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Waste to Energy: How can we get the most from our waste?

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Abstract

What is in your waste bin? Banana peels, used napkins, a broken pencil? You may think they are useless waste. But they're not: they are waste *biomass*! They are made of once-living things and they store energy. We can convert that energy into other forms and use it to light a reading lamp, cook a meal, or as fuel in our cars. Using waste instead of *fossil fuels* reduces air and water pollution as well. The best part is that we already produce so much waste, so why not use it?

There are four types of waste biomass. Different waste conversion technologies turn it into energy. We wanted to know which combination would give us the maximum benefits. We found that we can gain lots of energy back from waste to help the environment. However, the right type of waste and conversion technology could be different for each part of the USA.

Introduction

Have you ever noticed that Nature doesn't let anything go to waste? For example, trees provide food and oxygen for animals, and they use animal waste (carbon dioxide and animal droppings) to produce energy. We call this a *closed-loop design*: the ecosystem recycles waste back into energies that continue the forests' cycle of life.

However, man-made systems today take resources from Nature and then return wastes that can't be used back in the ecosystem. For example, when we drive our cars we use fossil fuels that took Nature millions of years to make and we release harmful waste like carbon dioxide and toxic chemicals in the air. Wouldn't it be great instead if our cars turned waste into energy like the time machine in the 'Back to the Future' movie? People thought we would quickly run out of fossil fuels, but then we kept finding more. By the time we discovered they were harmful, we relied on them too much to quit. But we cannot keep using fossil fuels until we run out. We need to find other resources that make inexpensive energy to protect our planet for future generations.

In the *Back to The Future* movies, the time machine car takes food and organic waste and turns it into energy. Even though time travel is still not possible, using waste as fuel has definitely become a reality.

Photo credit: *Back to the Future II* (1989), Universal Pictures.

We generate large amounts of waste and dump it in landfills. What if we operated like Nature and recycled the energy trapped in waste biomass? There are a variety of technologies to convert biomass into fuel or electricity. Our question is: what type of waste and technology would give us the most benefits?

Methods

Everybody loves superheroes! Spiderman, Hulk, Wolverine... We can rank them by their different abilities, such as intelligence, speed, or fighting skills. Think of waste as our superheroes and their benefits as abilities. By using different types of waste and technologies, we gain different benefits. There are four major types of biomass waste: agricultural, animal manure, forestry, and landfill. And there are two types of benefits we could identify:

1. **Energy benefit:** We determined the type (like *biofuels* or electricity) and amount of *renewable energy* we can produce. However, conversion technologies also need energy to work. So the **net energy gain** is the difference between the energy it needs for conversion and the renewable energy it produces.

2. **Climate benefit:** We measured how much carbon dioxide is produced during all the life stages of waste: collection, transportation to a *biorefinery*, conversion into energy, and finally, used by people. This is called a *life-cycle* assessment (Fig. 1). Then, we calculated the decrease in *carbon emission* if we replaced fossil fuels with waste.

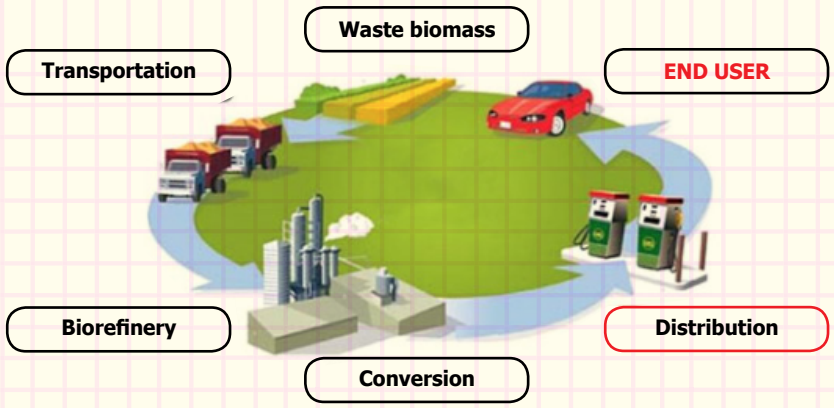


Figure 1:
We conducted a life-cycle assessment for each waste type and technology combination. Waste is first collected and transported to a biorefinery. Here it is turned into biofuels. Then, it is distributed to where people can use it. We calculated the amount of carbon dioxide gas produced at each of these stages.
(Image: University of Illinois CITL)

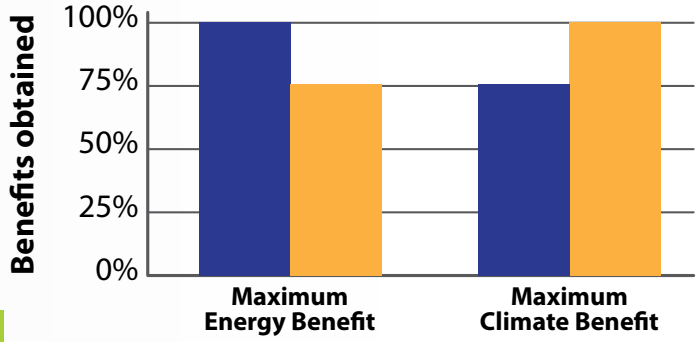
Results

- If we used all of the available waste biomass in the USA, we would produce about 3.8 exajoules of renewable energy every year. (That's a lot!) The net energy gain would be a little less – about 3.2 exajoules – but still a lot (approximately 4% of all energy used in the USA per year).
- By replacing fossil fuels with biofuels, we would reduce carbon emission by about 180 million metric tons per year. That is like removing 39 million cars from traffic.
- We couldn't find a single waste type or conversion technology that offers the maximum benefits in both energy and climate in all parts of the USA (Fig. 2).

Please see Figure 2 on Page 3

Figure 2:
The first two bars show that if we maximize energy benefits, then we don't get the maximum climate benefits. The second set of bars shows that if we maximize climate benefits then the energy benefits decrease. We can't maximize both energy and climate benefits. We need to choose one or the other.

How does maximizing energy benefits affect climate benefits?



Discussion

Our results show that waste biomass is a great energy resource. By using different technologies, we can recycle the energy as biofuels or electricity. These biofuels are already used in cars, trucks, ships, and airplanes (even in jets). By replacing fossil fuels we improve air and water quality and reduce our impact on *climate change*. Additionally, we send less trash into landfills and operate closer to a closed-loop system, just like Nature.

However, there are some challenges. Remember superheroes? We discovered that no single "superhero" is ranked highest in all abilities. This means that a single type of waste and conversion technology can't give us the maximum benefits for both energy and climate. Also, some types of waste are hard to find in certain areas of the USA. For this reason, we recommend gathering a team of superheroes to do the job – like the Avengers! First, we should determine which benefit, energy, or climate is most needed in each part of the USA. Looking at the available waste type, we can select a conversion technology that will maximize the kind of benefit needed. This approach would give our country the overall maximum energy and climate benefits.

Conclusion

Working like Nature by recycling energy and matter can make our lives easier and protect our planet for future generations. Why not start practicing today? Here are a few ideas:

- Conduct a life-cycle assessment of an item (like a T-shirt). Research its impact on the environment, starting from the resources it uses for production, to the time it arrives at your house.
- Build a closed-loop system in a jar that can take care of itself. Observe and keep a log every day. Check out the "How to Build a Closed Terrarium" video in the Reference section below.
- Design and build a toy car powered by a renewable energy source like wind, water, or solar energy.

REFERENCES

Boo Liu and Deepak Rajagopal. (2019) *Life-cycle energy and climate benefits of energy recovery from wastes and biomass residues in the United States. Nature Energy*.
https://doi.org/10.1038/s41560-019-0430-2

Kiddle Encyclopedia: Biomass Facts for Kids
https://kids.kiddle.co/Biomass

Natural World Facts: How to Build a Closed Terrarium
https://www.youtube.com/watch?v=y0u9k-MSo8U

Glossary of Key Terms

Biofuels – a fuel that is produced from biomass. Biofuels include bioethanol, biodiesel, and biogas.

Biomass – any material made from plants and animals which has stored sunlight in the form of chemical energy.

Biorefinery – a facility that converts biomass into biofuels, electricity, heat, or other chemicals.

Carbon emission– release of carbon dioxide from the land to the atmosphere, like when humans burn fossil fuels.

Climate change – a change in climate patterns since the mid 20th century. Most scientists believe it is caused by human activities such as using fossil fuels.

Closed-loop design – a system where the waste of an organism becomes a resource for another; it can take care of itself forever without creating waste.

Exajoules – 1 exajoule is equal to 10^{18} joules. A joule is a unit of energy or work done. 1 joule is approximately the amount of energy needed to lift up an apple to 1 meter height.

Fossil fuels – fuels that come from very old life forms that have decomposed over a long period of time. The three most important fossil fuels are coal, petroleum, and natural gas.

Life-cycle assessment – a calculation of environmental impact (counting carbon emissions) from all stages of a product's life. A life cycle assessment of waste biomass calculates carbon emissions during collection, transportation, and the process through conversion technologies.

Renewable energy – energy from resources that Nature will replace, like wind, water, and sunlight. Renewable energy is also called "clean energy" or "green power" because it usually doesn't pollute the air or the water.

Check your understanding

1. How do energy and matter recycle in a closed-loop system?

2. Why is it important for us to use the energy in waste biomass?

3. We conducted life-cycle assessments for each waste and conversion technology combination. Why is that important?

4. What are some challenges of using waste biomass for energy? How can we overcome those challenges?

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