Ethanol or Biodiesel? A Systems Analysis Decision

by

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Part I— The Senator's Problem

Bill Nowak, an aide to Senator Ed Worden, placed an agitated call to Terry Hansen, a Congressional budget analyst, to ask for her help in estimating the energy e ciency involved in growing corn and converting it into ethanol for fuel.

"Terry, this is urgent. My boss needs this information for a preliminary hearing to decide whether research funds should be allocated for a corn-to-ethanol project in his home state of Iowa or to a project that involves the conversion of soybeans to biodiesel fuel in Illinois. He needs an estimate of the relative energy e ciencies of the two processes by Monday. Senator Worden thinks that you are the person who has the knowledge and connections to get the information we need together that fast."

"I'd love to help you, Bill, and I even have some ideas on how to go about it, but I just don't have the time to do what you're asking right now. I am very sorry."

"You said that you have some ideas, though. Could you direct the work of someone on your staff that could do it for you? I'd really appreciate any help that you could give me. We're up against a wall on this one."

"Well, I do have two exceptional student interns working for me. I could get them started on getting that estimate for you."

"Great, Terry. I desperately need some information for that meeting."

"OK, Bill, we'll do our best for you."

After hanging up, Terry called her student interns, Dan and Mary, into her o ce and explained Senator Worden's request to them.

"You would be working with a short deadline. Do you want to give it a try?"

"Sure," said Mary, "but how should we go about it?"

"I'll give you all of the help that I can, but the details will be up to you. I see the job divided into three stages: First you will have to look into the chemistry involved in the production of the two fuels. Next you'll have to make a list of the fossil fuel energy inputs that go into growing corn and soybeans, for example, the fertilizer energy input, and so forth. After that you will have to look into the amount of fossil fuel energy that is required to convert each of the crops into its respective biofuel and to get that fuel to its market. e sum of all of those energy inputs will give you the gross energy input for each crop.

"Remember though," Terry cautioned, "you must subtract any energy that can be recovered from the use of side products from the gross energy input to get the net amount of fossil fuel energy required in each case.

"After you have calculated the energy needed to make a liter of each of the two fuels, you should find out how much energy is given off when a liter of ethanol and a liter of biodiesel is burned. Comparing the net energy required to grow enough corn and soybeans to make a liter of these fuels to the energy that is given off when a liter of each of the fuels is burned will give you their relative e ciencies. is is called the EIEO, energy in/energy out for a fuel. at is what we need for Senator Worden."

"We'll try to summarize the chemistry involved in the two processes and make a list of the energy inputs involved, but where can we get the quantitative data on the energy inputs and the energy evolved on combustion?" asked Mary.

"My friend, Professor Molly McCleish, is a world class expert in those areas," replied Terry. "If you call her with specific requests, she should be able to help you. She is a very busy person though and I don't want you to call her more than once. So prepare the list of information that you need very thoroughly before you call."

"Since I am the chemistry major, I suppose I should track down the chemistry involved in the two processes," offered Mary.

Upon returning from the library, Mary explained the chemistry that she had learned to Dan.

"Dan, my understanding is that the sugars in the corn kernels ferment to form ethanol and the corn stalks and husks that are left over are a useful by-product that is called 'stover.' is material can be burned as a fuel."

"Let's see if I get this," Dan said. " e corn sugars ferment to form ethanol and the 'stover' is the corn husks and stalks that are left over and that's a useful by-product, right?"

"Yes, and to form biodiesel, fats are extracted from soybeans and reacted with water and base to form both glycerol and fatty acids. en the fatty acids are reacted with methyl alcohol to form their methyl esters, and these are the actual biodiesel fuel. e base is recycled and a chemical called glycerol is formed as a useful by-product when the fats react with the base."

"I've heard of glycerol, but what is it used for?" asked Dan.

"It's a water-soluble organic solvent that is used in all sorts of pharmaceutical and cosmetic preparations," replied Mary.

"Well, Dan," Mary continued, "if you've got the picture, let's start to think about our energy inputs and outputs for making ethanol and biodiesel fuels."

Part II—Compiling Your Fossil Fuel Input/Output (EIEO) Lists

It is now time for your team to compile a qualitative list of the energy inputs that are required to grow corn and soybeans, and to convert these grains into ethanol and biodiesel fuels. You will be provided with appropriate forms on which these inputs should be entered (**Form #** and **Form #**).

When your team has completed its lists of energy inputs using Forms # and # , you should then compile a quantitative list of the energy outputs that can be derived from each of the two biofuels. ese outputs should be listed on **Form #3**. Next, compare your list with those generated by the other teams. When you are satisfied that your list is complete and does not contain extraneous items, present them to your instructor who will, as Professor McCleish would for Mary and Dan, provide you with the numbers, i.e., the quantitative values, that you need.

e quantitative values that you enter on Form #3 provide you with the numbers that you need to carry out your relative e ciency calculations for the two biofuels. e net energy value (energy in minus energy out, EIEO) that you obtain for each of the biofuels will allow you to determine each fuel's energy e ciency percentage, which is the information that Senator Worden needs. Your calculations should be performed and entered on **Form #** .

Questions

. In the event that your calculations do not indicate that Senator Worden's favored corn-to-ethanol process is more e cient than the alternative soybean-to-biodiesel process, which of the following paths do you believe that Senator Worden should take?
   - a. Ignore Mary and Dan's data completely.
   - b. Accept the students' data and switch his support from the ethanol process to the biodiesel route.
   - c. Accept that the data favor the biodiesel route, but argue that factors (political, environmental, economic, etc.) other than just energy e ciency must be considered when making this policy decision, and that these other factors favor the ethanol route.

. e traditional route for the manufacture of glycerol is based on the reaction of water with a chemical called epichlorohydrin. In addition to glycerol, hydrochloric acid, a strong acid, is also formed in this reaction.
   - a. Would you expect the formation of biodiesel from soybeans to impact the viability of this process?
   - b. "Green" chemical processes are those that have a minimal impact on the environment. Which route to the formation of glycerol, biodiesel or epichlorohydrin is more "green"? Explain your reasoning.

3. What societal consequences would result if increasingly large amounts of corn and/or soybeans are used for the manufacture of biofuels?
4. Farmer's organizations and large manufacturing corporations such as Monsanto and the Archer Daniels Midland Company lobby actively in support of grains to biofuels processes, whereas environmental groups are generally opposed to these processes. Explain the reason for these opposing views.

Form #1

Corn to Ethanol Energy Inputs

Farm Energy	**Energy (Kcal/L)**
1)	
2)	
3)	
4)	
etc.	
Total:	

Non-Farm Energy	**Energy (Kcal/L)**
1)	
2)	
3)	
4)	
etc.	
Total:	

Form #2

Soybeans to Biodiesel Energy Inputs

Farm Energy	**Energy (Kcal/L)**
1)	
2)	
3)	
4)	
etc.	
Total:	

Non-Farm Energy	**Energy (Kcal/L)**
1)	
2)	
3)	
4)	
etc.	
Total:	

Form #3

Corn to Ethanol Energy Outputs

Energy (Kcal/L)

1)

2)

3)

etc.

Total:

Soybeans to Biodiesel Energy Outputs

Energy (Kcal/L)

1)

2)

3)

etc.

Total:

Form #4

Overall Efficiency Calculations for the Ethanol and Biodiesel Systems

Total Energy Input, Ethanol (Kcal/L): ______________

Total Energy Output, Ethanol (Kcal/L): ______________

Overall Percent Energy Efficiency (EI/EO) Calculation, Ethanol:

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Total Energy Input, Biodiesel (Kcal/L): ______________

Total Energy Output, Biodiesel (Kcal/L): ______________

Overall Percent Energy Efficiency Calculation, Biodiesel:

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