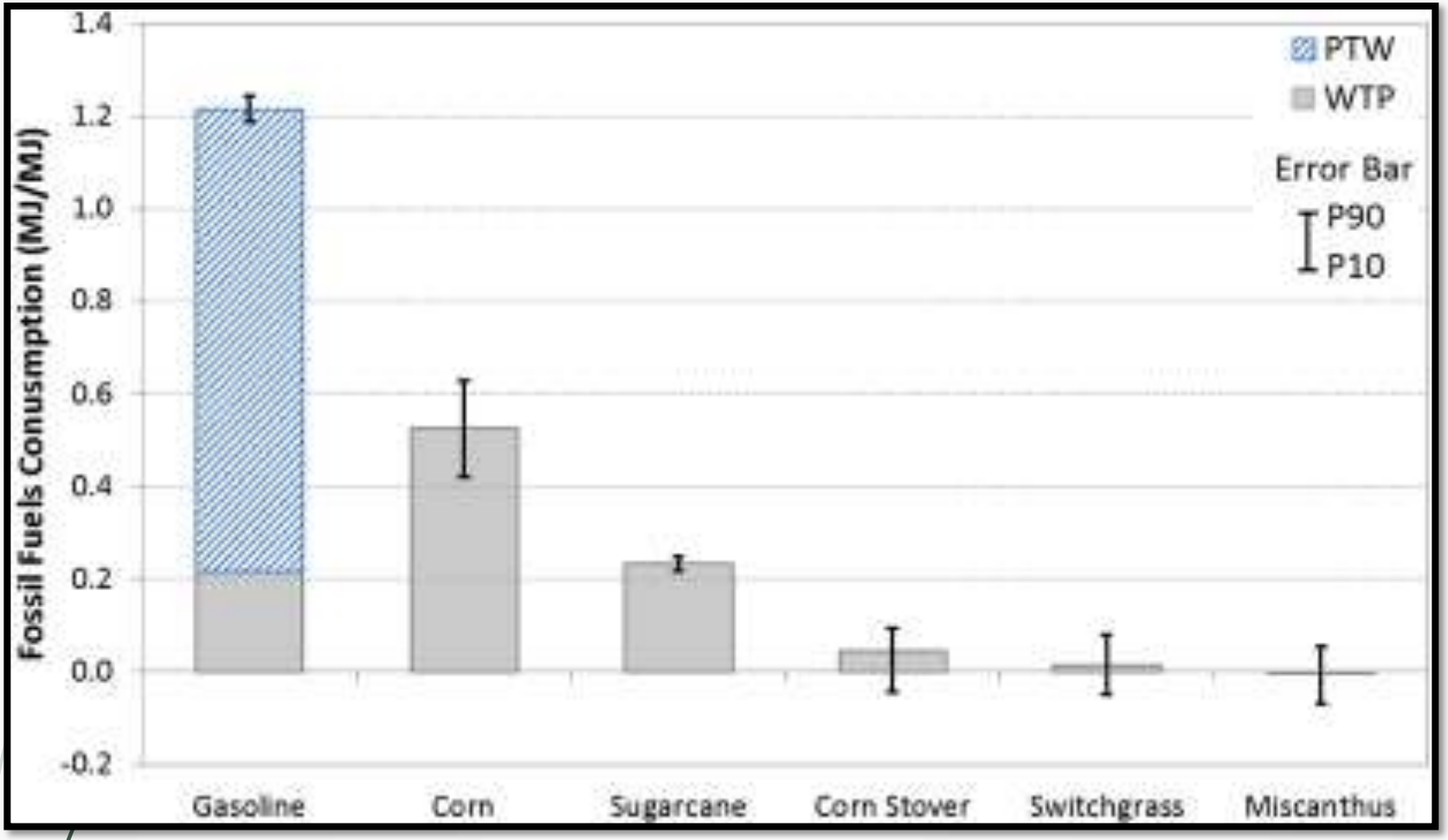
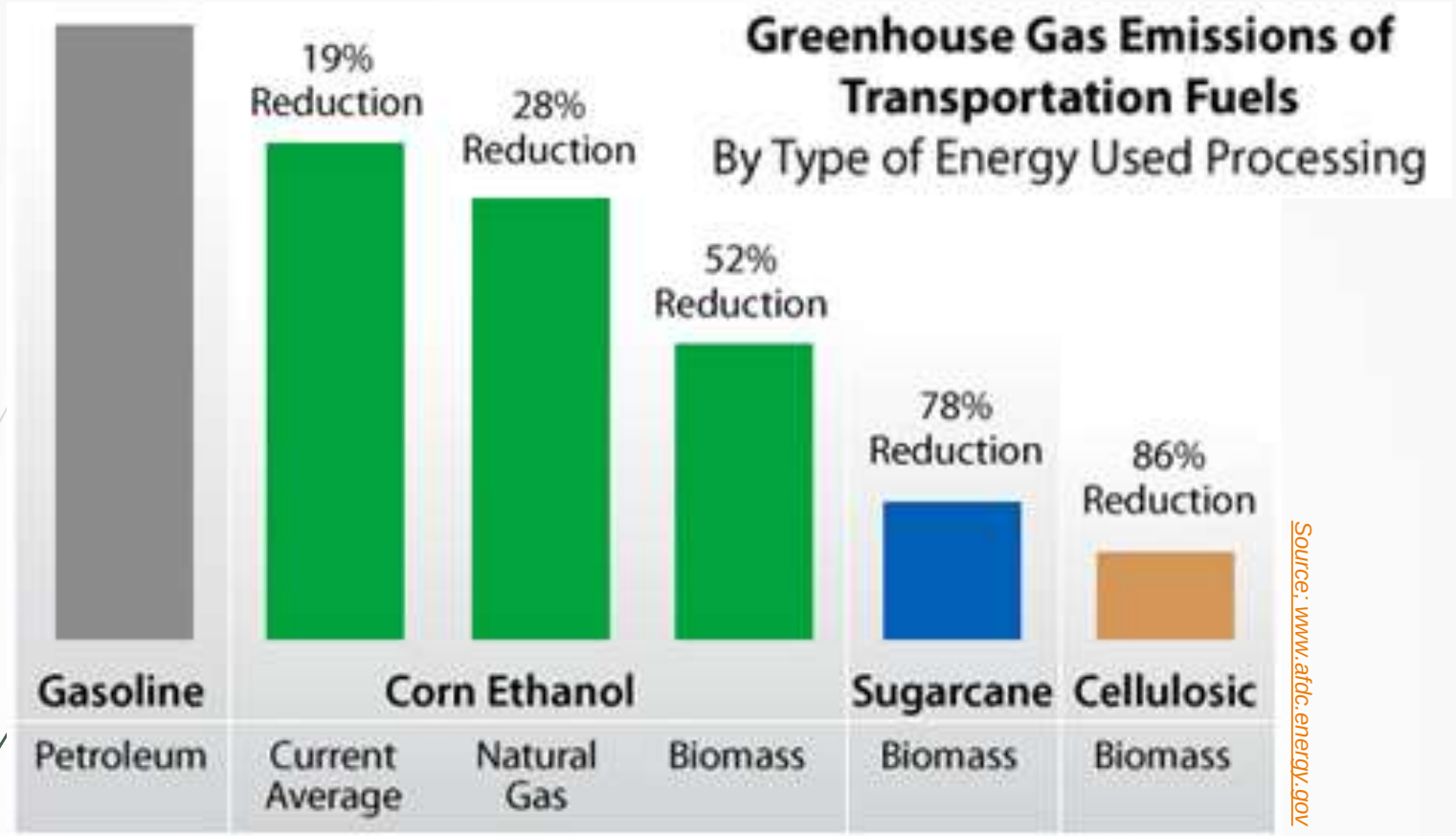
Sustainable Fuels

- **When assessing a fuel, one of the main considerations is whether or not that fuel is sustainable.**
  - A sustainable fuel is one that can be used for long periods of time in such a way that it satisfies human needs without compromising the ability to use it or other resources.
- **Fossil fuels are not sustainable fuels because…**
  - Fossil fuels are limited in supply, and most supplies that are affordable and easily accessible will run out within our lifetimes.
  - Fossil fuels will continue to rise in price as easily accessible supplies of fossil fuels become more limited.
  - Fossil fuels compromise our ability to enjoy and utilize other resources due to their impact on the environment, particularly in regards to the byproducts of their use, including CO_2, mercury, lead, and methane emissions.
  - The use of fossil fuels is associated with an increased risk to devastating environmental and health disasters, with examples that include Exxon Valdez in Alaska and Deep Water Horizon in the Gulf of Mexico.
  - From the point of acquisition to the point of use, fossil fuels are inefficient; e.g. gasoline requires 1.2 units of energy for every 1 unit of energy produced.



- **One of the main concerns of the use of fossil fuels is the amount of fossil fuels it takes to make fossil fuels.**
  - For every gallon of gasoline produced, it takes the energy equivalent of over 1.2 gallons of gasoline to produce it.
  - This means that the product of petroleum products is a losing battle – the more produced, the more fossil fuels that are needed.

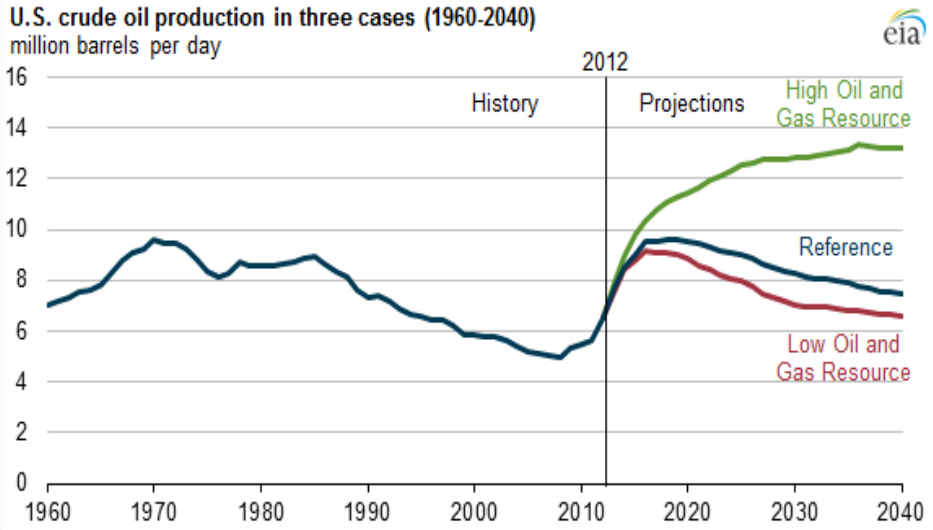
Source: http://iopscience.iop.org/1748-9326/7/4/045905/article



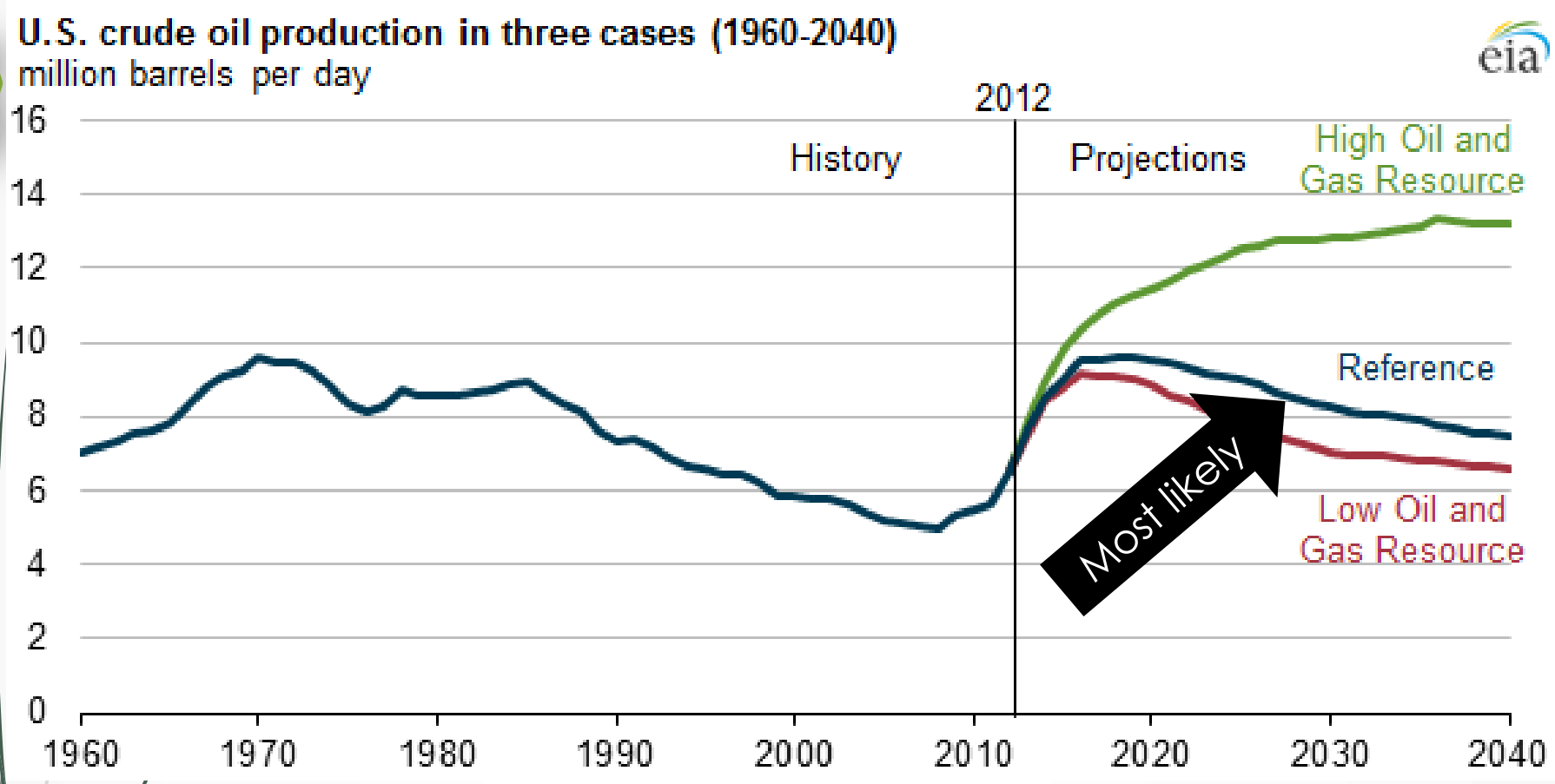
- **Another main concern is the release of greenhouse gases due to the use of petroleum fuels.**
  - Global greenhouse gas emissions would have to be reduced by 50-85% from the levels they had in 2000 by 2050 in order to keep global CO_2 levels beneath 400 ppm.
  - Failure to keep CO_2 levels under 400 ppm could have devastating effects, including unprecedented levels of flooding, drought, and damaging weather events that could permanently alter agriculture, the economy, and civilization (climate.nasa.gov/effects)

Supply of Oil

- **With recent discoveries of shale oil reserves, the supply of oil seems unexpectedly plentiful, and prices have had a general downward trend.**
  - Shale oil is oil that was previously inaccessible to drilling because it trapped in rock formations.
  - Using hydraulic fracturing, or fracking, the rock is broken by highly-pressurized liquid to enable supplies of natural gas to escape and be collected to be used as natural gas fuel.
- **Because of large supplies of shale oil in North America and due to advancements in fracking, the US is now one of the leading producers of fossil fuels.**
  - However, most projections of the US Energy Information Administration project that supplies of shale oil will peak by 2020.
  - This means that this supply of fuel is not a compete or long-term solution to US- or global-energy needs.
  - By 2040, supplies of this fuel will likely return to levels only somewhat greater than a decade ago.



Source: http://www.eia.gov/todayinenergy/detail.cfm?id=15731



- **This graph shows the estimated projects of the US Energy Information Administration.**
  - The reference line is what the EIA expects to be the most likely outcome given current trends in energy production.
  - While US oil production (led by shale oil) will show an initial surge, by 2020 the amount of shale oil will likely decline.

Shale Oil

- **Shale oil shows potential as a source of fuel because…**
  - Combustion of natural gas from shale oil tends to have lower greenhouse gas emissions than many other kinds of fossil fuels.
  - The US has a large domestic supply of shale oil deposits.
- **However, shale oil also has a number of drawbacks.**
  - Both mining and processing of oil shale cause a significant release of greenhouse gases, particularly methane gas (which is 21 times more potent as a greenhouse gas than carbon dioxide).
- **Mining and processing of oil shale often cause ecological disturbance of the mined land and can change local communities.**
  - Mining of shale oil and disposal of spent shale waste from mining impacts wildlife and air & water quality; the leaking of methane and extraction chemicals into groundwater supplies is also a common problem.
  - Shale oil production can also have significant social and economic impacts on local communities; while it can lower unemployment in the short run, it can also cause disruptions to roads, schools, and police and fire protection.
- **The large amount of water required for oil shale processing is also a concern, especially in western states facing high rates of drought.**
  - Currently, oil shale extraction and processing require several barrels of water for each barrel of oil produced (though some of the water can be recycled).

Source: http://ostseis.anl.gov/guide/oilshale/

Replacing Fossil Fuels

- **While current sources of fossil fuels (such as gasoline, diesel, and natural gas) are not considered to be sustainable, they are currently widely used because…**
  - They are a concentrated source of fuel.
  - They are available in any city.
  - They have a price that is currently affordable to most consumers.
  - They work in the vehicles most people currently drive.
  - People have used fossil fuels for so long that it is an engrained part of our culture.

Replacements for Fossil Fuels

- **To replace fossil fuels, we will need to find a fuel that is…**
  - Less expensive than fossil fuels.
  - Less harmful than fossil fuels to the environment and to human health.
  - Similar to fossil fuels in regards to engine efficiency.
  - Has a life cycle that is more efficient than fossil fuels.
  - Can be produced within the United States.
  - Able to be used in existing vehicles.
  - Able to be transported as easily as fossil fuels.
  - Able to be distributed as easily as fossil fuels (e.g. gas stations).
  - Is carbon neutral (does not increase atmospheric levels of carbon dioxide).

Three Components of Sustainability

- **More simply put, fossil fuels need to be replaced by a fuel that is more sustainable.**
  - Sustainability refers to choosing practices that allow for needs to be met without compromising future generations.
  - The use of fossil fuels is linked with problems that are only expected to worsen with continued use, including environmental degradation, climate change, threats to human health, and an increase to their cost over time.

- **Sustainability has three components – economic, ecological, and social.**
  - Ecological sustainability means that a choice will not reduce the ability of an ecosystem to provide renewable goods and services.
  - Social sustainability means that a choice will be fair, equitable, and available to all users without unnecessary or unfair lifestyle or cultural changes.
  - Economic sustainability means that a choice will not use up an unreasonable amount of a person's income or benefit one group of people at the unfair expense of another group.

Source: www.gopixpic.com

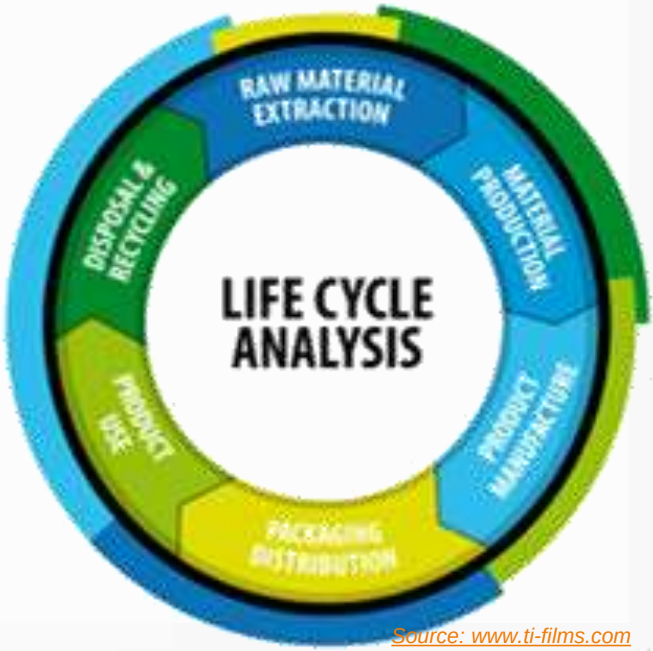
Common Themes of Sustainability

- **Common themes of sustainability include:**
  - Stewardship of Natural Resources: Human beings have a responsibility (economic, moral, and otherwise) to care for the living things around them.
  - Systems Approaches: Natural Systems exist for a reason – living species have adapted to take advantage of these systems in order to minimize the energy required for existence. Adapting to these systems increases the sustainability of a practice by reducing energy inputs.
  - Long-term Planning: Short, quick fixes are rarely sustainable. Sustainability requires foresight, planning, investment, and education,
  - Adaptation to Change: Living things change. Sustainable systems must benefit from, rather than fight, change.
  - Sustainability Must be Socially and Economically Justified: If sustainability comes at the expense of one group of people, it is not sustainable. If sustainability is not affordable to a group of people, it is not sustainable.

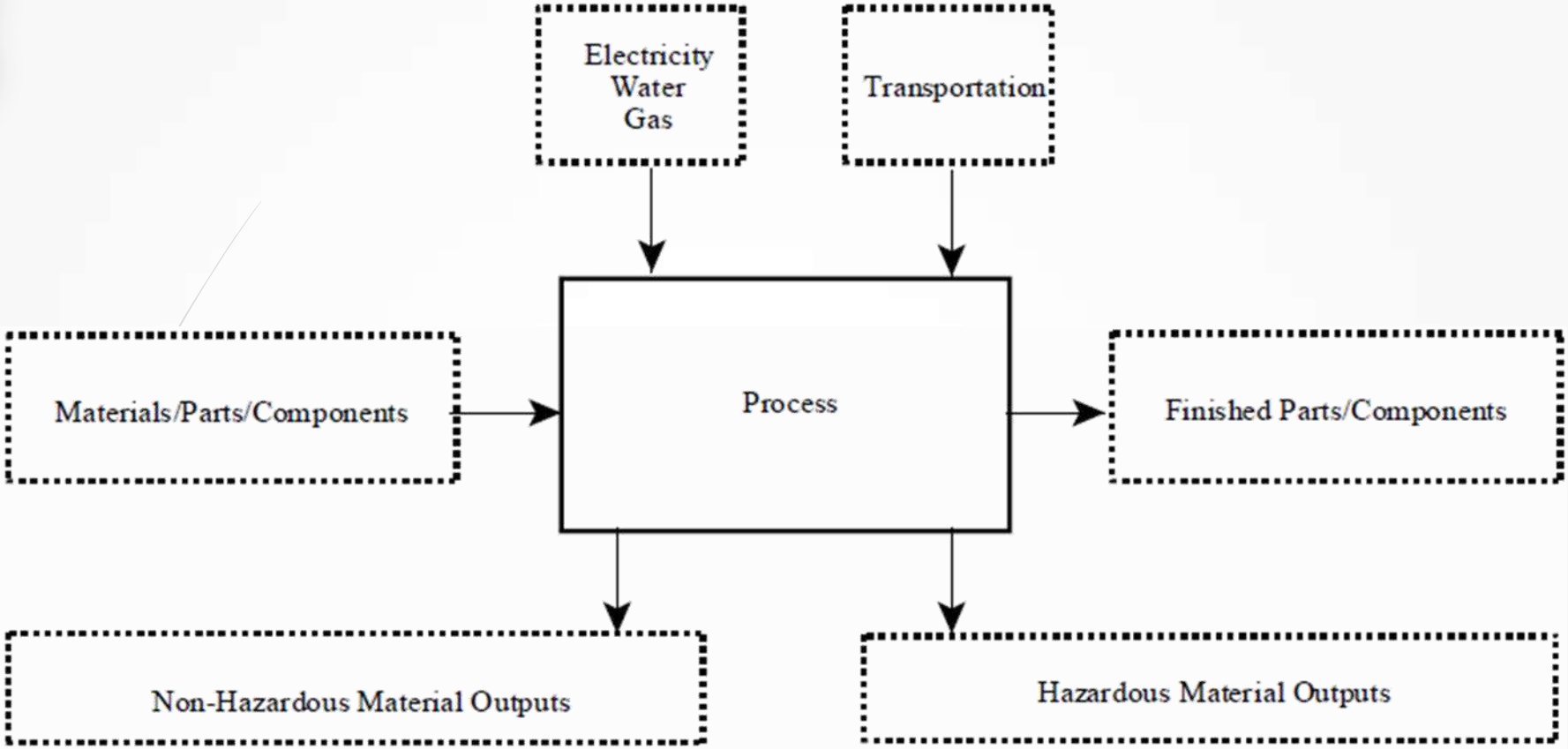
Life Cycle Assessment

- **One way to determine the sustainability of a fuel is to conduct a life cycle assessment of that fuel.**
  - A life cycle assessment (LCA) is the process of the assessing the environmental aspects and potential impacts associated with a product, process, or service, by 1) Determining all of the material and energy inputs, 2) Evaluating the potential environmental impacts associated with the product, and 3) Interpreting the results to determine the overall impact of the product or process.

- **A life cycle assessment usually considers the following aspects of a product:**
  - Acquisition of raw materials needed to make the product.
  - Refinement or manufacturing of the raw materials.
  - Production of the product.
  - Use/reuse/maintenance of the product.
  - Disposal of the product.



Source: www.ti-films.com



- Life Cycle Assessment focuses on the inputs of transportation, electricity, water, and fuel as well as the materials needed for the item.
- LCA also focuses on the outputs, including the finished product as well as the byproducts such as pollutants and waste.

Source: www.glbrc.org

Tapwater vs. Bottled Water

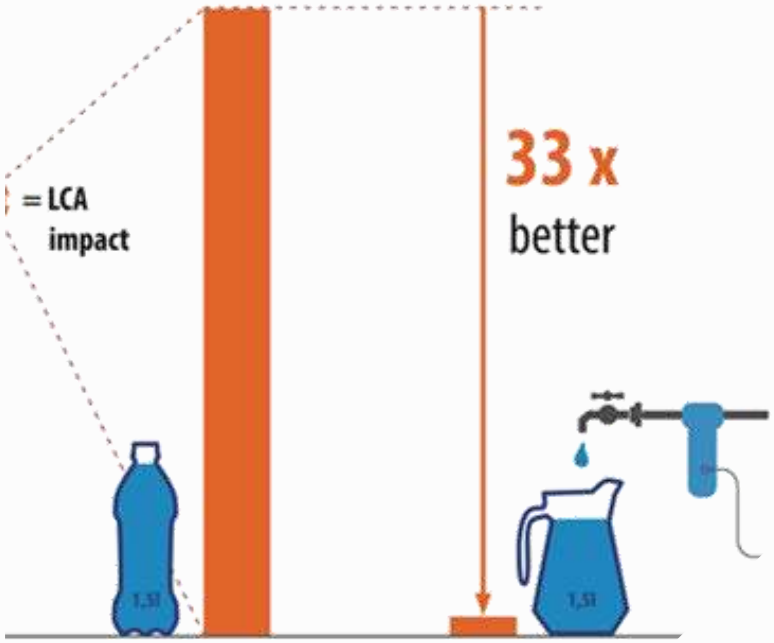
- **For example, a life cycle assessment could be used to determine whether bottled water or tapwater was better for the environment.**
  - First we would need to consider the inputs needed for each kind of water.

- **Inputs for tapwater include…**
  - The actual freshwater you would consume.
  - The materials and energy needed to install the pipes and plumbing.
  - The energy and materials needed to pump the water.
  - The energy and materials needed to filter the water.
  - The materials and energy needed for the glass to hold the water and to clean it.

Source: www.filtersfast.com

Tapwater vs. Bottled Water

- **Inputs for bottled water include…**
  - The water to be consumed.
  - The materials and energy needed to install the pipes and plumbing.
  - The energy and materials needed to pump the water.
  - The energy and materials needed to filter the water.
  - The plastic (a petroleum product; 17 million barrels are used for bottled water per year) and energy needed to produce the bottle.
  - The energy and materials needed to transport the bottled water to the store and to your home.
  - The water needed to produce the product (while water is also an output, it requires 3x the amount of water in the bottle to produce the actual bottle).
- **You could also include money spent by the consumer.**
  - This money equates to $0.0015 per gallon of tapwater.
  - It equates to $10.00 per gallon of bottled water.



Source: http://www.futureproofed.com/images/uploads/projects/13506_PWA_Visual_03_1.png

Tapwater vs. Bottled Water

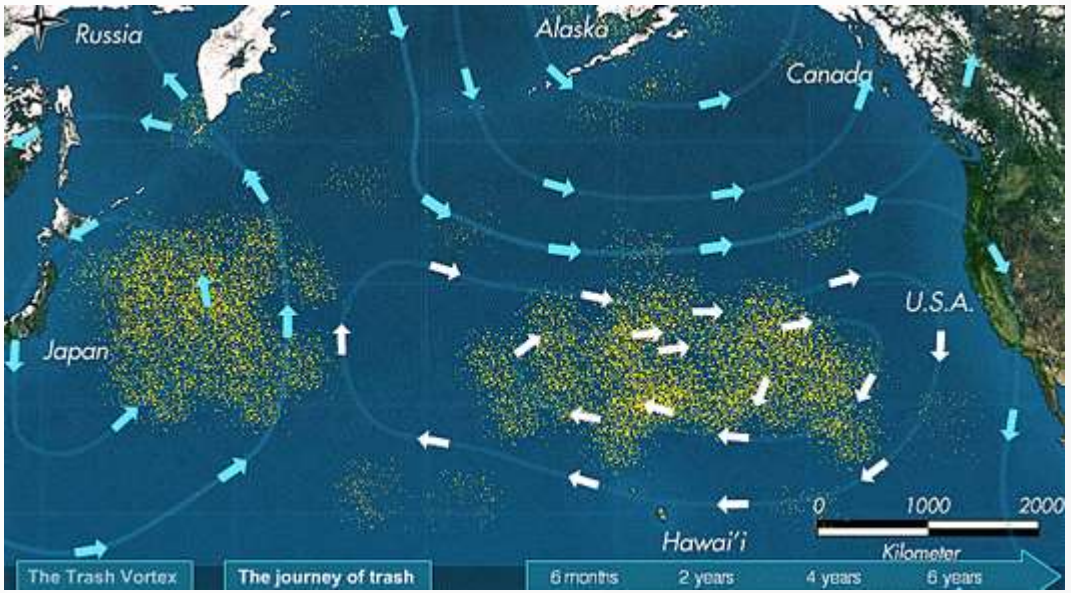
- **Next you would consider the outputs from the consumption of each kind of water.**
- **Outputs for tapwater include…**
  - The greenhouse gases released due to the energy needed to pump and filter the water.
  - The tapwater itself.
- **Outputs for the bottled water include…**
  - The greenhouse gases released from pumping and shipping.
  - The greenhouse gases released from producing the plastic bottle.
  - The landfill waste that results due to the fact that only 20% of the bottles are recycled (80% end up in landfills).
  - The pollution that may result from the production of the packaging.
  - The possible harm to wildlife if the plastic bottles or packaging make their way into an ecosystem.
  - The actual water itself.

Source: hubpages.com

Tapwater vs. Bottled Water

- **Tapwater is much more sustainable than bottled water when you consider all inputs and outputs of each option.**
  - While energy is needed and greenhouse gases are released in order to provide tapwater to each home, bottled water requires far more energy, materials and money.
  - Furthermore, bottled water has far more negative outputs than tapwater, including increased greenhouse gas emissions, increased rates of pollution and landfill waste, and increased likelihood of harm to wildlife and ecosystems.

- **In fact, the long-term impact of plastic on the environment may be the biggest concern.**
  - Plastic does not degrade as quickly as other substances and much of it eventually finds its way to the oceans.
  - Currently, a collection of plastic waste called the Great Pacific Garbage Patch is floating between California and Hawaii and is estimated to span 3.43 square kilometers (the size of Europe).
  - Plastics are worn down into smaller molecular-sized "microplastics" that are ingested by wildlife and fish.



Source: www.greenbookweb.com

Choosing a Sustainable Fuel

- **When choosing between the options of fuels, it is important to consider all of the inputs and outputs that occur from the production of each type.**
  - No one fuel is perfect, and all have both benefits and drawbacks.
  - While fossil fuels are limited and have high rates of pollution from their acquisition and use, many renewable fuels such as ethanol and biodiesel have their own problems, including lower fuel mileage and a limited capacity for production.

- **While no fuel has a clear advantage, it is becoming more evident that the US needs to lessen its reliance on fossil fuels.**
  - Fossil fuels are limited in supply, extensively harmful to the environment, are not carbon neutral, and have an inefficient life cycle.
  - While it is unlikely that fossil fuels will be eliminated, and while it is likely fossil fuels will continue playing a role in US energy needs for decades to come, it is to the benefit of consumers and to the environment that the US lessens its dependence on fossil fuels as much as possible.

Petroleum

- **<u>Summary</u>: formed from prehistoric plants and animals and is generally utilized as either gasoline or diesel fuel.**
  - Must be acquired by drilling and refined by boiling at different temperatures to separate different petroleum products.
  - Not renewable.
- **<u>Benefits</u>:**
  - Energy dense and very efficient for transportation energy.
  - Cost-effective (for the time being).
  - Technology is proven and available now.
  - Distribution infrastructure is already widely available.

Petroleum

- **Drawbacks:**
  - Most of petroleum is imported, meaning the US energy security is directly affected by the policies of other nations (particularly Russia and Middle Eastern nations).
  - Emits large amounts of greenhouse gases and toxic pollutants (particularly, CO_2, mercury, and others).
  - Very inefficient from drilling to the fuel tank, requiring more energy for production than is available from the product.
  - Very damaging to the environment if leaks or spills occur.
  - Limited in quantity and will become increasingly limited in decades to come.
  - Use of petroleum a leading potential cause of climate change.

Shale Oil Natural Gas

- **<u>Summary</u>: a form of natural gas (fossil fuel) found in shale rock formations in North America which is acquired through hydraulic fracturing (fracking).**
  - Fracking is a controversial practice in which fluid is injected at extremely high pressure in order to fracture the bedrock in order to allow the gas to escape and be collected.
  - When compressed or liquefied, the gas can be used as a transportation fuel.
  - Not renewable.
- **<u>Benefits</u>:**
  - Large domestic supplies of shale oil within the US.
  - Emits fewer greenhouse gases when combusted (the cleanest fossil fuel).
  - Creates more domestic jobs.
  - One gallon of compressed natural gas (CNG) is cheaper than one gallon of petroleum-based gasoline.
  - Technology is proven and available now.
  - Distribution infrastructure is already available.

Shale Oil Natural Gas

- **Drawbacks:**
  - Extraction of shale oil (via fracking) has been linked with extensive environmental damage due to the fracking process and high likelihood of groundwater contamination.
  - Uses large quantities of water.
  - Results in large amounts of methane emission from drilling and leaky wells (and methane is 21x more potent than CO_2 as a greenhouse gas).
  - Concerns with lack of oversight, workplace safety, and negative impacts on communities near wells (crime, stresses to infrastructure, etc.).
  - May increase likelihood of earthquakes.
  - CNG fuel stations are currently rare and expensive to build.
  - New vehicle design needed to accompany equipment needed.

Biofuel

- **Summary: biofuel is a generic term applied to any renewable liquid fuel made from a biomass source (biological material derived from living, or recently living organisms).**
- **Biofuels is available in a variety of options, including:**
  - Conventional Biofuel – usually ethanol that is derived from starch (such as ethanol from corn grain).
  - Advanced Biofuel – include renewable fuels other than corn-grain ethanol. This can include ethanol from other kinds of renewable biomass such as sugar, lignin, etc.
  - Cellulosic Biofuel – renewable fuels derived from cellulose (the main ingredient in a plant's cell walls), primarily from the leaves and stalks/stems of plants.
  - Biomass-based Biofuel – includes biodiesel made from vegetable oil or animal fats as well as cellulosic diesel (diesel fuel made from cellulosic sources).

Biofuels

- **Benefits**:
  - Most are carbon neutral (absorb the CO2 released during combustion when plants are grown).
  - Have cleaner emissions and result in less air pollution because they burn more completely.
  - Have a higher octane rating.
  - Are renewable and can be replenished.
  - Can be produced domestically and provide additional job opportunities to American workers.
  - Some biofuels (e.g. biodiesel) have a similar energy content as petroleum-based fuels.
  - Depending on the source, the process of making biofuels requires less energy than is contained in the fuel itself.
  - Depending on the source, can create additional habitat (e.g. if prairie, switchgrass, or popular trees are used as the source of the fuel).
  - Could provide additional uses for what are currently waste products (e.g. corn stover, animal fats, waste vegetable oil).

Biofuels

- **Benefits (cont.)**
  - Could be distributed using existing infrastructure (pipelines, gas stations, railroads, etc.) and with minimal or no changes to existing modern vehicles.

- **Drawbacks:**
  - Can involve intense water and fossil fuel use (particularly corn ethanol under some conditions).
  - May reduce supplies of edible food and/or raise food prices in some cases (particularly corn ethanol under some conditions).
  - Depending on the source, the process of making biofuels can require more energy than is contained in the fuel itself (particularly corn ethanol if large amounts of fossil fuels are used).
  - Depending on the source, can cause greater greenhouse gas emissions than some fossil fuels (particularly corn ethanol if large amounts of fossil fuels are used).

Biofuels

- **<u>Drawbacks</u> (cont.)**
  - Depending on the source, a switch to biofuels can cause habitat loss (particularly if native habitat is removed and a single species, or monoculture, replaces it).
  - The potential amount of biofuel that can currently be produced per year is less than the amount of gasoline, diesel fuel, or natural gas that could be acquired from drilling (although this could change if methods to produce cellulosic ethanol can be improved).
  - Energy content of some biofuels (particularly ethanol) is lower than that of gasoline and diesel fuel.
  - Biodiesel does not work well in cold temperatures.
  - Older models of vehicles are often incompatible with biofuel use.
  - Some biofuels (particularly biodiesel) can vary widely in quality and are not as uniform in their performance as other sources of fuel.

Electricity

- **<u>Summary</u>: electricity can be used as a transportation fuel when it is used to power the battery off which a car acquires a portion or all of its mechanical energy.**
  - Electricity as a transportation can be either renewable or nonrenewable depending on the how the electricity was generated (e.g. cars powered on electricity from wind power are considered renewable while electricity from a coal-fired plant is not).
- **<u>Benefits</u>:**
  - There are no tailpipe emissions.
  - Electrical cars already exist and have been available on the market for decades.
  - Some infrastructure (e.g. charging stations) are found in select cities around the US.

Electricity

- **Drawbacks**:
  - If the source of electricity is fossil fuel-based (e.g. a coal-fired power plant), the CO_2 emissions are similar or possibly greater than a gasoline-powered vehicle.
  - Widespread infrastructure does not exist for electrical cars to the same extent as gasoline or diesel.
  - Currently, electrical transportation energy is insufficient for use for most large trucks and planes due to low energy density of batteries.

Hydrogen

- **<u>Summary</u>: Hydrogen can be used as a transportation fuel when utilized through hydrogen fuel cells.**
  - A hydrogen fuel cell generates an electrical current as its electron and proton are separated from each other.
  - Depending on how the hydrogen is acquired, this can be either a renewable or nonrenewable source of fuel.
- **<u>Benefits</u>:**
  - There are no tailpipe emissions other than water (and possible a miniscule amount of tradition exhaust components).
  - Can be made locally on a limited basis without a need for a pipeline infrastructure or tankers.
  - Hydrogen is an abundant element that is available everywhere.

Hydrogen

- **Drawbacks:**
  - More expensive than a gallon of petroleum-based gasoline.
  - Widespread use would require a pipeline infrastructure.
  - Would require large investments in filling stations.
  - Hydrogen storage tanks for vehicles are expensive.
  - Energy to produce hydrogen fuel is greater than the energy content of the fuel.
  - Currently, hydrogen fuel cells would be insufficient for use for most large trucks, trains, and planes.
  - Pure hydrogen is extremely flammable.
  - Currently, producing hydrogen is dependent on fossil fuels to provide the energy necessary to separate it from oxygen in H_2O (assuming water is the source of hydrogen).

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