

Biodiesel: Technology, Economics and Politics

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November 2008

acknowledgements to:

1. Dr Daniel Ginosar
2. Dr John Benneman
3. Nordic Biodiesel



Firstly:

*The terrible twins that trouble us
nowadays*

Peak Oil and Global Warming



Why we like liquid fuels



try doing this with hydrogen or
with batteries



In this talk ...

- Global warming: positive proof
 - Biodiesel: what it is
 - Biodiesel and greenhouse
 - Supercritical methanol
 - Why SC-methanol process is not in use today
 - Why biodiesel companies have gone bust
 - Is Algal biodiesel the answer?
 - The future of transport
-
-

Positive proof of global warming.



**18th
Century**

1900

1950

1970

1980

1990

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Definition of Biodiesel

Biodiesel – mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats.

FAME = Fatty Acid Methyl Ester

FAME is not Biodiesel until it meets the relevant standards



700 tonne/day biodiesel plant central Greece

How "Green" is Biodiesel ?

- The naïve or is it diplomatic view from Alfa Laval's *here* magazine (Nov. '07):
- "Because it is carbon dioxide neutral, its use does not contribute to greenhouse gases in the atmosphere, which many agree is what fossil fuels do."



Biodiesel is not as "green" as that

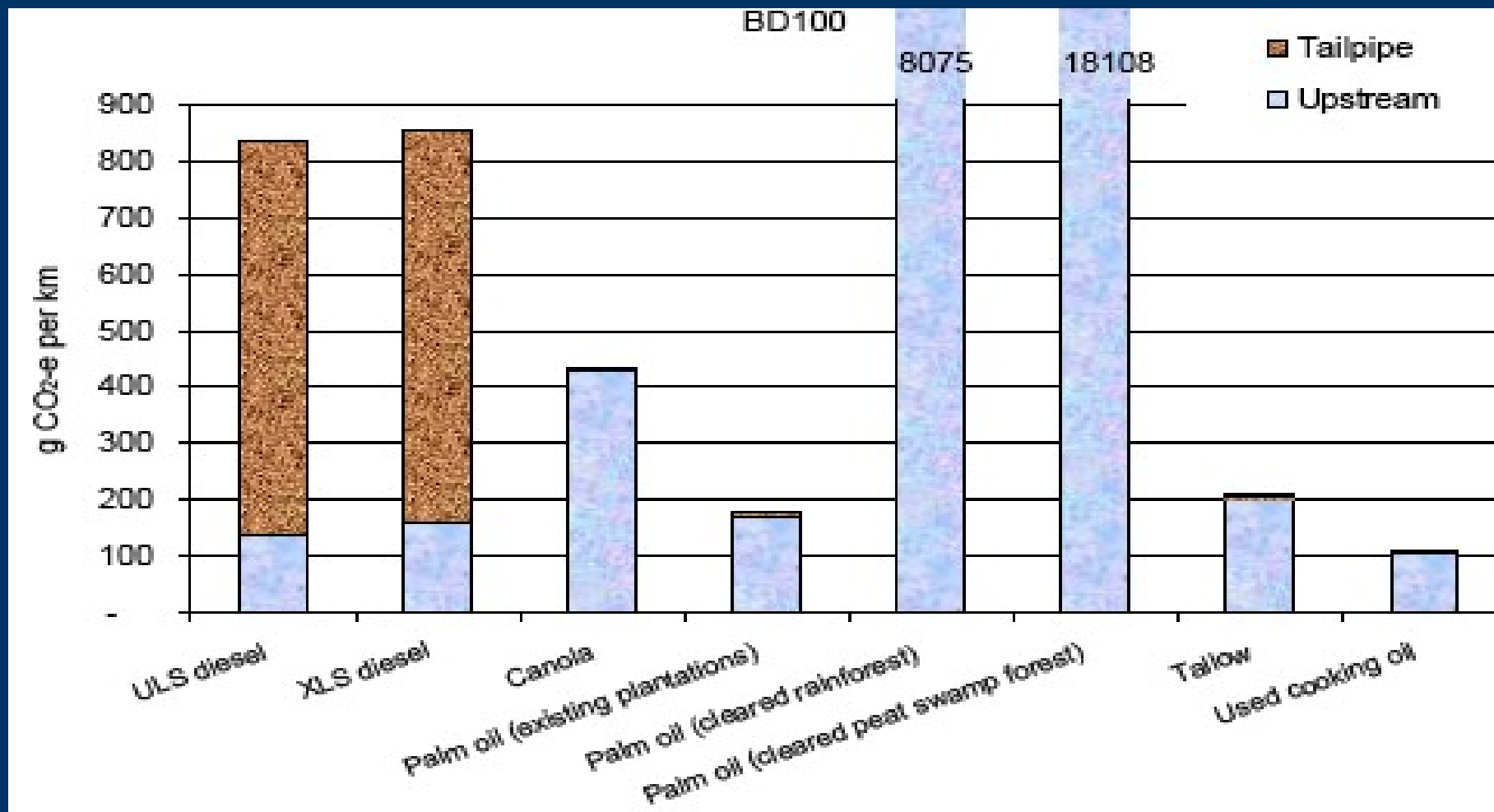
Jungmeier et al. 2003 Greenhouse gas emissions
(gCO₂e per kwatt-km)

Petroleum Diesel:	200
Biodiesel sunflower oil:	65
Biodiesel rapeseed oil:	110
Used frying oil:	-10

BUT note:

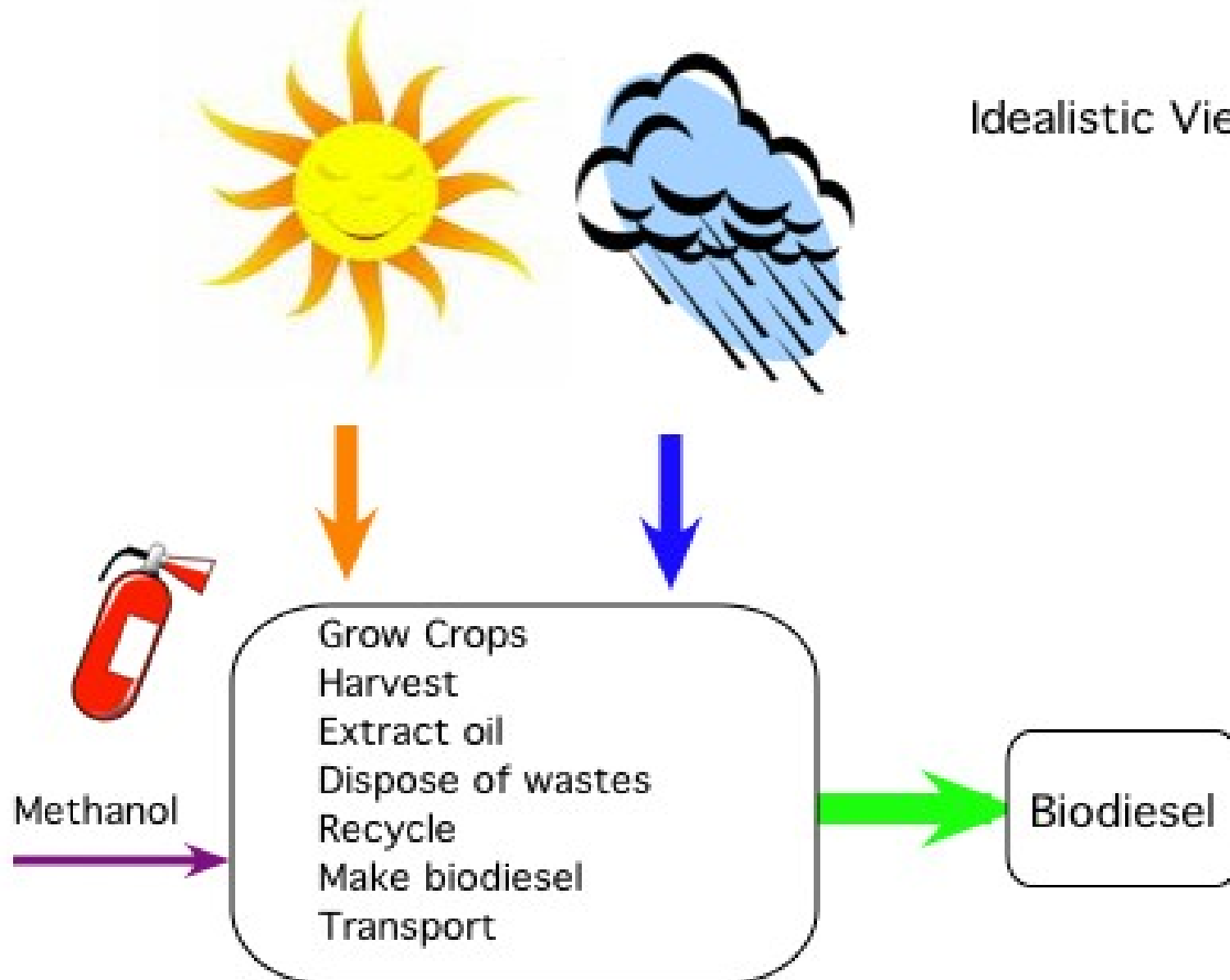
Up to half the GHG emissions from biodiesel are
due to N₂O from agriculture and combustion.

Comparative GHG releases

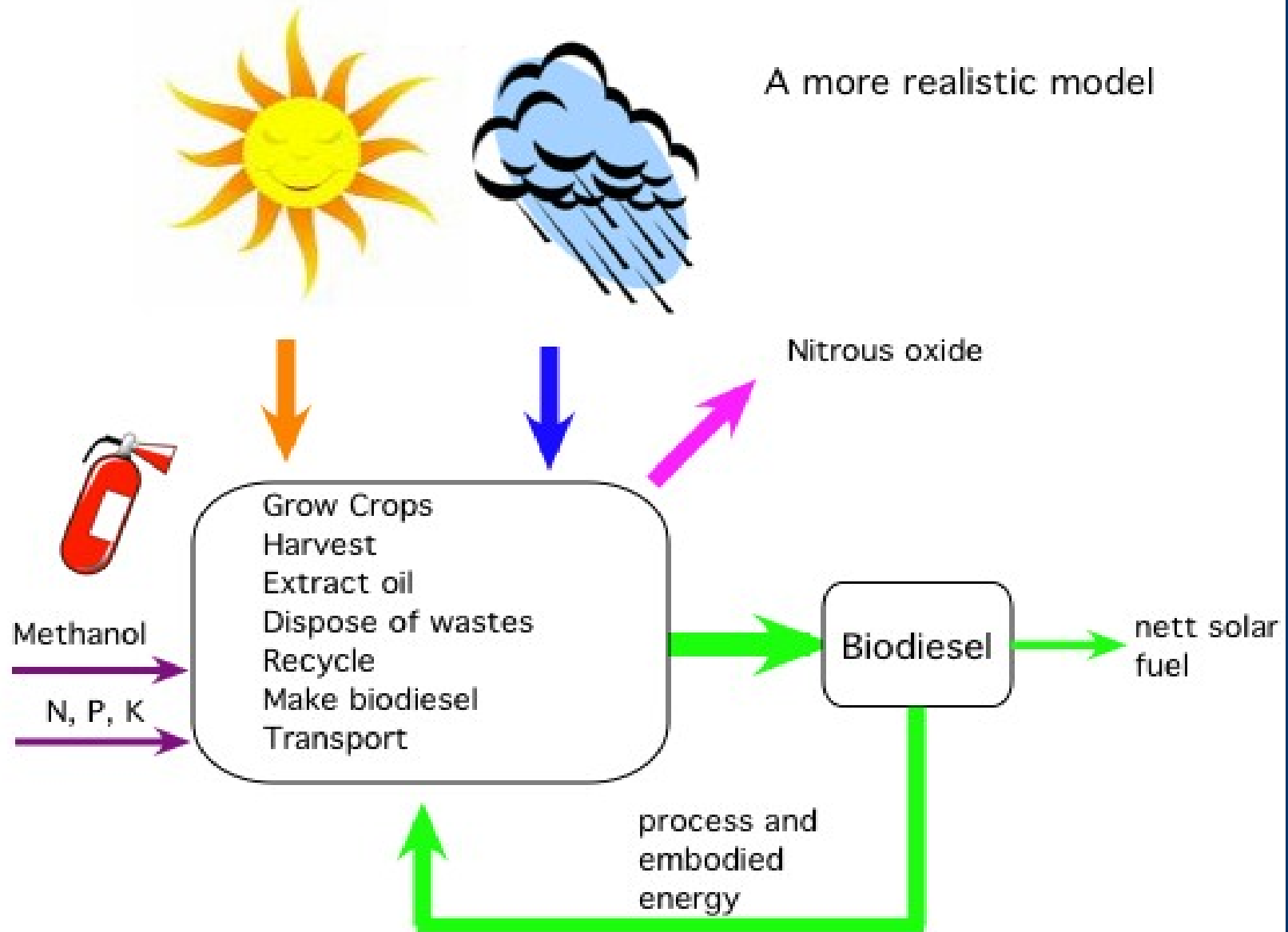


CSIRO Report August 2007

Idealistic View



A more realistic model



More recent studies present a gloomier view

80% of Europe's biodiesel comes from rapeseed, whose nitrous oxide (N₂O) emissions, required in fertilizers for growing, does global warming damage 1 to 1.7 times the CO₂ saved from using fossil fuels; corn bioethanol's factor is 0.9 to 1.5; but sugar cane bioethanol is sustainable at 0.5 to 0.9.

Posted by envirostats on Saturday, September 22, 2007

Nitrous Oxide

- GHG intensity $\text{N}_2\text{O} = 300 \times \text{GHGI}(\text{CO}_2)$
 - released from agriculture (3% to 5% of nitrogen fertilisers applied to canola)
The Times September 22, 2007
 - Nitrogen over-applied to crops?
 - N_2O release from biodiesel engine >> petrol. diesel
-
-

Biodiesel and Sustainability

- Australia uses 14 billion litres/year of diesel
- Less than 1% of which is biodiesel
- Compare yearly per head consumption:
 - Petroleum fuels (>1500 litres)
 - Cooking oil (10 to 20 litres)

To replace Petroleum Diesel completely using Canola (Rapeseed) Biodiesel

Crop yield: 2 tonnes per ha ($\text{ha} = 0.01 \text{ km}^2$)

To make 14 billion litres of biodiesel

Use 30 million tonnes of canola

Area needed: 15 million ha = 0.15 million km^2

Area of Australia = 7.7 million km^2

Fraction required biodiesel crop: 2%

Current crop coverage: 5%

40% increase in crop area needed

Big problems: (i) water for irrigation (ii) fertilisers

Times are tough for biodiesel companies...

- Mission Biofuels Ltd says current high feedstock prices make it unviable for to consistently produce biodiesel for the foreseeable future.
- Biofuel production has been criticised for creating ecological problems and diverting crops away from food supply, amid growing concern about global food shortages.

SMH 7th May 2008

ARF share price over 3 years

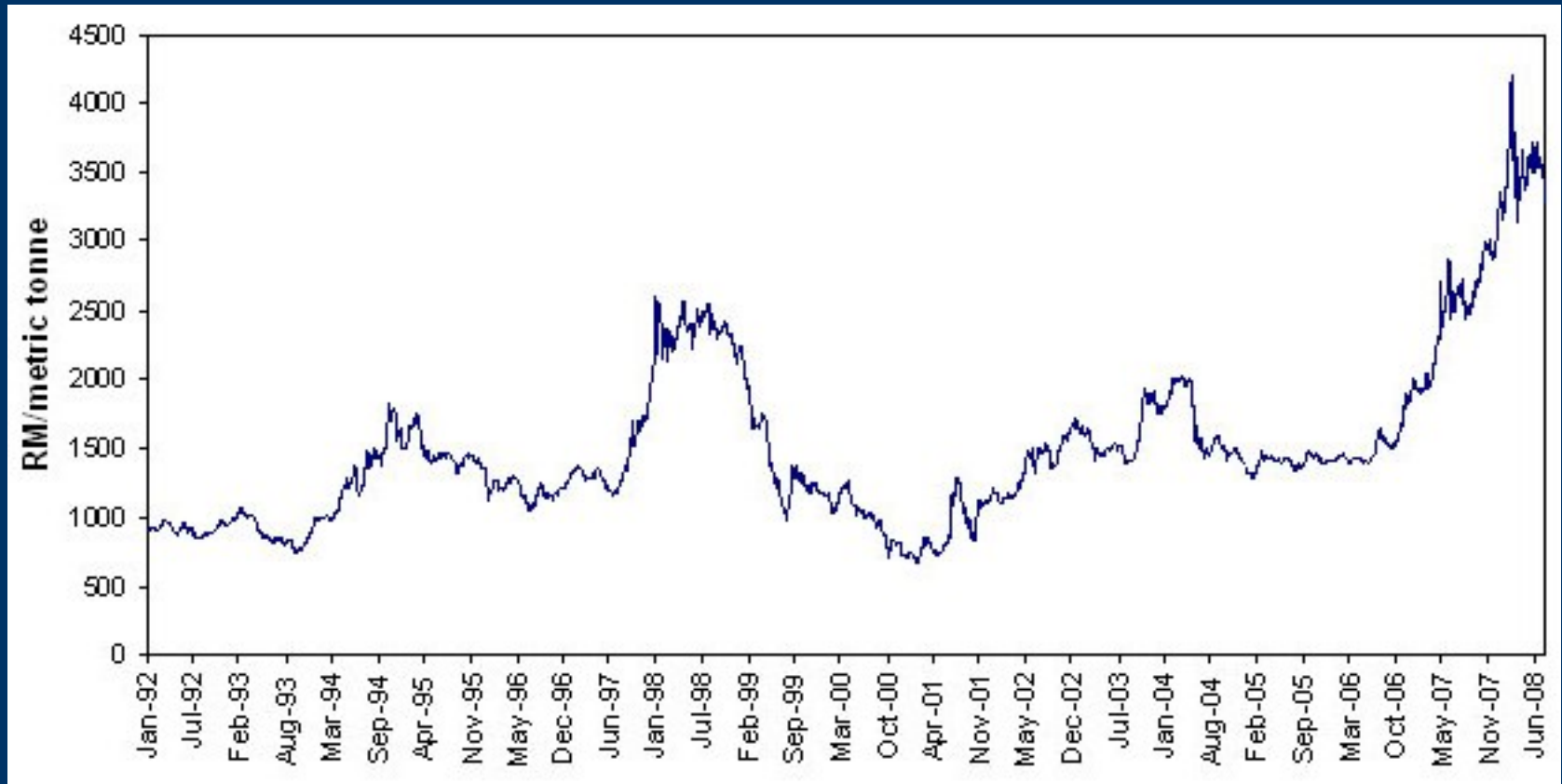


Aug 05

Aug 08

here is one reason... Palm oil (Kings Malaysia)

raw materials >85% costs



Oil Price (US\$/b)
65

92

130

Solution !

- Use cheap waste oils and fats
 - **Problem !**
 - Waste oils contain FFAs
 - There is no cost effective, elegant, neat process for FFAs
 - Sulfuric-acid ? KOMe ?
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-

Enter Supercritical Methanol

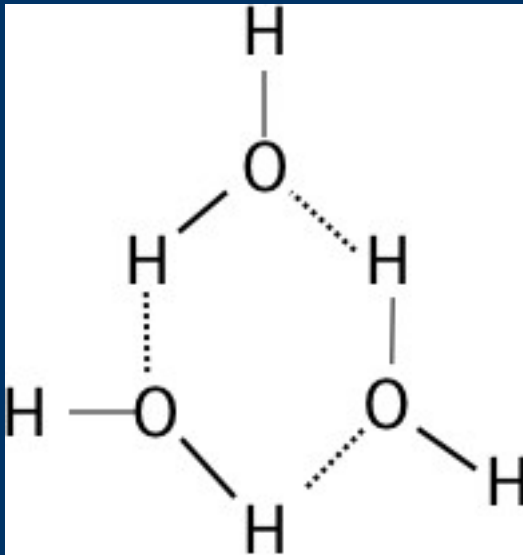


add any old waste oil and make
biodiesel in 4 minutes*

Temp > 240 deg C
Pressure > 80 bar

*Saka and Kusdiana Kyoto U

Structure of SC Water and Methanol ?



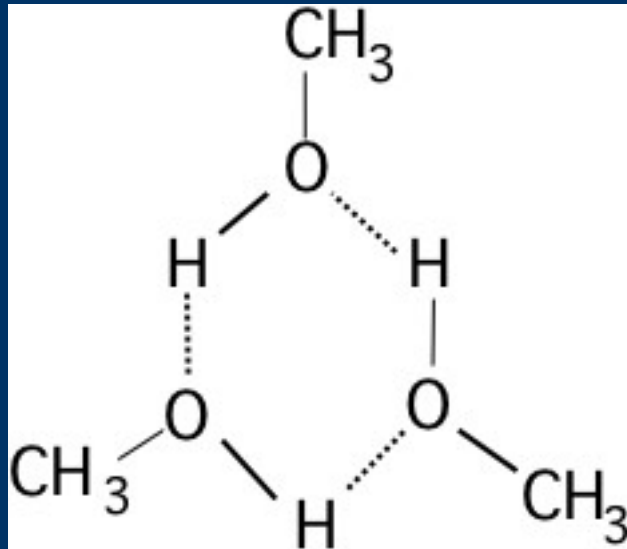
Conjecture, 1991.
3-molecule "benzene-ring"
structure

Symmetry explains
low polarity of SC
water and oil
solvency

Ring structure
explains decreased
dissociation to H^+
and OH^-

Structure of SC Methanol

TYamaguchi (Fukuoka, Japan), CBenmore, A Soper (1999)

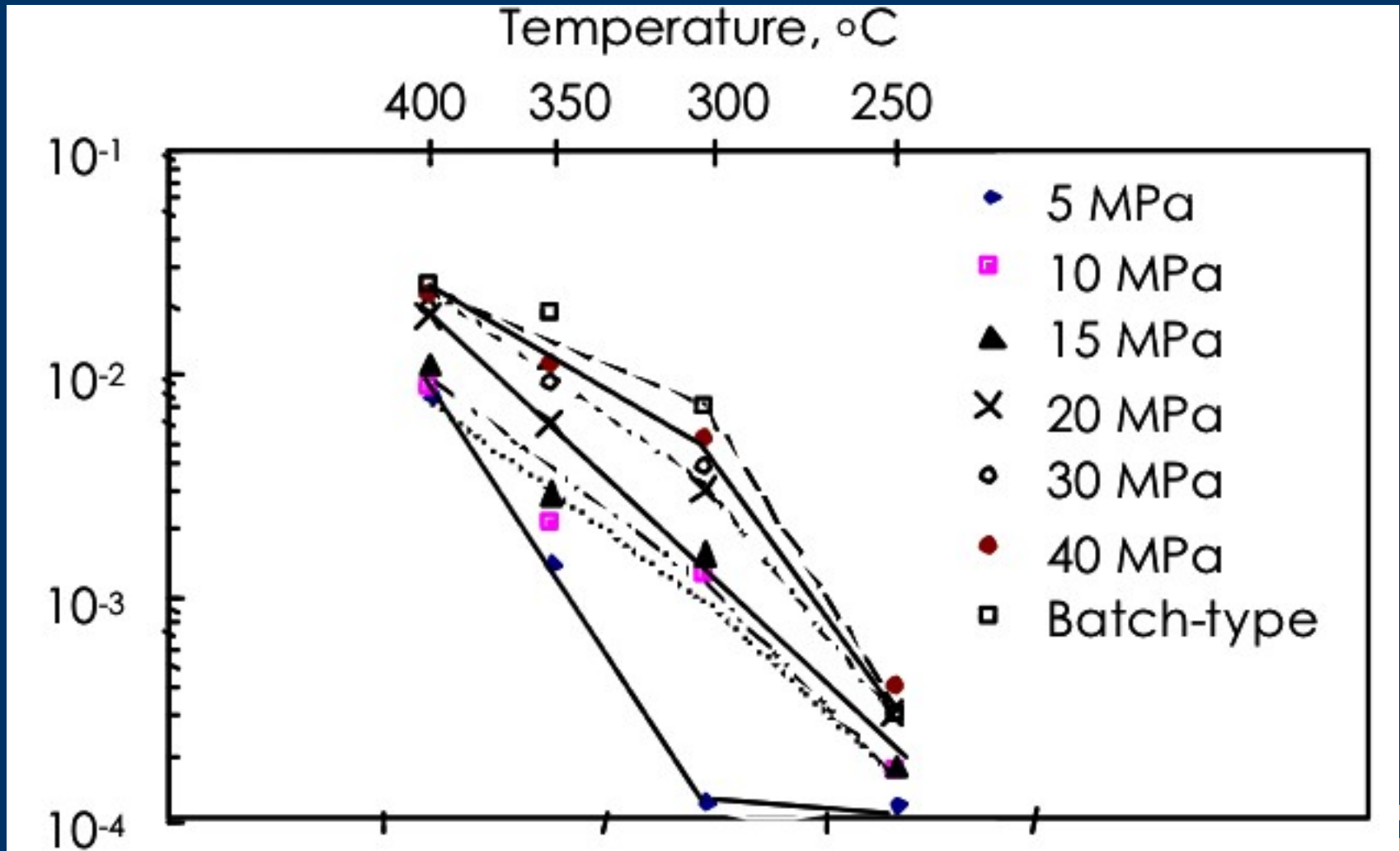


At high temperatures however the chains are more likely to curl back on themselves to form small ring-like clusters

hypothetical 3-molecule ring

Arrhenius plot: methanol vegetable oil, 42:1

(Saka and Kusdiana 2001)



This would explain the kinetics...

SC Methanol forms ring clusters with high solvency for hydrophobic oil unlike liquid methanol.

High temperatures promote both forward and reverse reaction rates.

Water should promote the reverse reaction limiting conversion.

- Immediate reaction
- Wow! Make biodiesel, with no catalyst in 240 seconds! It works with FFA as well.
- When can I start?

- **Later reaction**

- Did they say 42:1 methanol: oil ?
- Who is this Dr Ginosar who holds the patent on supercritical everything?
- Isn't the gear expensive ?

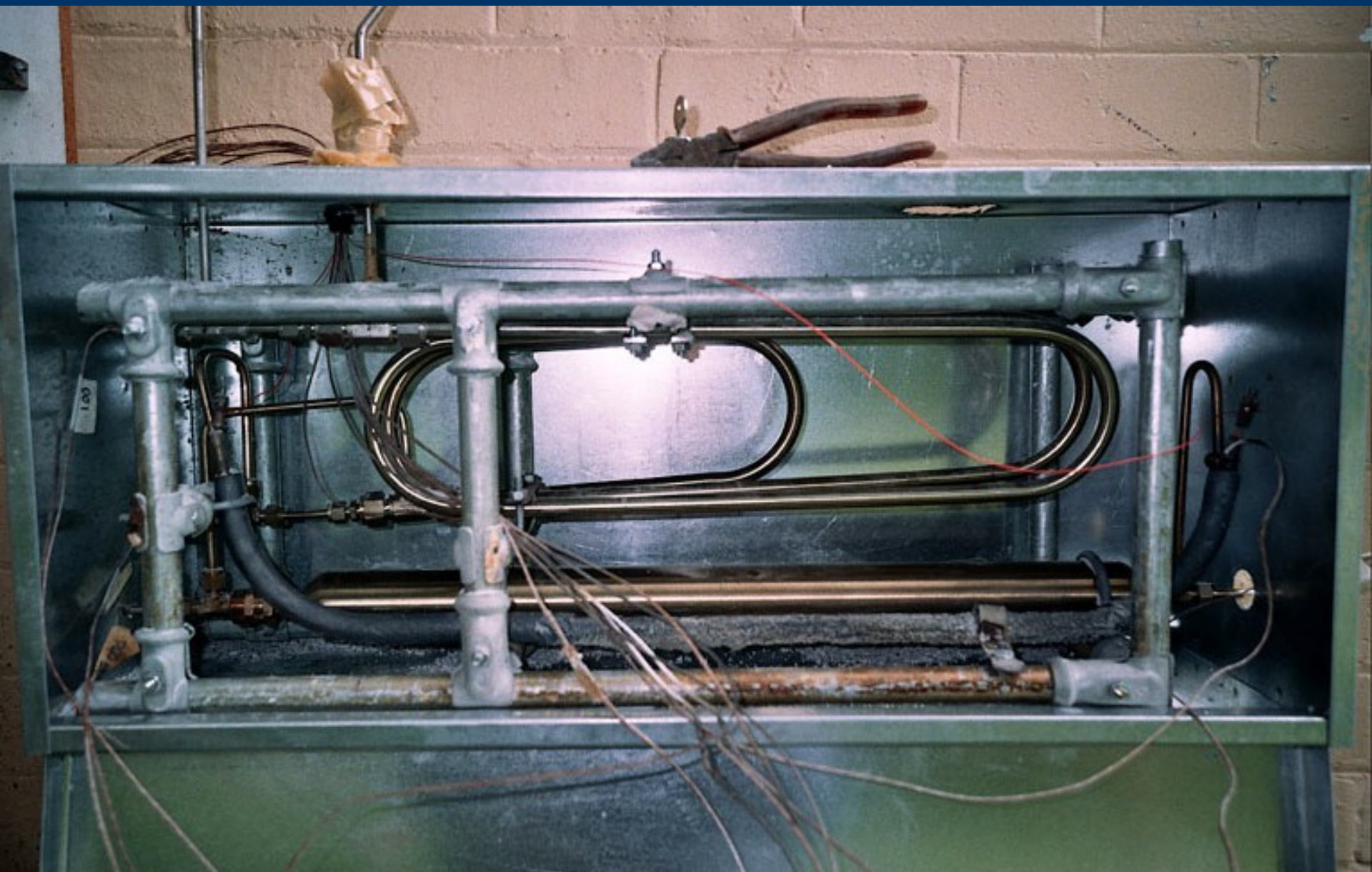


Dr. Daniel M. Ginosar

But it was too late



inside the hot box





*Mac-
Controller
running
SC
methanol
plant*

Traps for young players

SC MeOH s.g. is 0.4 (not 0.8)

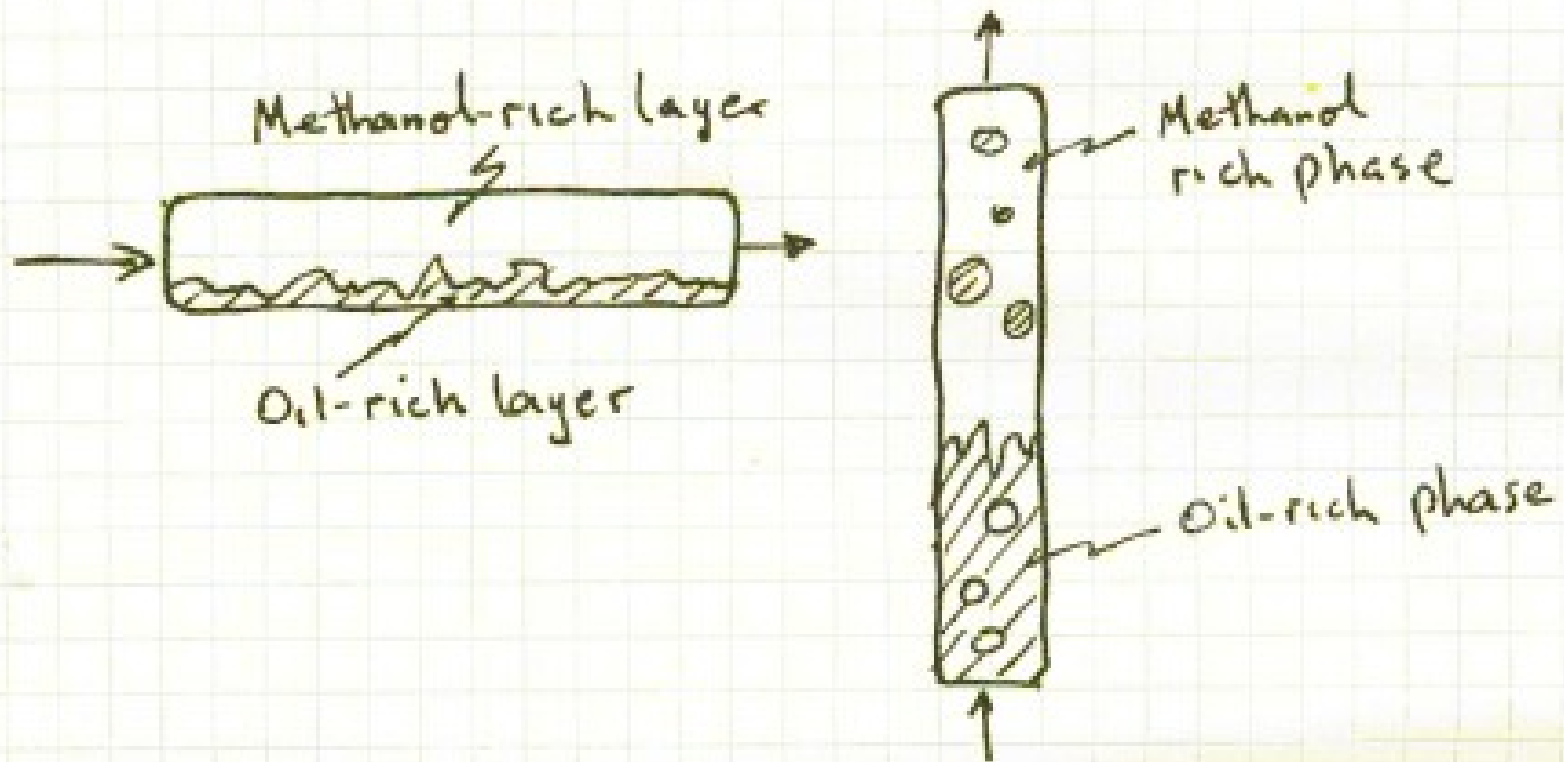
Need a catalyst for best results.

*SC MeOH does not form an
homogenous mix with oil.*

2 passes needed to reach Standard.

*RESULT: reactor is at least 8 times
bigger than you first thought.*

Inside a Supercritical reactor



Why SC MeOH is not economic

Fast Kinetics both forward and reverse reactions

High ratio MeOH : Oil = 42 : 1

High recycle rate (39 moles per 3 moles used.)

Large capex (the plant and the still)

Large opex (the heat to run them)

High pressure reaction

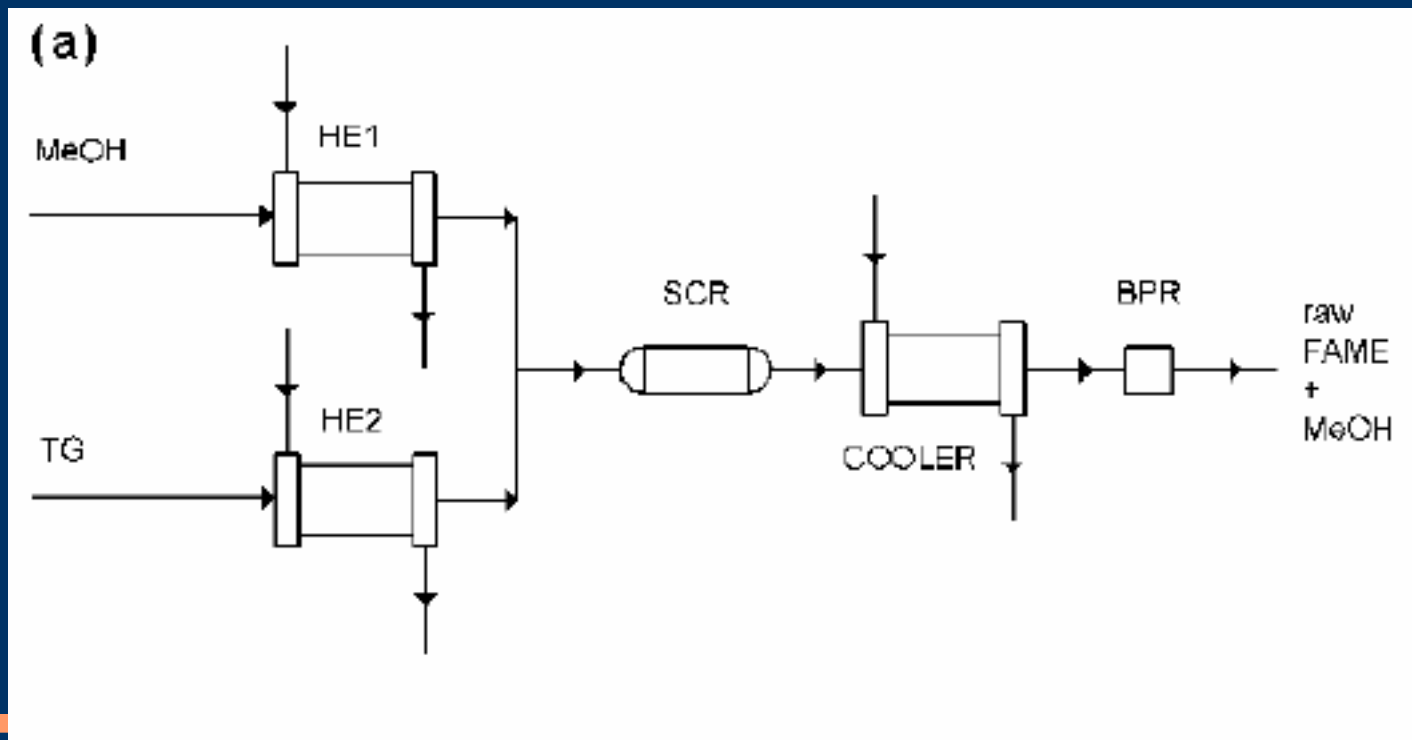
Feed pump, reactor and heat exchanger are expensive

Need two passes → two reactors in series

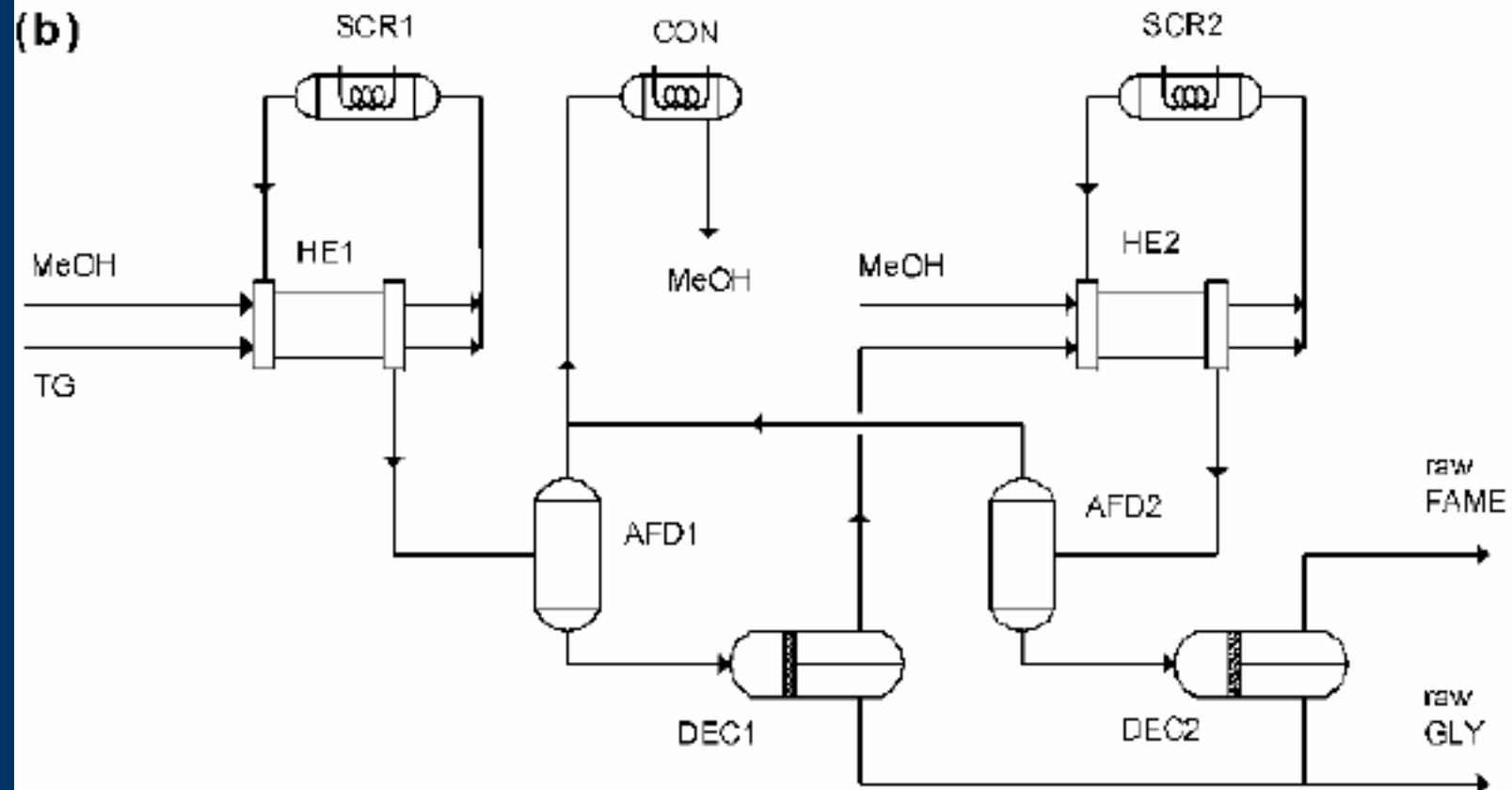
Simple SC MeOH Process

(Vera et al.)

High Opex



2-stage SC process: removal of glycerol. High Capex



How do we Esterify FFAs cheaply

- SC methanol is not cost-effective
- H_2SO_4 (erk)
- Potassium methoxide (\$\$ and erk erk)

Enter Heterogeneous Catalysis

1. Heterogeneous catalysts are not used up.
2. They do not make soap with FFAs.
3. Product needs minimal washing

Can we invent a process that does this?

Yes (I hope so): the SN2 Process for FFA

SN2's FFA biodiesel pilot plant



Novel design
specifically for
high FFA oil.

Solid state
catalyst.

Built in QLD,
Patentable IP.

Wish I could say
more.

Free Fatty Acid (FFA) levels in Feedstocks

Biodiesel feedstocks vary from edible oils to stinking wastes

- Refined vegetable oils < 0.05%
 - Crude soybean oil 0.3–0.7%
 - Restaurant waste grease 2–7%
 - Animal fat 5–30%
 - Trap grease 75–100%
-
- Clearly a niche market... back to the TTs
-
-

Algae to Biofuels ?

- Absorb CO₂
 - Convert to liquid fuels
 - Solve 2 problems at once: Peak Oil and Global Warming.
-
- What does it cost?
-
-

Comparative Oil Yields

Crop	OilYield tonnes/ha/year
Soy	0.31
Sunflower	0.56
Canola	1.2
Jatropha	1.5
Palmoil	4.0
Algae realistic	46
Algae unrealistic	184

Benneman, J. A brief history of microalgae biofuels at the Microalgae biomass summit November 2007”



Mixed ponds as used by 98% of commercial microalgae plants

Algae to biodiesel

- High capex: land + ponds
 - \$10 million per km²
 - High opex: Circulating pumping and harvesting \$100 per tonne of biomass
 - Oil manufacturing costs about USD 0.7/litre before we make biodiesel.
-
-

Vertical flow algal bio-reactor

looks great: what does it cost to roof over a small country ?



Issues with Algae

- Light absorption eff= 2%
 - Weak intensity can reach eff. = 20%
 - No obvious way around this
 - Huge volumes of water to move about
 - Area to deliver all USA's diesel needs is 40,000 km² to 150,000 km² (US DoE)
 - Capex = \$400 to \$1500 billion
-
-

Can we lower Algae Costs ?

- No concrete: Make a lake on flat ground
- Use saltwater
- Use a floating harvester
- Direct output from PS to lake (if poss.)



Algae Harvesting Barge

- # Jatropha

- Waste land
 - Does not need water
 - Cannot eat it: toxic
 - Yield: 2 tonnes per hectare per year
 - Algae looks better by 20 times in yield
 - Jatropha looks good in terms of capex.
 - Africa's mixed experiences
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Can we consume fuel in the future the way we do now?

- GHG issues aside... we are too reliant on petroleum for transport and food.
- Can we do with less?



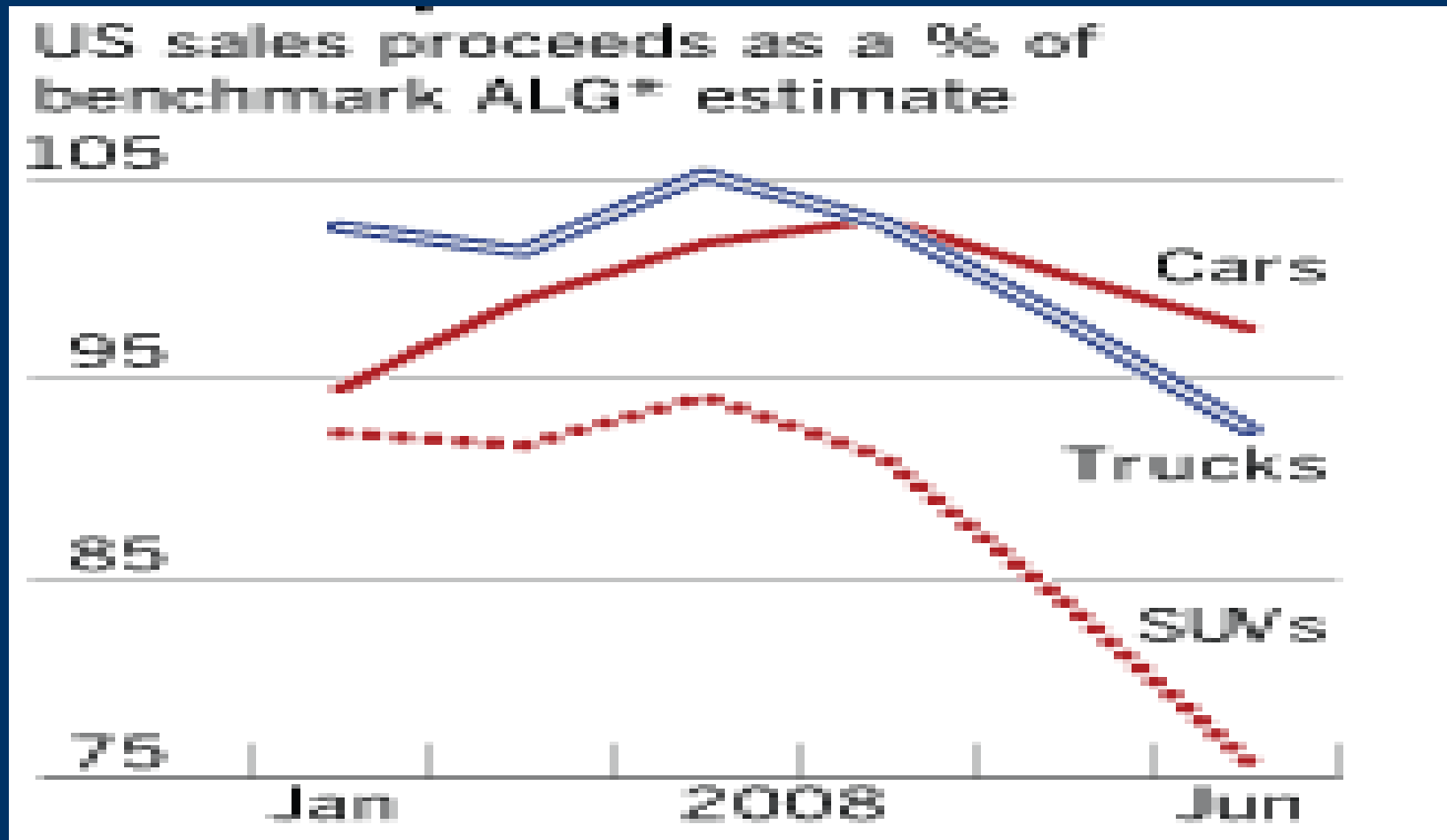
*Do we really need a 200-kwatt
Urban-Assault Vehicle (UAV) to
pick up the drycleaning or...*



... or would the No-More-Gas battery car, 120 kph, be more suitable ?



The market is saying so...



*but we may need to
segregate traffic*



Some energy balances

- To feed one American takes 1500 litres of petroleum per year*.
- Food contains roughly 1/10th the calorific value of the petroleum used to make it.
- Conclusion: Food is made from petroleum.
- *http://www.fromthewilderness.com/free/ww3/100303_eating_oil.html

Summary and conclusions

- Food-crop Biodiesel cannot replace petroleum
 - Not a “green” fuel
 - Nitrous oxide, alienation of cropland, burning forests etc
 - Waste oils and fats provide a niche market for biodiesel
 - Private vehicles are too thirsty
 - Why not Algae ?
 - Think now as if petroleum was all gone.
-
-

The legacy of petroleum and our Mission to find Alternatives

- We live in unprecedented luxury largely because of petroleum.
- Let's thank petroleum for its bounteous advantages. We have to go it alone from here.



References

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