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WHAT IS THE NET ENERGY OF ETHANOL?: A FOOLISH AND UNIMPORTANT QUESTION

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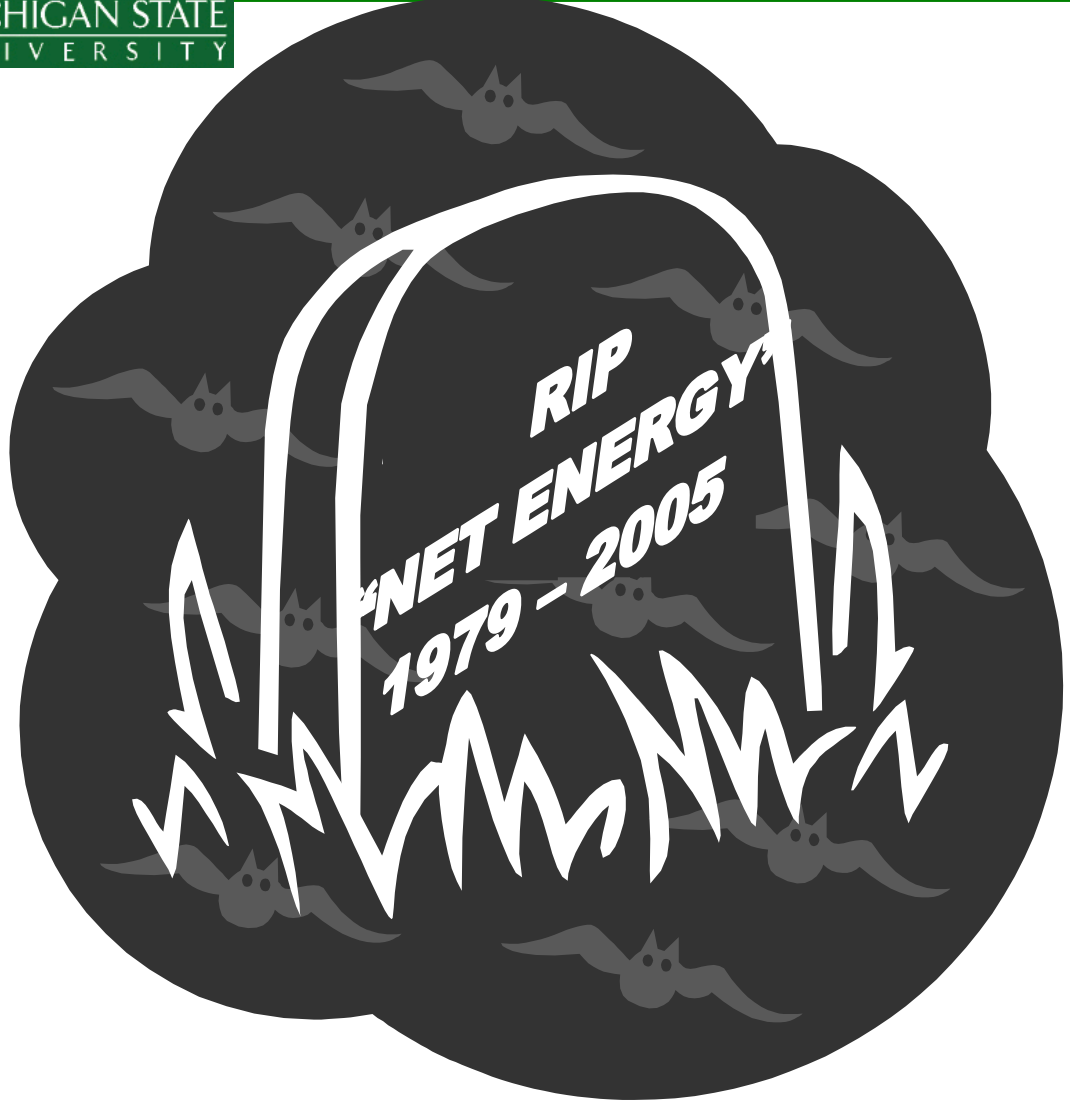

"I COME TO BURY NET ENERGY, NOT TO PRAISE IT"

Why should we bury “net energy”? I

- Because it is a convenient fiction, an academic toy
- Net energy doesn’t relate to the real world
- It doesn’t serve good energy policy formation
- *Why?*
  - Because it treats all energy from all sources (coal, oil, natural gas, solar, wind, hydro, etc) as equal
  - Ignores energy <u>quality</u>, only deals with energy <u>quantity</u>
  - But all energy is NOT created equal

Why should we bury “net energy”? II

- Professor Pimentel has further separated net energy from anything real: why?:
- Because he never **compares** ethanol with real fuels
- We have. According to his “net energy” standard:
  - Ethanol is **significantly better** than gasoline, diesel, jet fuel (ethanol is -29% vs. gasoline -39%)
  - Ethanol is **enormously better** than electricity (-235%)

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WHAT IS "NET ENERGY VALUE (NEV)"?

NEV = energy content of ethanol

– nonrenewable energy consumed in the system

+ nonrenewable energy consumed in alternative product systems for co-products*⬅ credits due to co-products

*this term not included in some studies

Ethanol NEV: Summary of Studies

Authors (Date)	NEV (Btu/gal)
Ho (1989)	*-4,000*
Marland and Turhollow (1990)	18,154
Pimentel (1991)	*-33,517*
Keeney and DeLuca (1992)	*-8,438*
Shapouri et al. (1995)	16,193
Lorenz and Morris (1995)	30,589
Agri.and Agri-Food, CAN (1999)	29,826
Wang et al. (1999)	22,500
Pimentel (2001)	*-33,562*
Shapouri et al. (2002)	21,105
Kim and Dale (2002)	23,886 – 35,463
Pimentel and Patzek (2005)	*-22,037 (-15,352*)*

** Including credit for DDG*

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PRESS COVERAGE IS A BIT ONE-SIDED, HOWEVER

A study last year by …David Pimentel shows that it takes so much fossil fuel to create ethanol, that we end up with a net energy loss. WSJ May 2002

David Pimentel of Cornell University's … has argued that ethanol is a lousy choice because it takes more energy to produce ethanol from corn than the ethanol ultimately yields. ABC News Sept. 2004

Pimentel found that it takes about 29 percent more energy to produce ethanol than you get from burning it. Audubon Magazine Oct. 2004

David Pimentel… published an analysis last year showing that about 70 percent more energy is required to produce ethanol than the energy that actually is in ethanol. Capitalism Magazine Sept. 2002

And many, many more…. The explicit argument always is that ethanol is bad because its "net energy" is negative.

SOME GRIM (THERMODYNAMIC) FACTS I

- First Law of Thermodynamics:
  - The total quantity of energy in the universe is fixed.
  - No process can create or destroy energy.
  - At steady state, total energy into a process must equal energy out of that process
- Therefore, the “net energy” of any system is zero
- Actually, things are worse than this.

SOME GRIM (THERMODYNAMIC) FACTS II

- Second Law of Thermodynamics:
  - All spontaneous processes proceed with a loss of some inlet energy to output heat energy that cannot be captured.

- Therefore, the “net (useable) energy” of any system is not zero but actually negative.

DON'T LOSE HEART, PLEASE

- Consistent with the Laws of Thermodynamics we can:
  - Increase the *quality* of useful energy while accepting that the *quantity* of useful energy must decrease.
- All BTU (kcal, erg, whatever) are **not** created equal.
- Burn 3 kcal of coal to get 1 kcal of electricity
  - "Net energy" is -235% (per Pimentel definition)
  - But electricity is higher quality energy than coal
- Refine 100 kcal of crude oil to produce 81.5 kcal fuels
  - "Net energy" is -39% (per Pimentel)
  - But gasoline is higher quality energy than crude oil
- I disagree strongly with the whole "net energy" concept—but ***if*** you accept it you must also ask this question

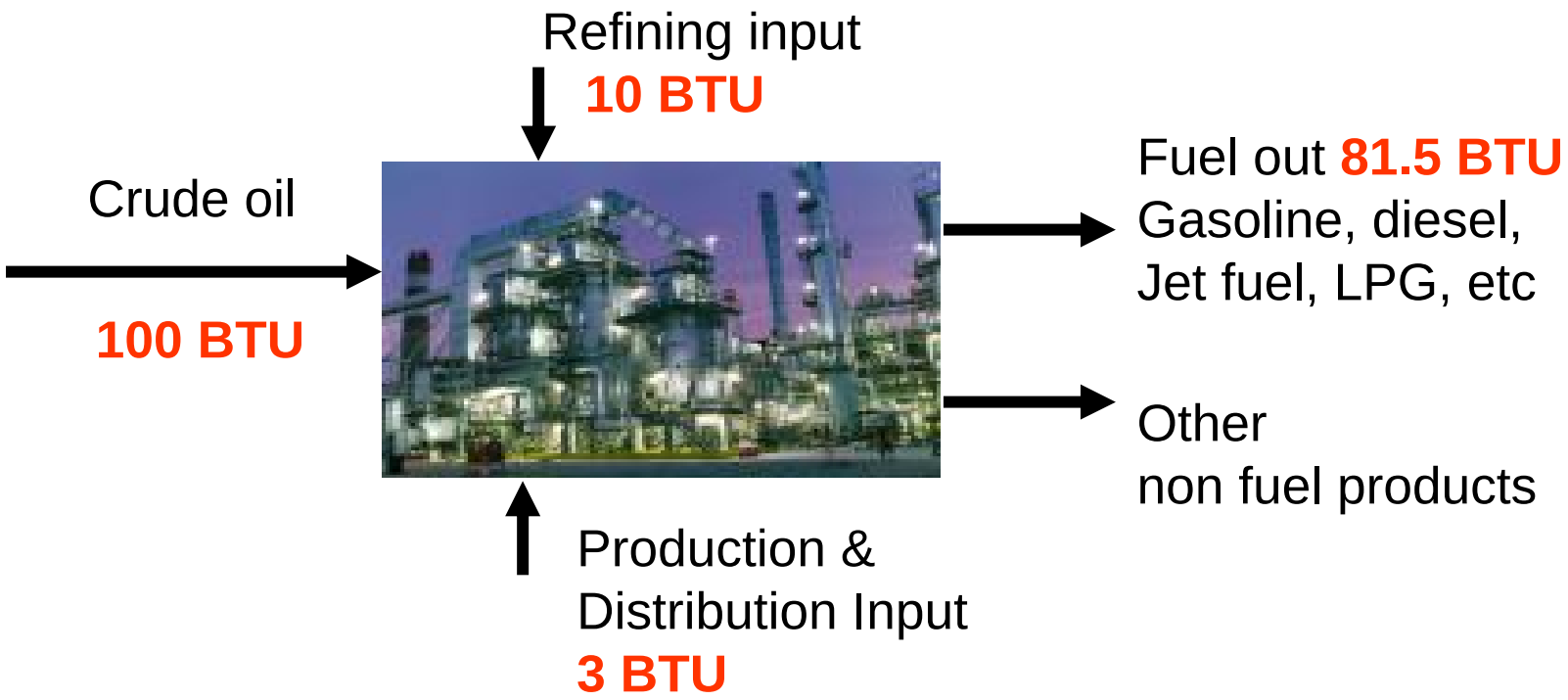
A Question Follows:

- *Are we <u>really</u> going to stop burning coal for electricity or refining crude because their "net energy" is negative?*
- Absurd – so let's not apply that reasoning to ethanol
- Unfortunately, that is exactly where the net energy analysis (mis)leads us

Most Recent Pimentel & Patzek Study*

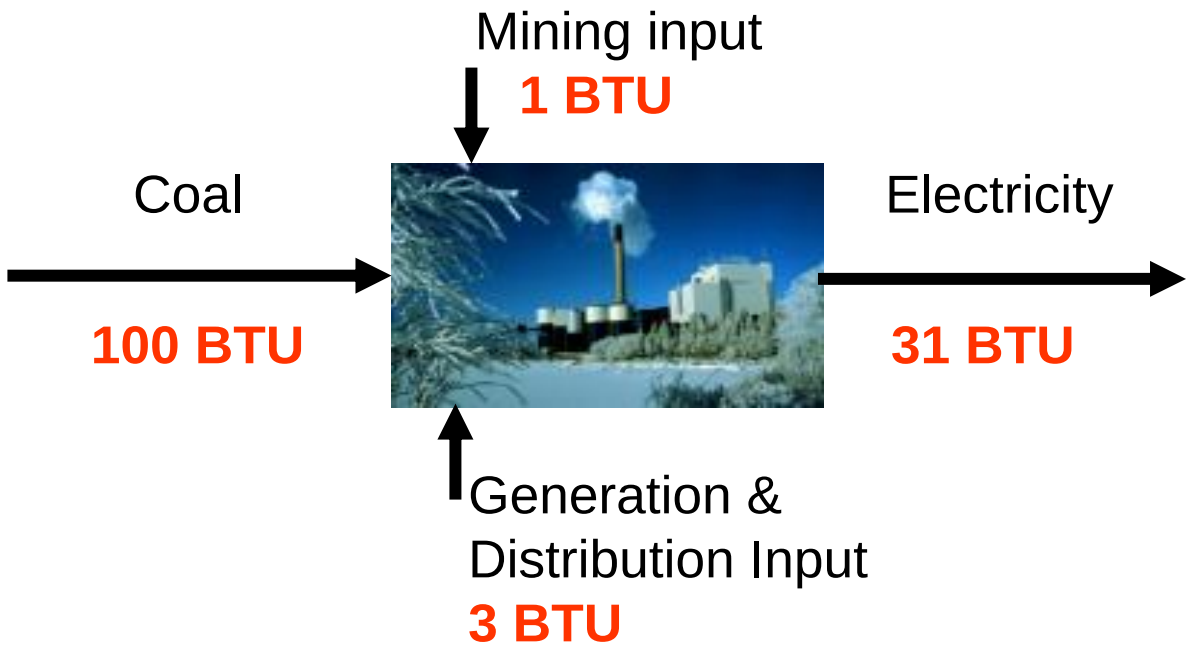
- Define ethanol's % net energy as:
  - [(Ethanol Heating Value – Fossil Energy Inputs)/Ethanol Heating Value] x 100
- They calculate net energy for ethanol from:
  - Corn - 29%
  - Switchgrass & wood - 50 to -57%
- Many details wrong:
  - ISO standards for LCA not applied
  - Lignin not used to fuel cellulose ethanol plant
  - Absurd data chosen– energy value for labor in ethanol plant is half total U.S. energy consumption
  - and so on…
- But let's apply their approach to other fuels-do the comparisons they should have done

Petroleum Refining



$$\text{NET ENERGY} = \frac{81.5\ \text{BTU} - 113\ \text{BTU}}{81.5\ \text{BTU}} = \textbf{- 39 \% (vs.-29\%)}$$

Electricity Generation From Coal



$$\text{NET ENERGY} = \frac{31\ \text{BTU} - 104\ \text{BTU}}{31\ \text{BTU}} = \textbf{- 235 \% (vs. -29\%)}$$

Logical Consequences

- If “negative net energy” means anything, then:
  - Shut down all coal (& natural gas) electricity generation (70% of total)
  - Shut down all oil refineries—98% of vehicles
- “Net energy” is a foolish argument
- All energy production systems sacrifice some quantity of energy for increased energy quality

SO WHAT DO WE SUGGEST?

- Glad you asked that question
- What we suggest is:
  - Stop talking about “net energy”
  - “Net energy” is inherently susceptible to corruption and misuse
  - Focus on energy quality first
  - Compare thermodynamic efficiencies within a process and between alternative processes after energy quality objectives are fixed.
- For the case of biofuels, the key energy quality objective is to displace oil with biofuels
- We wimp out here and do both
  - consider “net energy”
  - and oil displacement
- Also evaluate some key environmental metrics

Goal of Study

- Calculate **net energy value (NEV)** of ethanol derived from different sources (i.e., **corn grain**, **corn stover** and **switchgrass**)
  - Based on lower heating value
- Estimate **greenhouse gas (GHG) emissions** associated with using ethanol as E10 fuel in a compact passenger vehicle
  - E10 fuel: 10 % ethanol and 90 % gasoline (by volume)
  - Compare to GHG emissions associated with gasoline fueled vehicle
  - Based on 100 year global warming potential
- Estimate **crude oil displacement**

Cropping Scenarios

- Continuous corn cultivation (**CC**)
  - Harvest grain only
- Continuous corn cultivation with stover harvest (**CCS**)
  - Harvest grain and stover
  - Second pass harvest mode for corn stover
- Switchgrass cultivation (**SW**)
  - Cultivation period: 4 years

Assumptions in Biomass Production

- Farming and Biorefinery location: **Fulton County, Illinois**
- Current tillage practice for corn culture
  - Conventional tillage (CNT): 39.52%
  - Reduced tillage (RT): 25.4%
  - Conservation tillage (CST): 35.08 %
    - no till (13.1%) and mulch till (21.9%)
- Harvest rate of corn stover: 50 %
- No-tillage is applied to switchgrass cultivation

Assumptions *(cont'd)*

- Biomass yield
  - Corn grain: **8,151** kg/ha (dry basis)
  - Corn stover available: **4,076** kg/ha (dry basis)
  - Switchgrass: **11,651** kg/ha (dry basis)
- Soil organic carbon and nitrogen dynamics are predicted by DAYCENT model.
- Transportation distance for biomass
  - 26.7 km (radius of Fulton County)
  - Transportation mode: Truck

Type of Biorefinery

- Corn grain
  - wet milling
    - Yield: **0.29** kg of ethanol per dry kg of corn grain
    - Products: ethanol, corn oil, corn gluten meal (CGM), corn gluten feed (CGF)
- Corn stover
  - ammonia fiber explosion (AFEX) pretreatment
    - Yield: **0.3** kg of ethanol per dry kg of corn stover
    - Products: ethanol, protein, electricity, steam
- Switchgrass
  - ammonia fiber explosion (AFEX) pretreatment
    - Yield: **0.3** kg of ethanol per dry kg of switchgrass
    - Products: ethanol, protein, electricity, steam

Net Energy Value of Ethanol

[MJ kg^{-1}]	Corn grain	Corn stover	Switchgrass
Ethanol	**26.8**	**26.8**	**26.8**
Used	**-25.0**	**-23.6**	**-5.6**
Credits	**3.5**	**23.8**	**10.1**
NEV	**5.3**	**27.0**	**31.3**

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Crude Oil Displacement (CODis) Based on Ethanol

CODis = crude oil used in **gasoline fueled vehicle system**

- crude oil used in **E10 fueled vehicle system**

[g kg^{-1}]	Corn grain	Corn stover	Switchgrass
CODis	619	623	658

CODis Based on Cropping System

- Different cropping systems
  - Corn cultivation (CC)
    - Corn grain harvested
  - Corn cultivation (CCS)
    - Corn grain and stover harvested
  - Switchgrass cultivation (SW)

kg ha^{-1}	CC	CCS	SW
CODis	**1,453**	**2,164**	**2,161**

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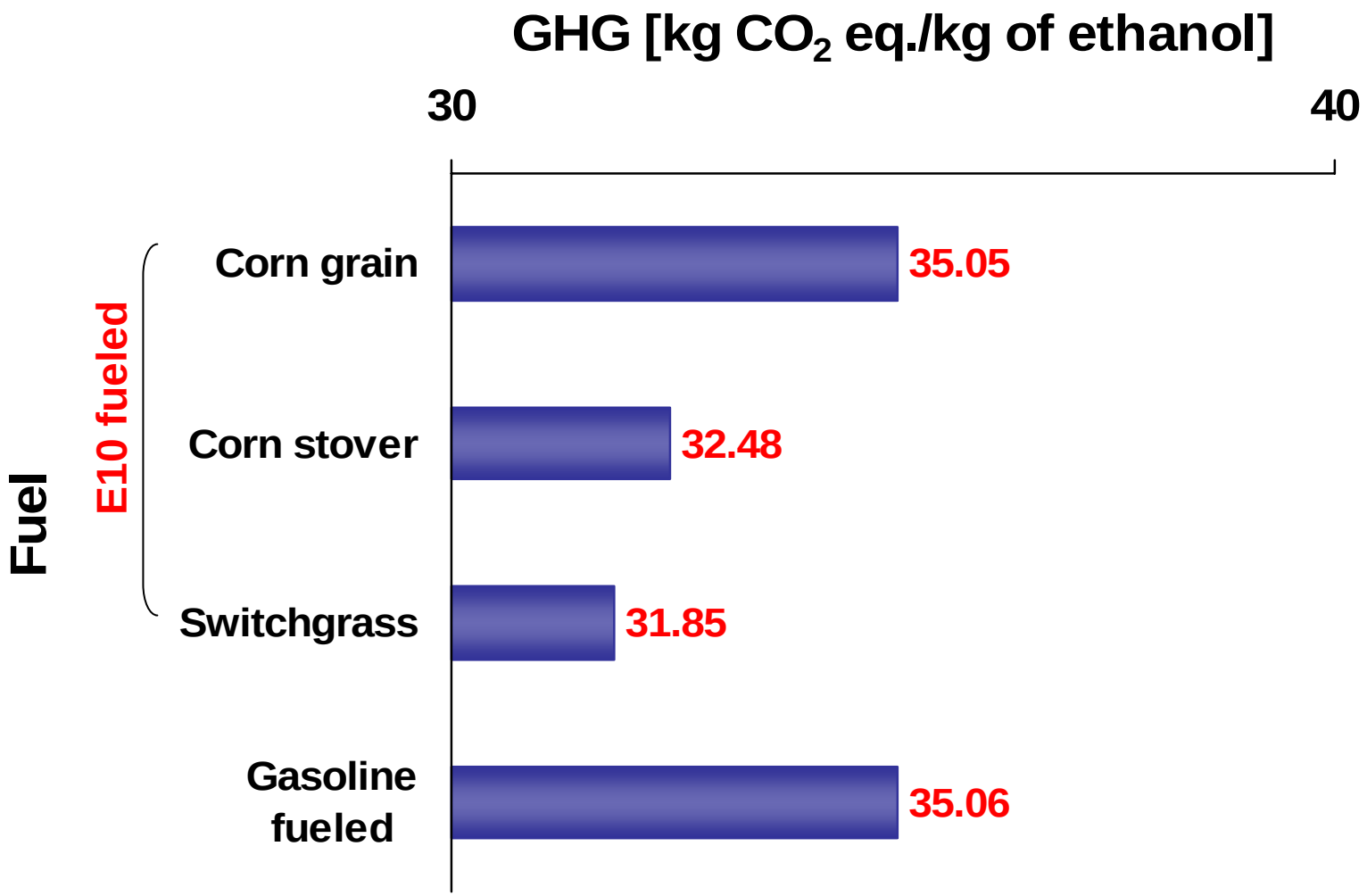
Greenhouse Gas (GHG) Emissions Based on Ethanol



Greenhouse Gas Emissions Based on Cropping Systems

[ton ha^{-1}]	CC	CCS	SW
E10 system	**82.31**	**119.4**	**104.5**
Gasoline system	**82.32**	**122.3**	**115.1**
Difference	**Nil**	**-2.9**	**-10.5**

Conclusions

- The net energy value of biomass ethanol is **positive** regardless of biomass
  - 16,193 ~ 88,872 Btu/gal
- Using ethanol would gain **nonrenewable energy**
- Using ethanol as E10 fuel would save **crude oil**
  - 619 ~ 658 g/kg of ethanol
- Using ethanol as E10 fuel would reduce **greenhouse gas emissions**

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Questions ??