Anaerobic Digestion
"Garbage to Energy"
is
Twice as Dirty as Coal

David Bubenik, Ph. D.

Electrical Engineer

47 Years Professional Experience

420 Homer Avenue, Palo Alto

Executive Summary

- The Anaerobic Digestion (AD)-fueled "Garbage to Energy" process returns 1.6 metric tons of CO2 to the atmosphere for each MegaWatt-hour (MWh) of energy it delivers

- A coal-burning generator—the benchmark of carbon-dirty energy—releases 0.8 metric tons CO2 per MWh delivered

- AD / Coal CO2 ratio = 1.6/0.8 = 2:1

- The AD "Garbage to Energy" carbon footprint is double that of a coal-burning generator

- The carbon in the biomass fuel for AD "Garbage to Energy" comes from the CO2 nature sequestered from the atmosphere
  - <u>A carbon-smart policy would keep that carbon sequestered</u>
  - Shouldn't Palo Alto adopt one?
    - If not Palo Alto, then who?

AD

Coal
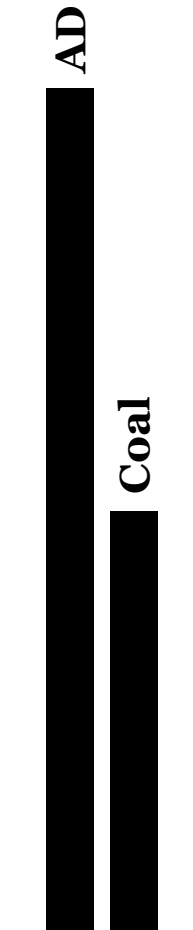
Data Source:
http://www.cityofpaloalto.org/news/displaynews.asp?NewsID=2553&TargetID=65
Follow link: "**C. deLa Beaujardiere Numbers (4-2010)**"

1. Plants Remove CO2 from the Atmosphere

- This magnolia leaf is made of hydrogen, oxygen, and <u>carbon</u>

- That carbon comes from the CO2 the leaf sequestered from the atmosphere

- An AD "Garbage to Energy" electrical generator would return this CO2 to the atmosphere
  - at a major financial cost
  - for a negligible energy return
  - with a huge carbon footprint

- Why would Palo Alto want to do that?

I use a leaf as a visualization aid for aesthetic reasons. The discussion and conclusions apply to any AD feedstock: sludge, food scraps, …

2. Make Biogas, Release 40% as CO2

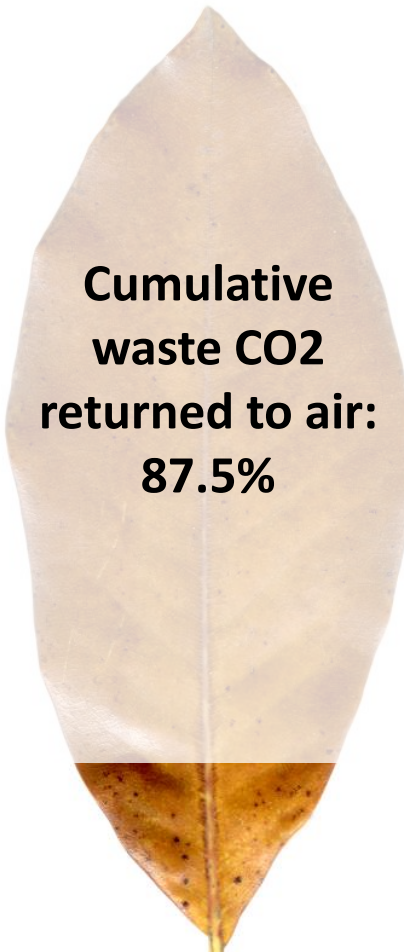**Cumulative waste CO2 returned to air: 40%**

- The AD process converts the feedstock to biogas

- That biogas consists of
  - Methane: 60%
  - Carbon dioxide: 40%

- The carbon dioxide yields zero energy
  - But it is returned to the atmosphere

- Cum score:
  - Sequestered carbon returned to the atmosphere as CO2: 40%
  - Saleable energy delivered: 0

3. Burn the Usable Biogas, Lose 70%

Cumulative waste CO2 returned to air: 82%

- Burn the biogas methane to H_2O & CO_2

- That yields heat energy…
  - which powers a motor…
  - that drives an electric generator

- But, per the laws of thermodynamics, 70% of that heat energy is lost as "waste heat"
  - That's why your car's engine gets so hot

- The unmasked leaf area shows the 18% carbon fraction that actually produces electrical energy

- Cum score:
  - Sequestered carbon returned to the atmosphere as CO_2: 82%
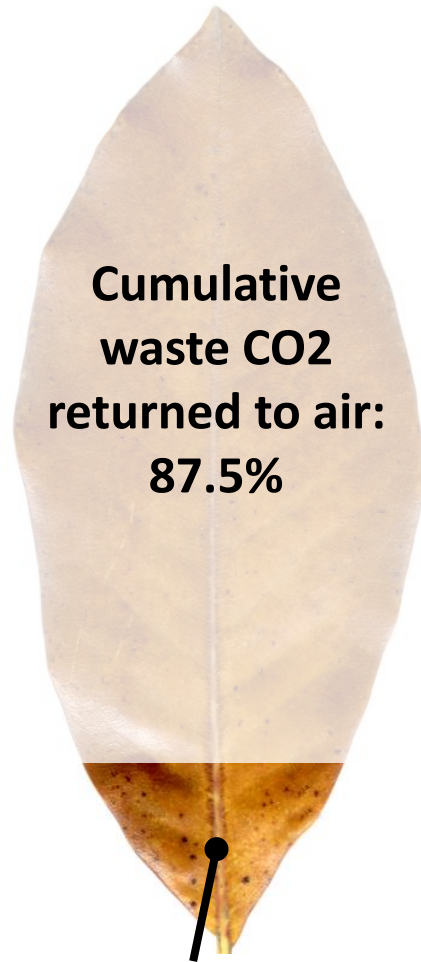 - Saleable energy delivered: 0

4. Pay 30% Operating Tax

Cumulative waste CO2 returned to air: 87.5%

- Thirty percent of the generated electrical energy is spent upfront to power the "Garbage to Energy" operation

  – Trade term: "parasitic load"

- Associated carbon release: 5.5%

- Cum score:

  – Sequestered carbon returned to the atmosphere as CO_2: 87.5%
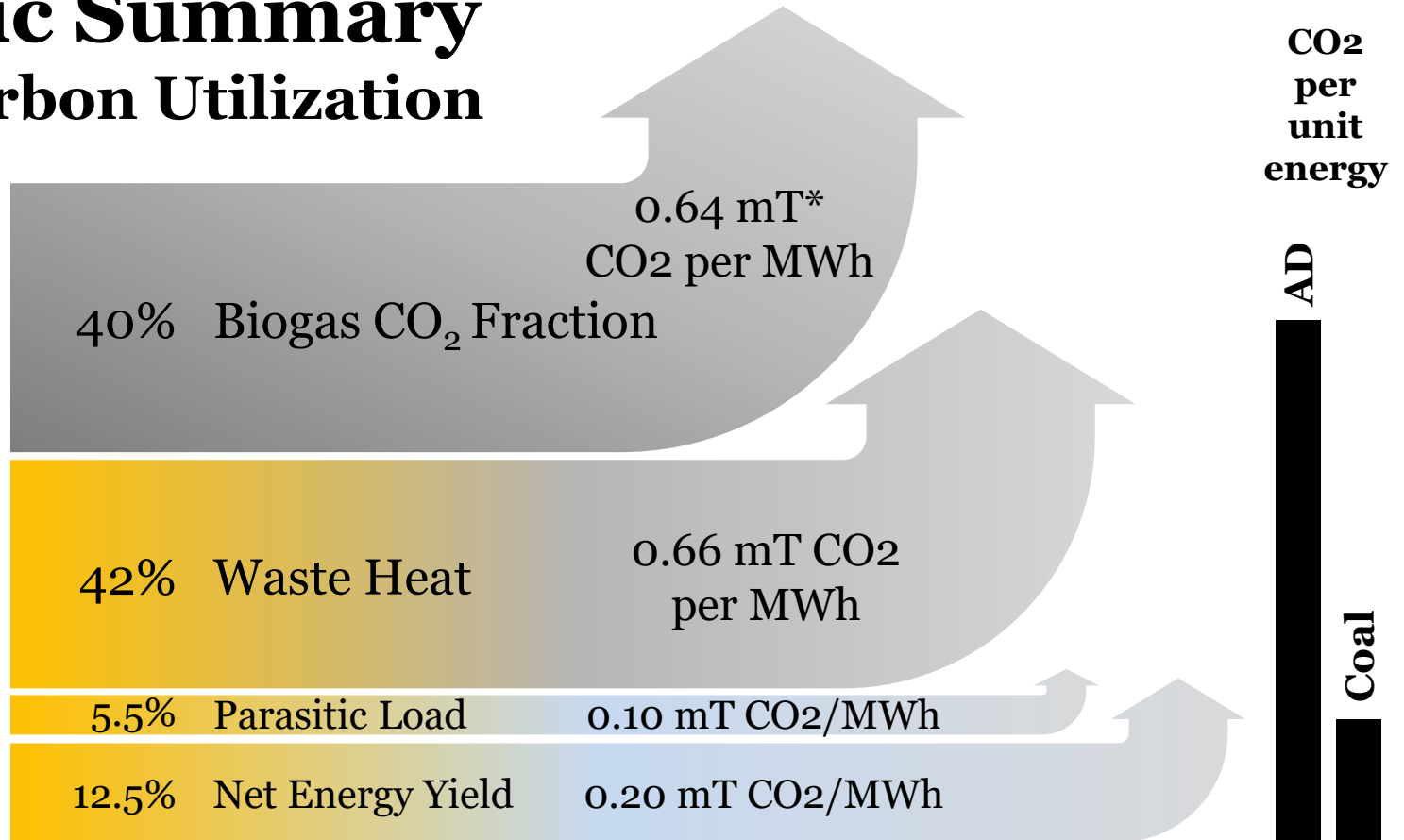
  – Saleable energy delivered: 0

5. Deliver Energy to Users

Cumulative waste CO2 returned to air: 87.5%

This carbon yields all of the saleable energy

- Fraction of the feedstock carbon that delivers "Garbage to Energy" electricity to users: 12.5% (1/8)

- Fraction for a coal-fired generator: 30% (~1/3)

- Final score:
  - Sequestered CO2 returned to the atmosphere: 100%
  - Fraction released unproductively: 87.5%
  - CO2 per AD-generated MWh delivered: 1.6 metric tons
  - CO2 per coal-fired MWh delivered: 0.8 metric tons
  - CO2 ratio: AD "G2E" / Coal = 1.6/0.8 = 2:1

- Bottom Line: The carbon footprint of an AD-fueled generator is twice that of a coal-burning generator

Graphic Summary
of AD Carbon Utilization

CO2 per unit energy

AD

Coal

0.64 mT* CO2 per MWh

40%   Biogas CO$_2$ Fraction

42%   Waste Heat   0.66 mT CO2 per MWh

5.5%   Parasitic Load   0.10 mT CO2/MWh

12.5%   Net Energy Yield   0.20 mT CO2/MWh

Total AD CO2 per MWh delivered: 1.60 mT

Coal generator CO2 per MWh: 0.80 mT

AD to Coal CO2 ratio: 2:1

* mT = metric ton = 2,200 lbs

Takeaways

CO2
per
unit
energy

AD

Coal

- All the carbon in the biomass that fuels an AD "Garbage to Energy" electrical generator comes from CO_2 that plants sequestered from the atmosphere

- An AD-fired generator returns all of that CO_2 to the atmosphere
  - at a major financial cost
  - for a negligible energy return
  - with a huge carbon footprint

- Per unit of energy delivered, the AD process has double the carbon footprint of a coal generator—the benchmark of carbon-dirty energy

- A carbon-smart policy would keep the sequestered carbon sequestered

- Shouldn't Palo Alto adopt one?
  - If not Palo Alto, then who?

Data Source:
http://www.cityofpaloalto.org/news/displaynews.asp?NewsID=2553&TargetID=65
Follow link: "**C. deLa Beaujardiere Numbers (4-2010)**"