

Order from Chaos (hopefully): A Preliminary Protocol for Determining EROI for fuels

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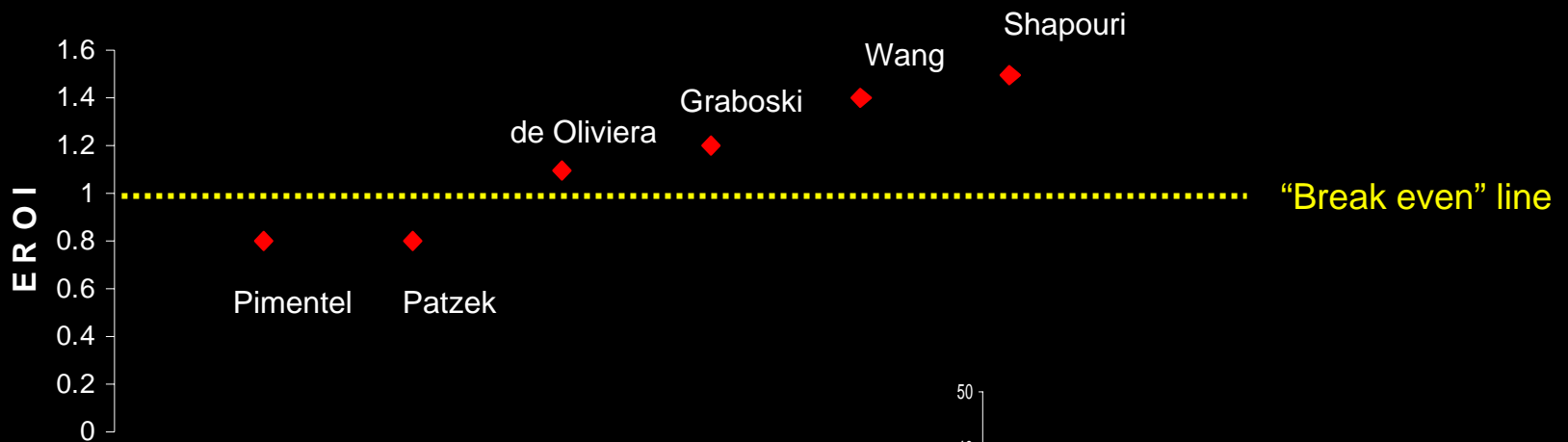
David Murphy

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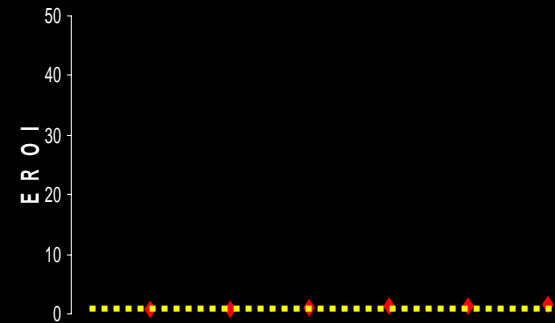
With thanks for financial support to
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The Main Problem

- Different results cause much confusion
 - e.g. EROI from corn-ethanol



- Why are these numbers different???



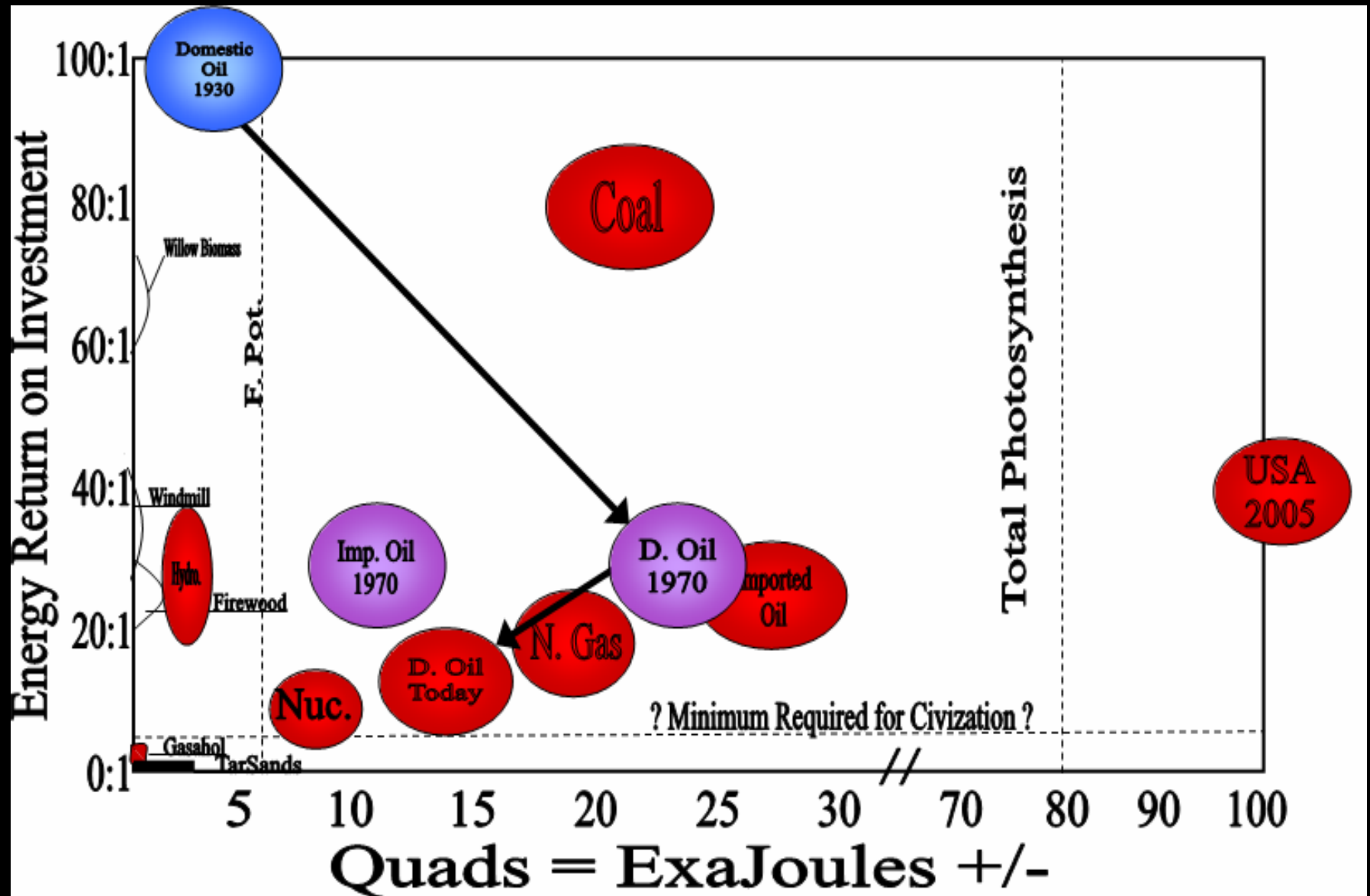
...or are they?

Reasons for the Problems

1. Need potential magnitude of fuel as well as EROI
2. Lack of explicit protocol for how to measure inputs
3. Often lack of explicit statement of assumptions, methods, and objectives
4. Importance of time and space
 - i.e. static, time series, projections (w/technology, depletion)
5. Determination of Boundaries – MOST IMPORTANT

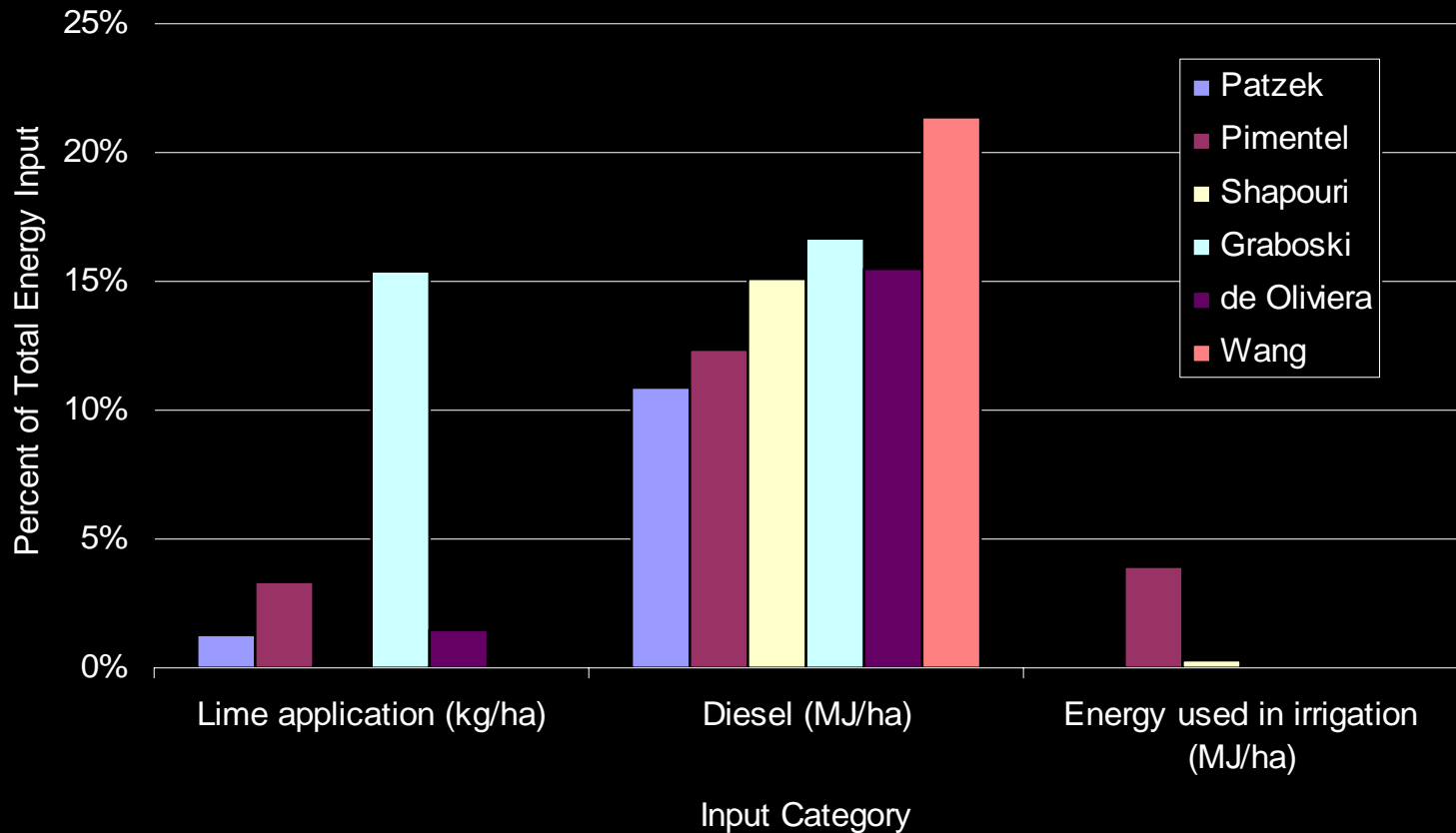
We seek your criticisms and contributions to this important issue – chall@esf.edu

1. Magnitude



2. Explicit protocols for inputs

Percentage of Total Energy Use in Agriculture for Selected Inputs

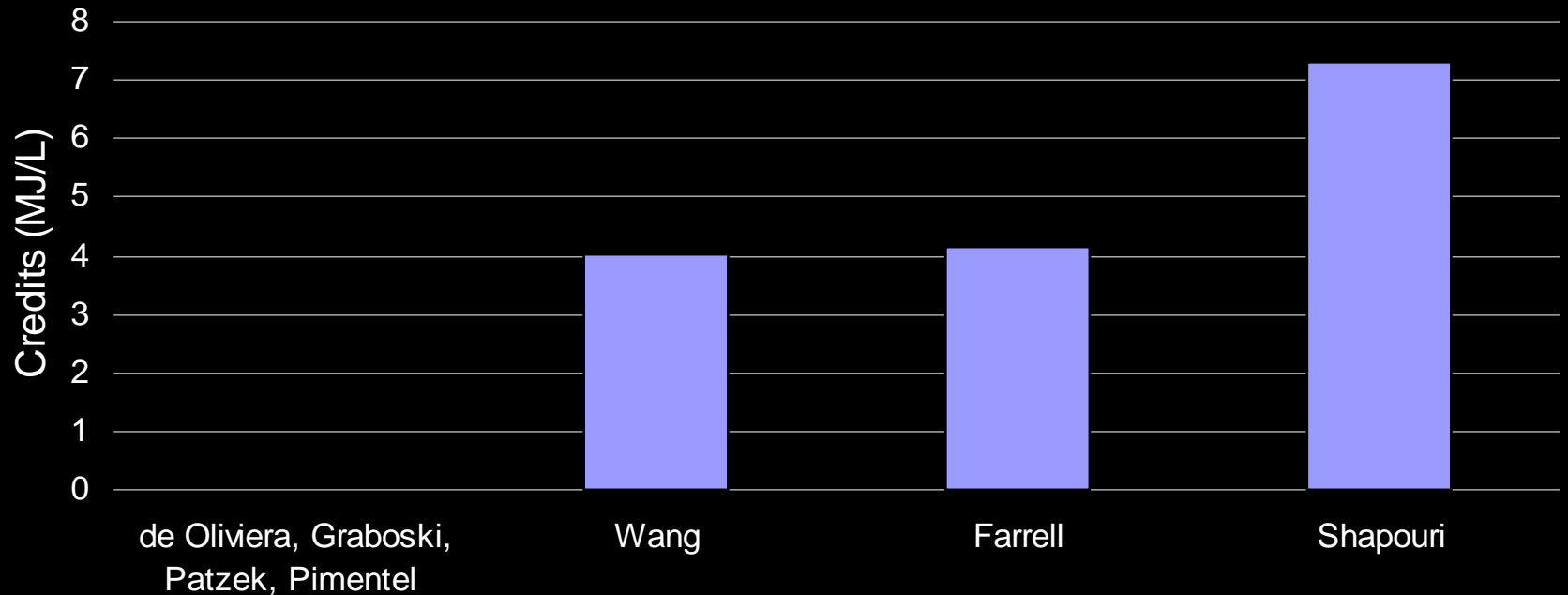


Estimates of agreed upon inputs are generally not the major reason for EROI disparities...high estimates often balance low estimates in different publications

3. Different weighting (including zero) for coproducts

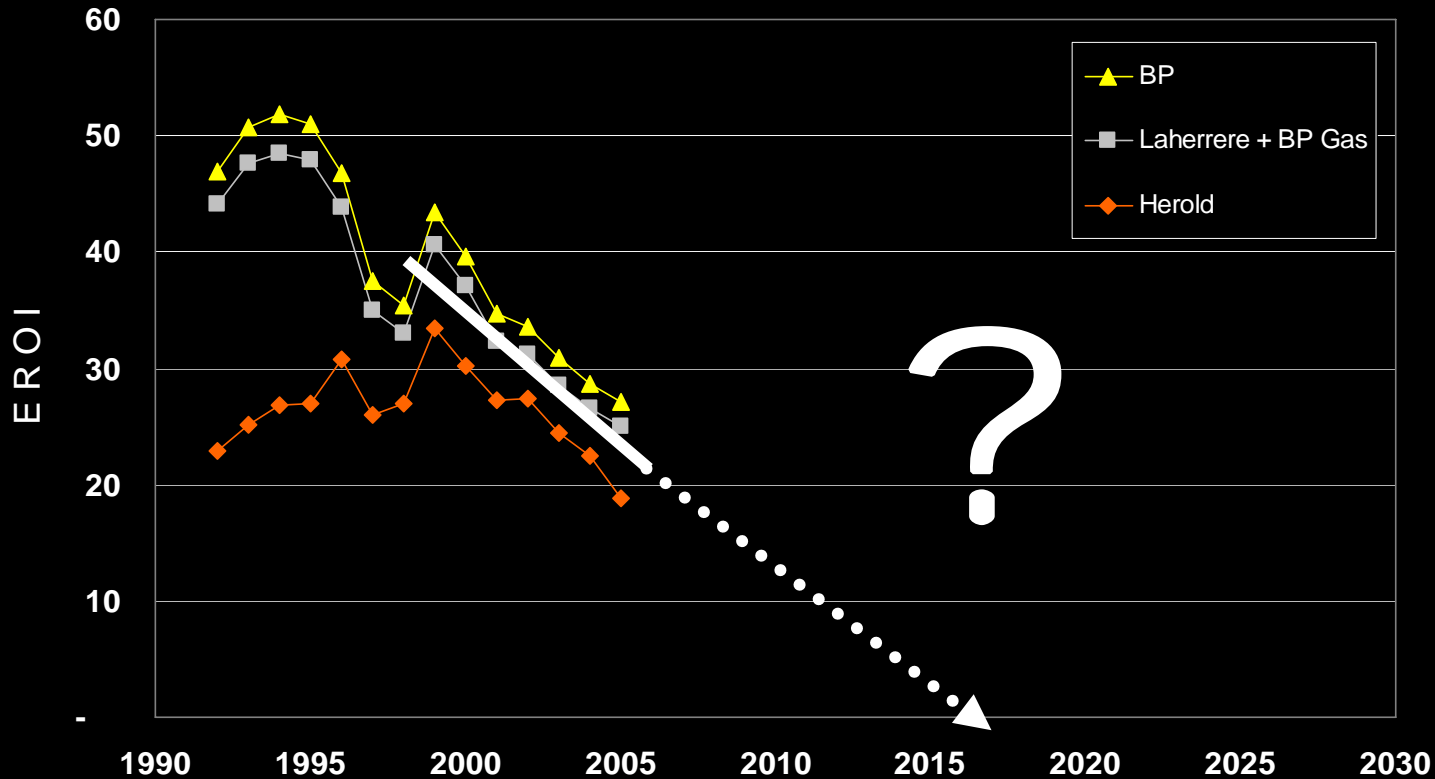
e.g. Cow food

Published Coproduct Credits for Corn-Ethanol Production



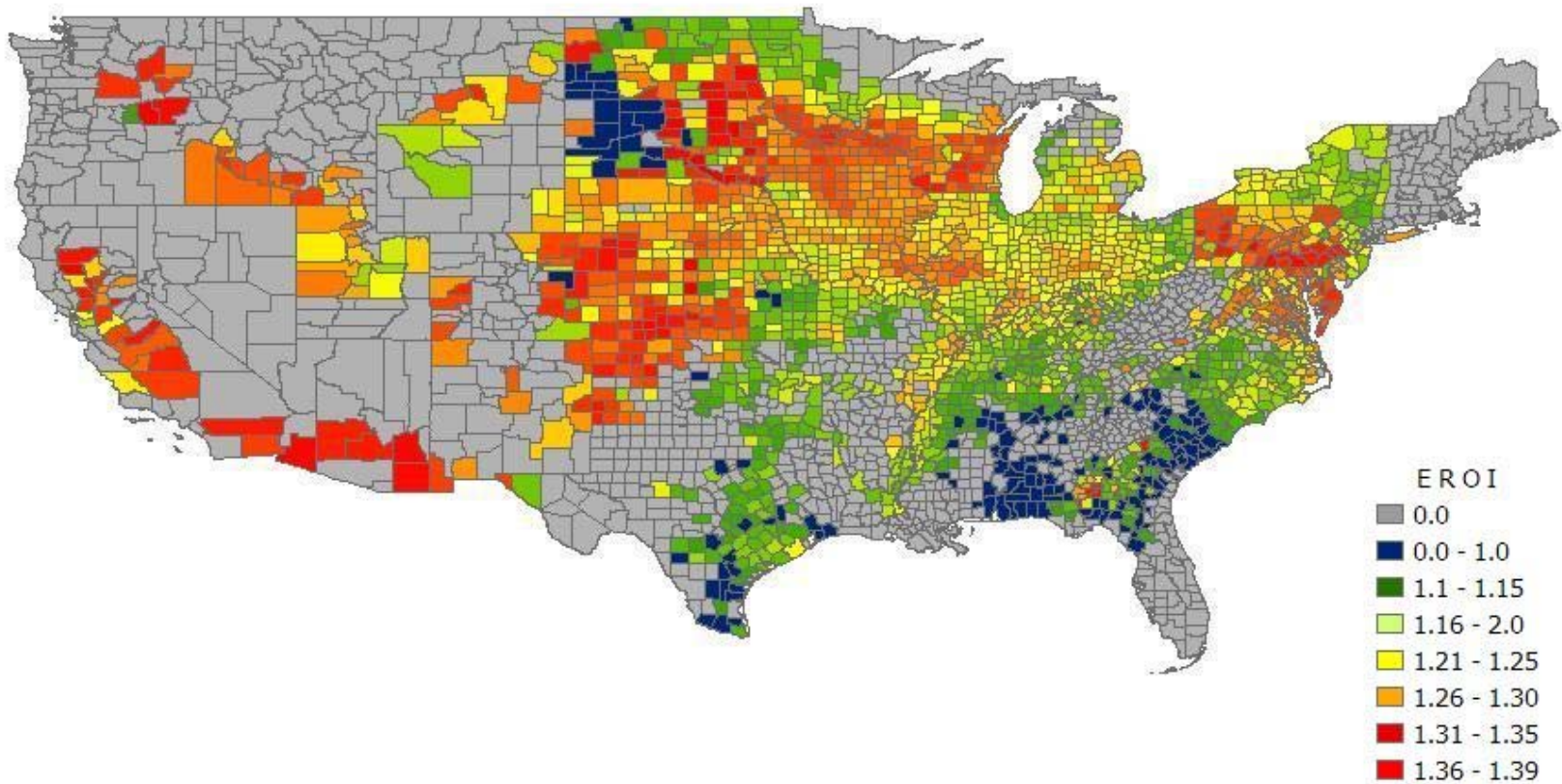
4a. Time: series & projections

EROI for Global Oil and Gas



4b. Space

U.S. Corn - Ethanol EROI



5. Conceptual Boundaries: E_{out}

Where in the production chain do you measure it?

- Earth's Surface?
- Refinery Output?
- Final Demand?



5. Conceptual Boundaries: E_{in}

The Problems: Boundries

Big Question: What is E_{in} ?

$$EROI = \frac{E_{out}}{E_{in}}$$

Subsidies

Externalities

Fuel vs. Energy production

E_{in} Indirect (?)

Steel Mill

Constru and Depreci

E_{in} Direct

E Direct

E Direct

E To Allow Use?

Environment (?)

- Pollution
- Soil Erosion
- Loss of Ecosystem

Labor Support ?? e.g.

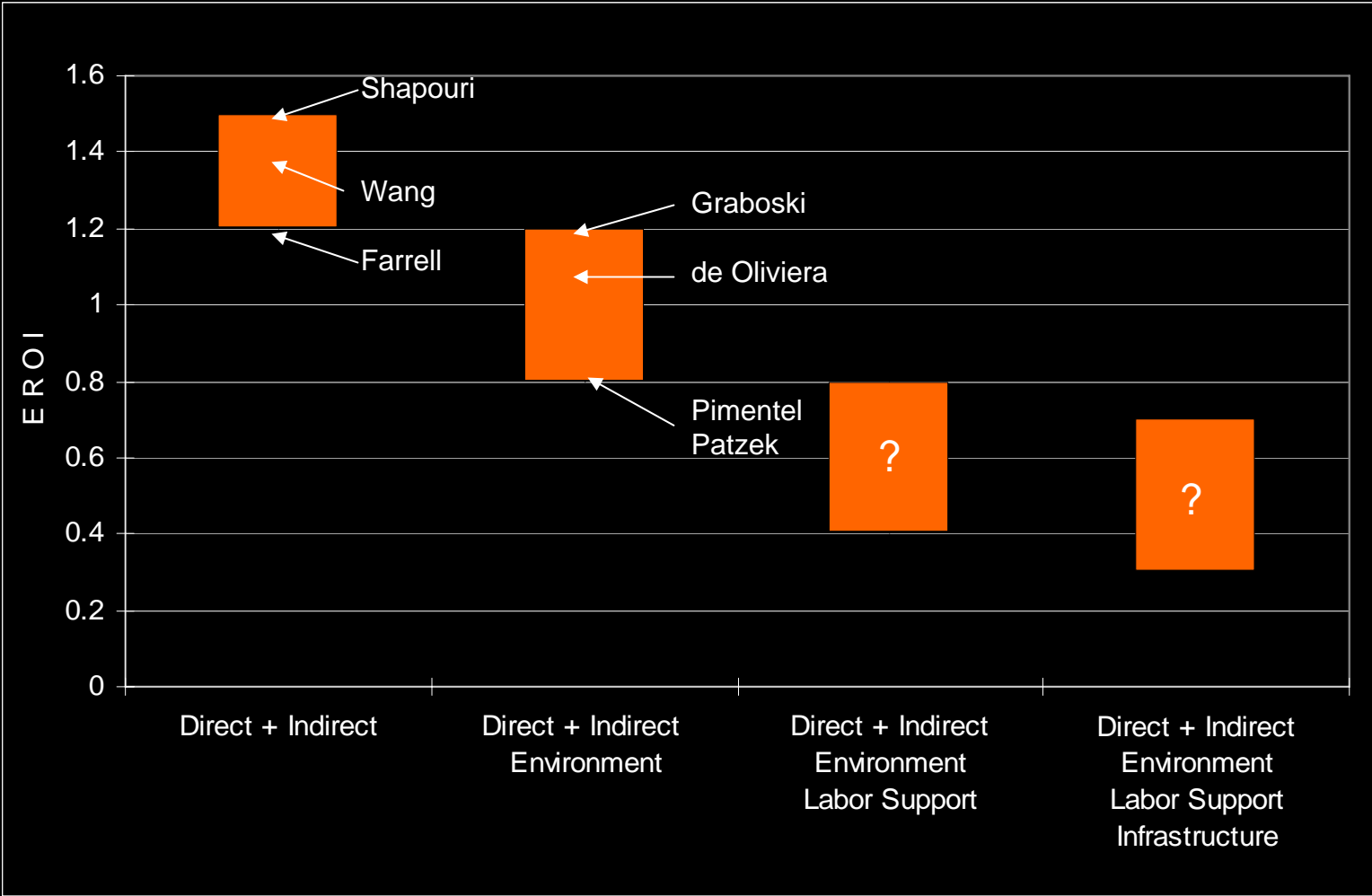
Depreciation

- ? Medical
- ? Replacement
- ? Homemaker
- ? Food
- ? Education

Environmental Cost



Estimating Effect of Boundaries



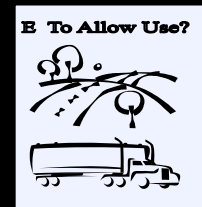
Proposed Macro-protocols

Start from Base Case

- Use objective hypothesis testing
- Use actual working technologies
 - i.e. corn vs cellulosic ethanol
 - After base case is done, then one can project technological change, impact of depletion, etc.
- E_{out} Should be at point of final demand
 - i.e. gasoline not crude oil...
 - (even if we don't do this now)
- Other assumptions can be used if compared to base case

Steps

1. Define Objective
2. Define Boundaries
 - a) Energy_{out}
 - b) Energy_{in}
 - c) Environment
 - d) Labor Support
 - e) Infrastructure
 - f) Other
3. Define Quality
4. Define Units



Environment (?)
- Pollution
- Soil Erosion
- Loss of Ecosystem



1. Objective

- Usually:

$$\text{EROI} = \frac{\text{Energy Output}}{\text{Energy Input}}$$

2a. E_{out}

- Define the substance for which you are calculating EROI
- Be explicit about where the output is being measured (refinery gate, pump, etc.)

2b. E_{in}

- Determine in energy units, if possible
- If energy units unavailable, convert
 - MJ/\$GDP \cong 9.0 MJ/\$ (USA, 2004)
 - Heavy Construction \cong 13.3 MJ/\$
 - Oil Industry \cong 20.0 MJ/\$

4. Units

- Define inputs and outputs in SI energy units
 - 1 bbl crude oil \cong 6.16 GJ
 - 1 ton bituminous coal \cong 25.82 GJ
 - 1000 ft³ natural gas \cong 1.09 GJ
- BUT not all outputs are created equal (different qualities of oil, etc.)

Protocol Table

| | Original Value | Conversion Ratio | Final Value (SI Units) | Rationale |
|----------------------|----------------|------------------|------------------------|-----------|
| Direct*: i) Gasoline | 40 L | 42.4 MJ/L | 1,696.0 MJ | |
| ii) Diesel | 88 L | 47.7 MJ/L | 4,197.4 MJ | |
| iii) Electricity | 13.2 kWh | 3.6 MJ/kWh | 47.5 MJ | |
| Indirect | | | | |
| Environment | | | | |
| Labor Support | | | | |
| Infrastructure | | | | |

The End