Biorefining Opportunities in the Biodiesel Sector

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Biorefinery Training Course

13 September 2010, Amsterdam, The Netherlands

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1. Introduction
2. Biodiesel reference case
3. Biorefining opportunity 1 – valorisation of glycerol
4. Biorefining opportunity 2 – alternative feedstock
5. Further biorefining opportunities

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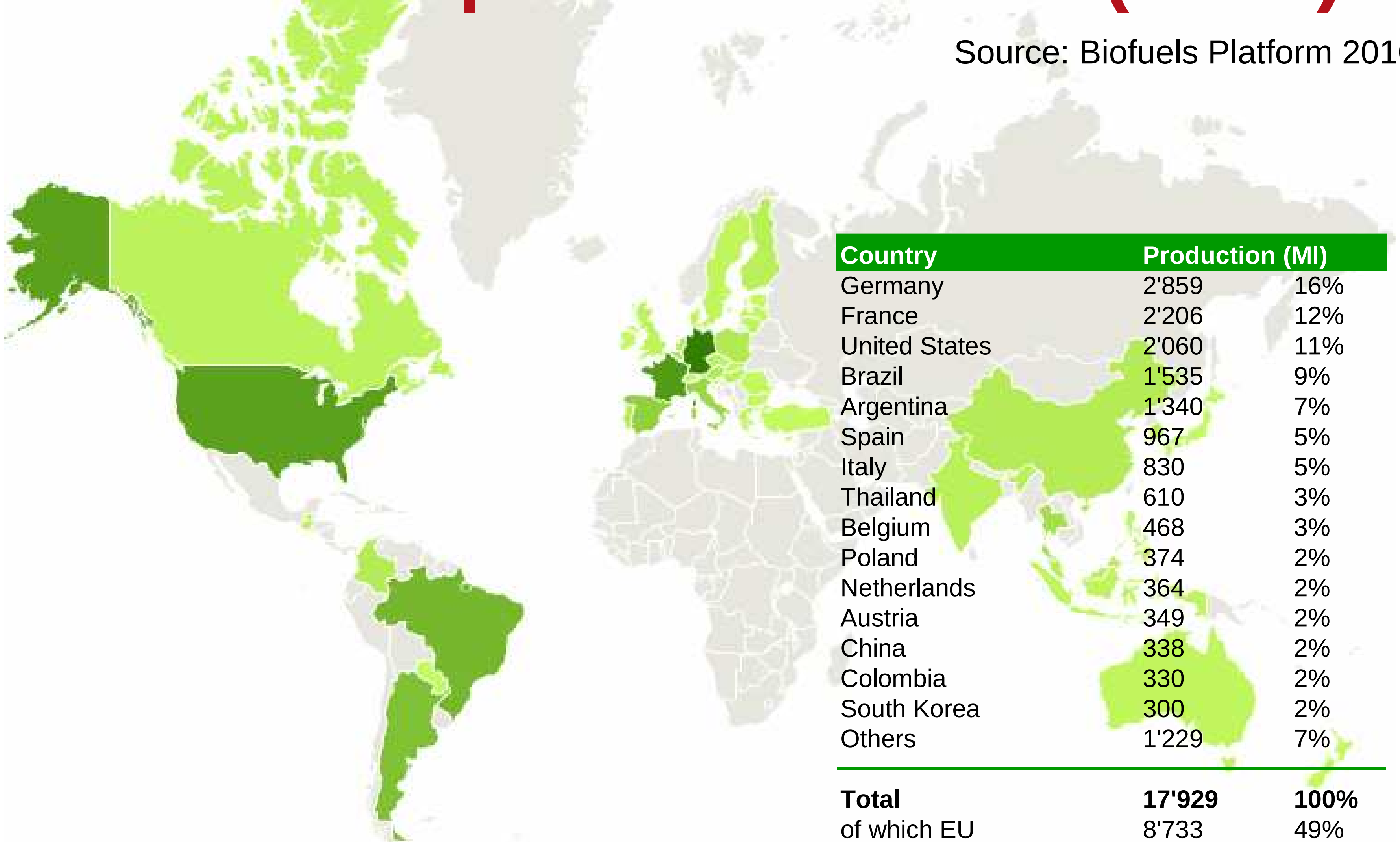
Biodiesel production WW (2009)

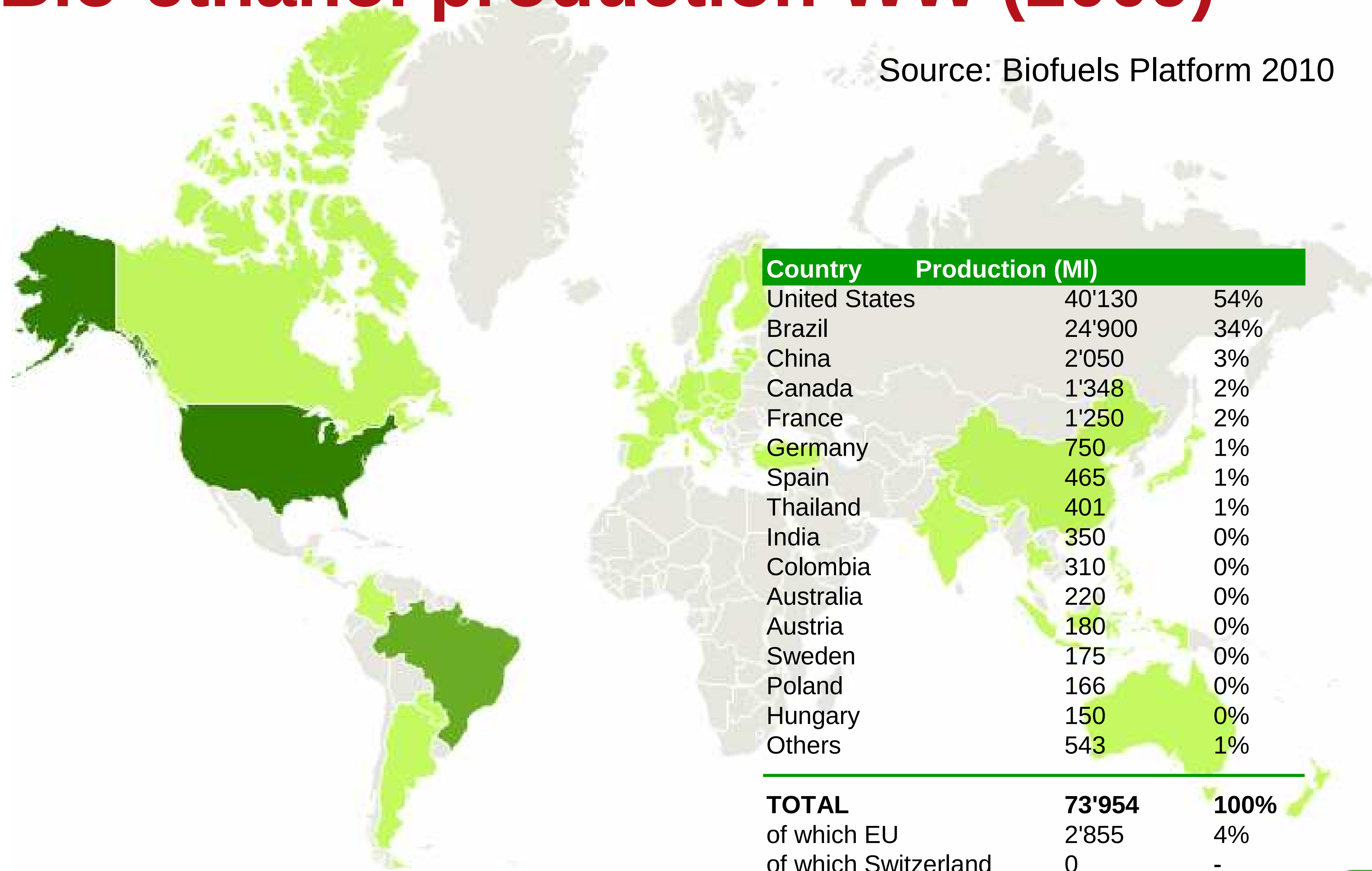
Source: Biofuels Platform 2010



Country	Production (Ml)	
Germany	2'859	16%
France	2'206	12%
United States	2'060	11%
Brazil	1'535	9%
Argentina	1'340	7%
Spain	967	5%
Italy	830	5%
Thailand	610	3%
Belgium	468	3%
Poland	374	2%
Netherlands	364	2%
Austria	349	2%
China	338	2%
Colombia	330	2%
South Korea	300	2%
Others	1'229	7%
Total	**17'929**	**100%**
of which EU	8'733	49%
of which Switzerland	8	-

Bio-ethanol production WW (2009)

Source: Biofuels Platform 2010



Country	Production (Ml)	
United States	40'130	54%
Brazil	24'900	34%
China	2'050	3%
Canada	1'348	2%
France	1'250	2%
Germany	750	1%
Spain	465	1%
Thailand	401	1%
India	350	0%
Colombia	310	0%
Australia	220	0%
Austria	180	0%
Sweden	175	0%
Poland	166	0%
Hungary	150	0%
Others	543	1%
TOTAL	**73'954**	**100%**
of which EU	2'855	4%
of which Switzerland	0	-

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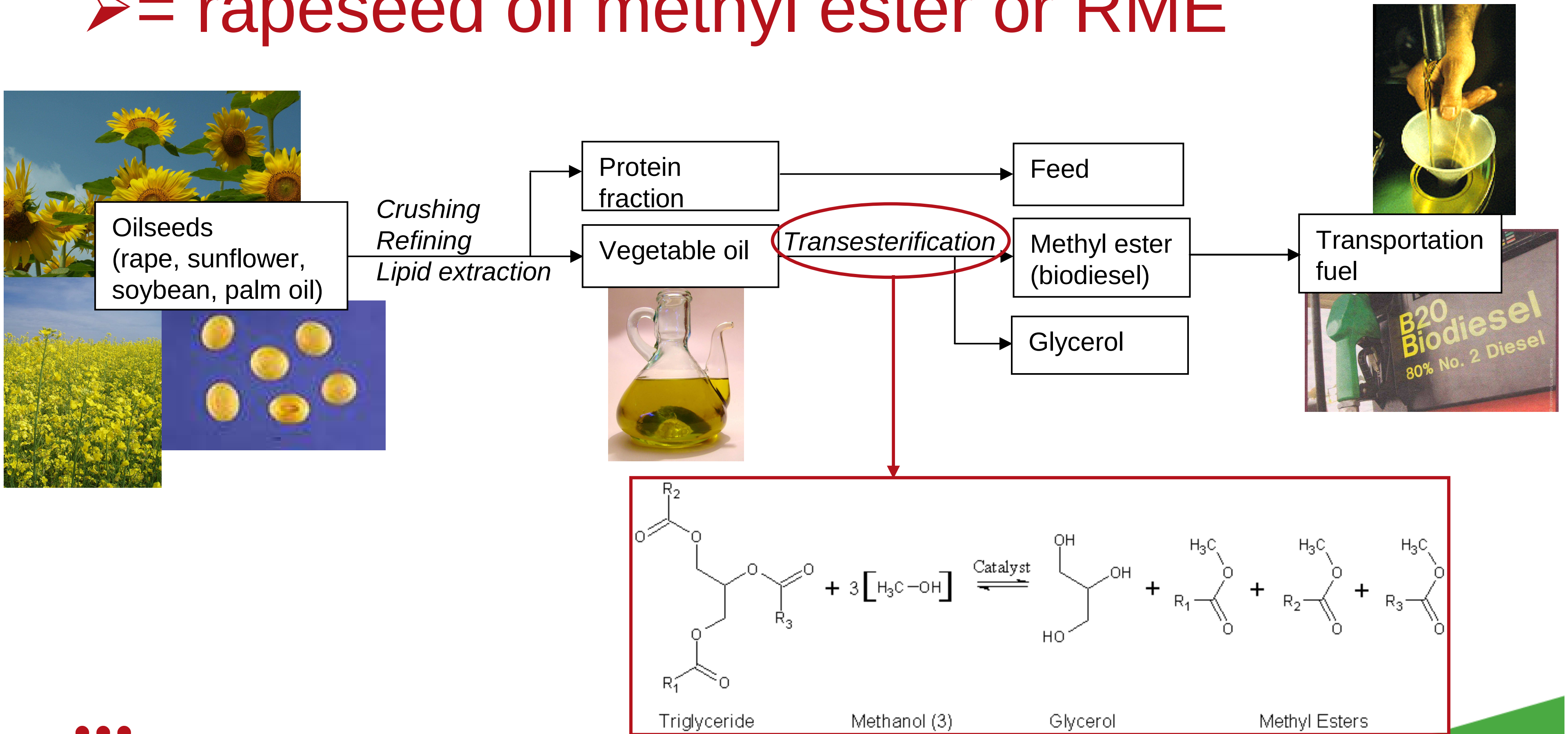
What is Biodiesel

- renewable, environment friendly fuel
- = rapeseed oil methyl ester or RME



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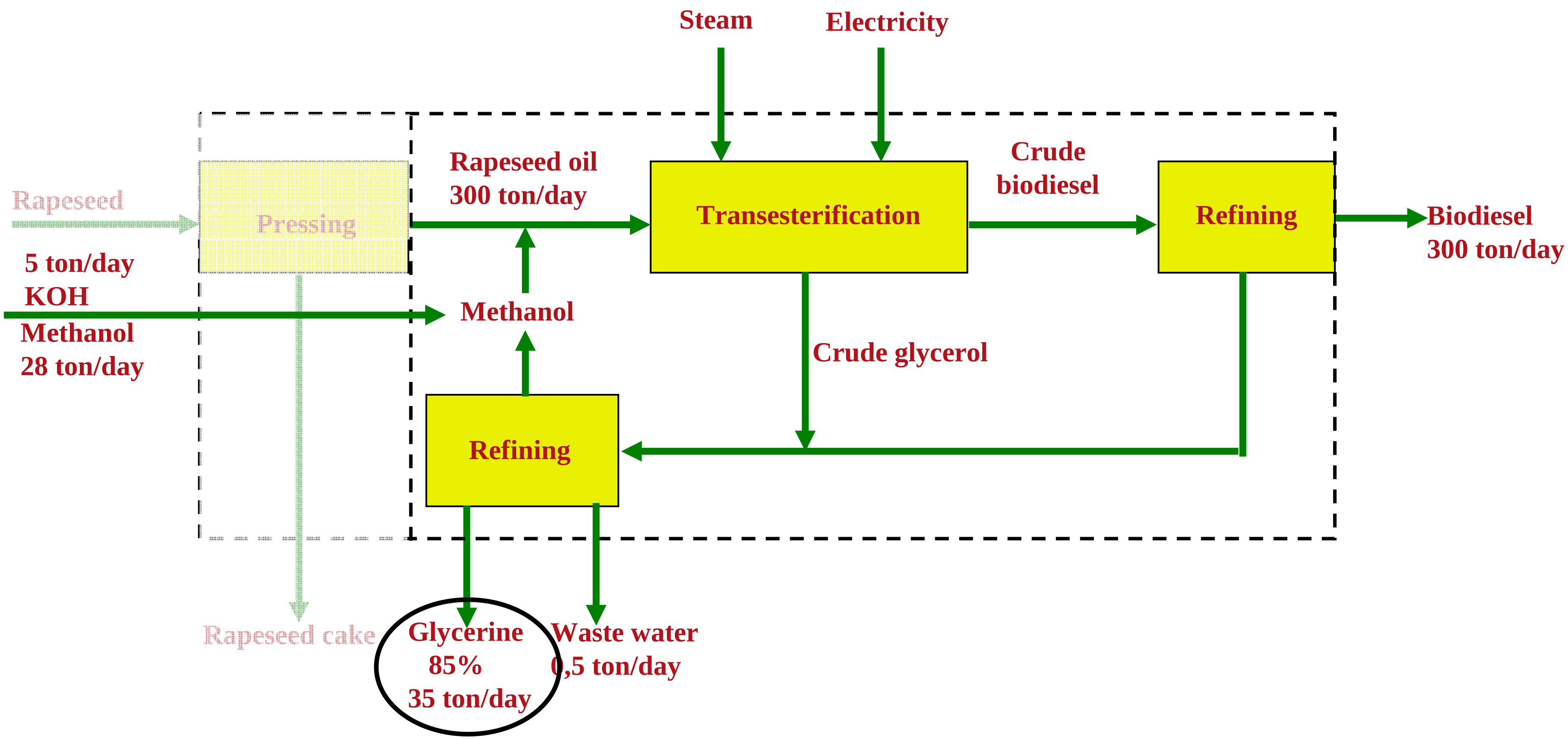
Reference case



Average size rapeseed-based plants: 150-250 ktonnes biodiesel
Average size used oil / animal fat-based plants: 50-100 ktonnes biodiesel

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Results economic assessment

Reference case		Unit	€/unit	Unit/T Biodiesel	€/T Biodiesel
Raw material	Rapeseed oil	T	640.00	1.00	640.00
Auxiliaries		T		0.11	34.0
Energy	Steam + electr				4.6
Co-products	Glycerol	T	50.00	0.12	-5.8
Variable cost					**672.8**
Capex	20,000,000	€			
Depreciation	12 years				16.7
Labour	28	#	100 000		28.0
Other costs	9	% of capex			18.0
Fixed costs					**62.7**
Total product cost					**735.5**
Product value	**Biodiesel**				**700.0**

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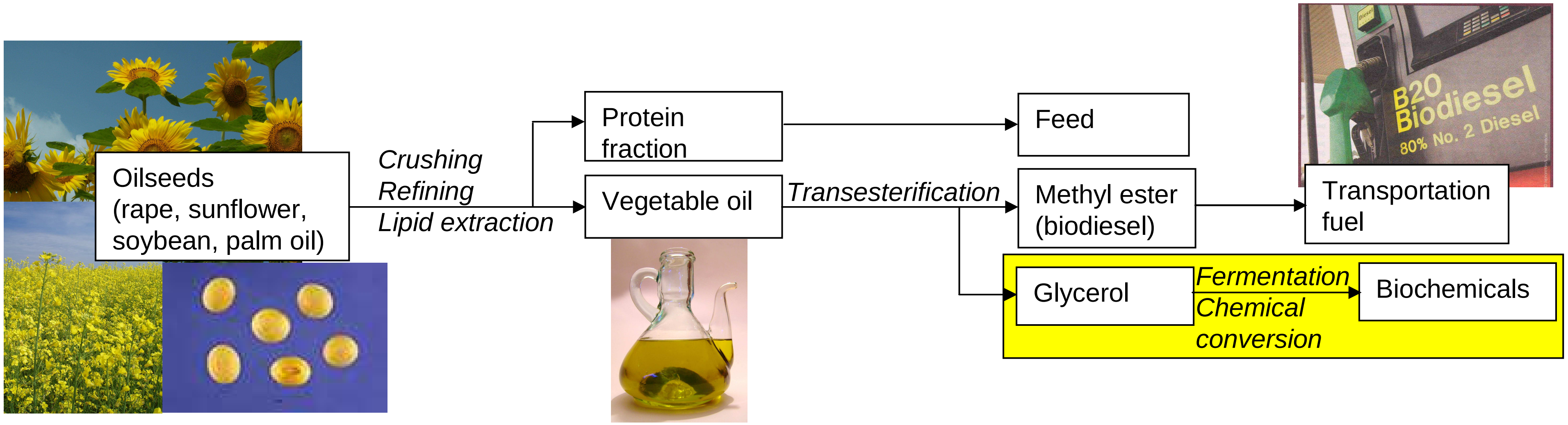
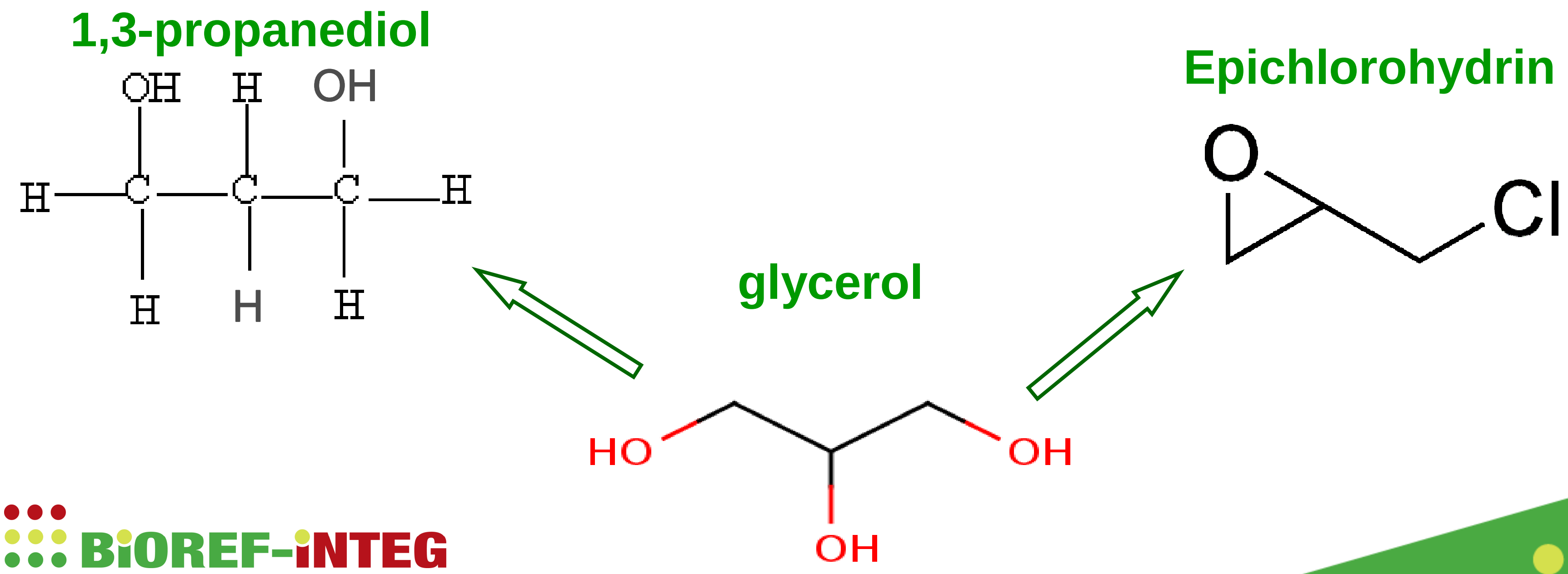
Biorefining opportunities

- Valorisation of glycerol

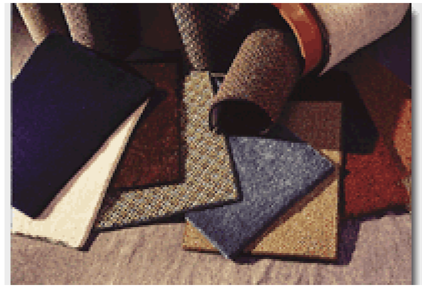


Integrated biorefinery cases

- 1,3 propanediol as a bulk chemical through fermentation of glycerol
- Epichlorohydrin as a specialty chemical through catalytic hydrochlorination of glycerol



1,3-propanediol



Properties:

- Applications in polyester, cosmetics, foods, lubricants, and medicines
- Industrially: important monomer to synthesize a new type of polyester, polytrimethylene terephthalate (PTT) – fibre and textile applications

History:

- In the past: niche applications due to high production cost
- Current: opportunities due to low glycerol price
- 1995: new chemical route by Shell for use in a new polyester, Corterra
- DuPont + Genencor: new biotechnological route

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1,3-propanediol

Characteristics	**Glycerol**	**Glucose**
Organism	*Klebsiella pneumoniae* *Clostridium butyricum*	Recombinant *E. coli*, modified in more than 10 genes
PDO concentration	80-85 g/l	135 g/l
PDO production rate	3.0 g/l/h	3.5 g/l/h
Yield (w/w)	55%	51%
Type of process	Anaerobic, fed-batch	Aerobic

Patel *et al*., 2006

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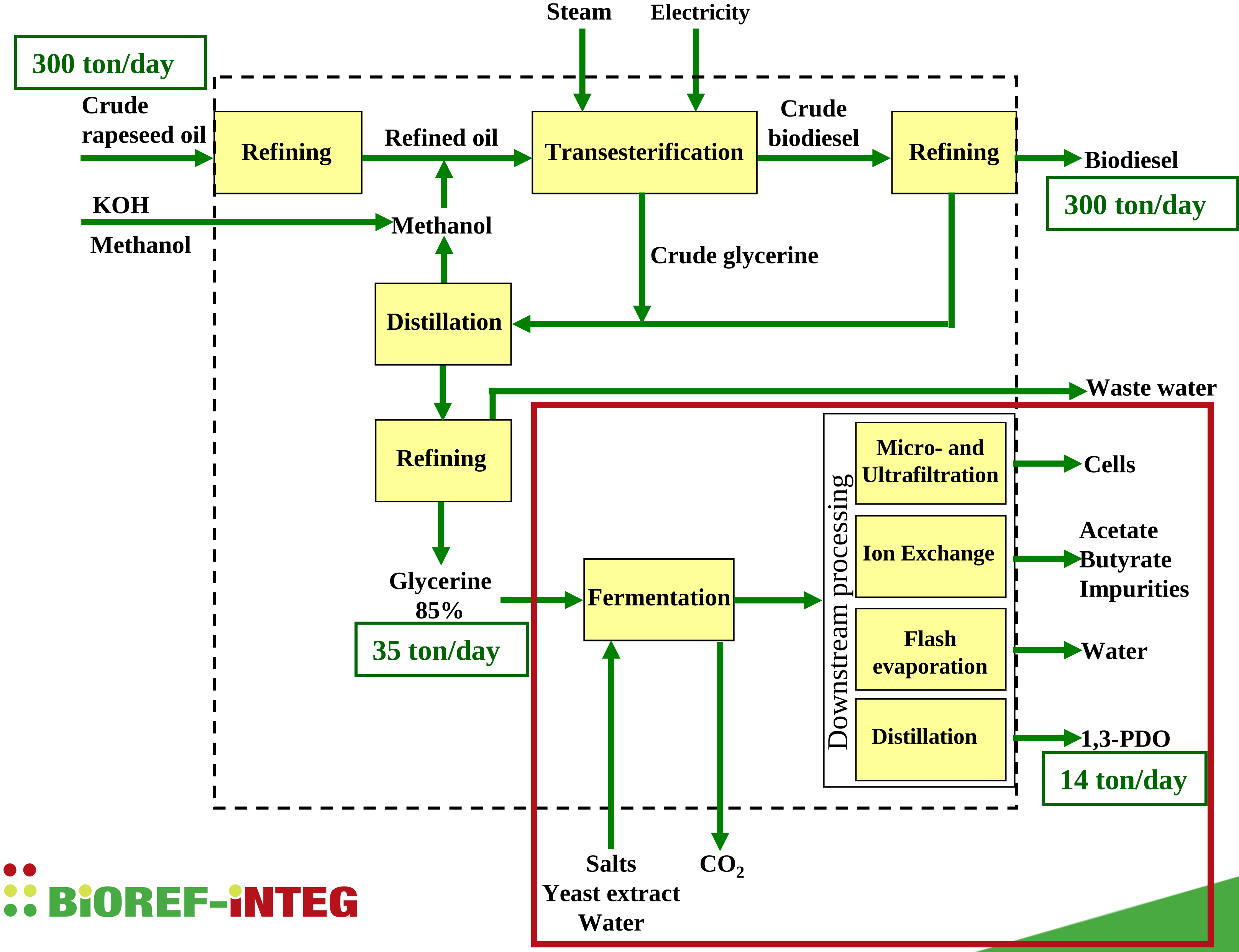
1,3-propanediol



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Epichlorohydrin

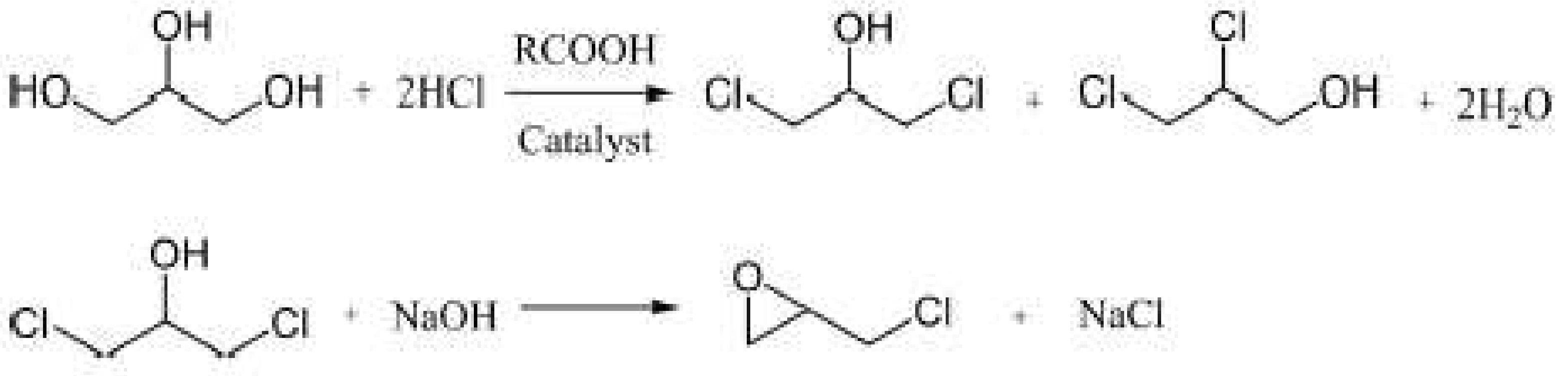
Properties:

- high volume commodity chemical
- used largely in epoxy resins
- glycerol was by-product of early epichlorohydrin production

History:

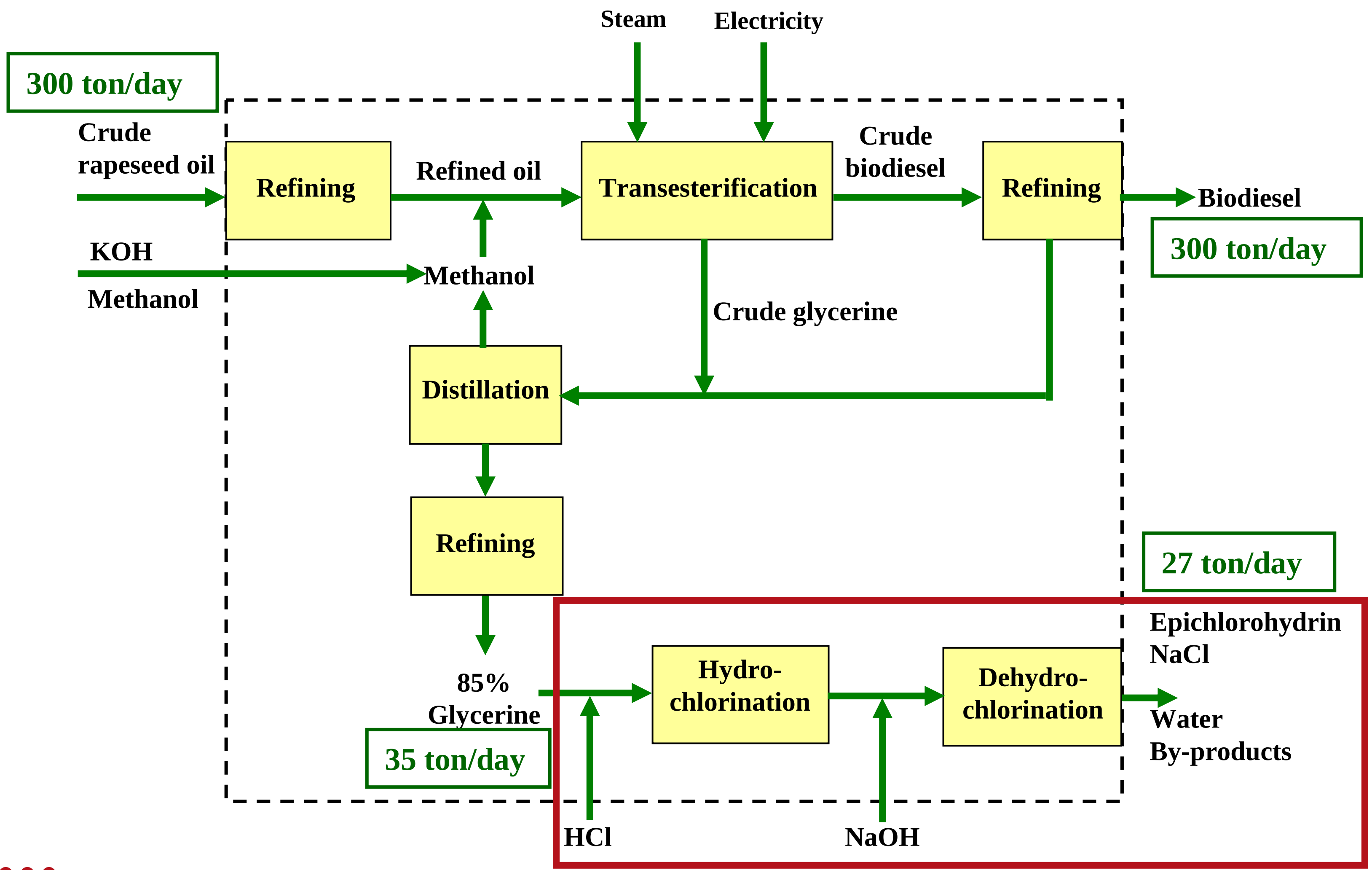
- production out of glycerine already described in 1862!
- the historically high cost of glycerine has prevented its development as a commercial process so far
- is currently being commercially developed:
  - DOW Chemical Company -> glycerine to epichlorohydrin (GTE) process
  - Solvay -> EPICEROL®

Epichlorohydrin



Two-step process for the production of epichlorohydrin that employs renewable glycerine as feedstock. Only one equivalent of waste chloride is produced.

Epichlorohydrin



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Results economic assessment

		Unit	€/unit	Unit/T Biodiesel	€/T Biodiesel
Reference case					
Co-products	Glycerol	T	50.00	0.12	-5.8
Capex	20,000,000	€			
Total product cost					**735.5**
Integrated case: PDO					
Co-products	PDO	T	1300.00	0.05	-60.7
Capex	37,000,000	€			
Total product cost					**728.7**
Integrated case: EPI					
Co-products	Epichlorohydrin	T	1250.00	0.09	-112.3
Capex	35,000,000	€			
Total product cost					**677.0**
Product value	**Biodiesel**				**700.0**

Technical feasibility

Statement	Biodiesel	
	PDO	Epi
Process development		
The integrated concept does not require significant downstream processing	0,4	1,4
All steps of the integrated concept are well identified	1,8	1,8
Required technologies are already developed for the targeted products	1,8	2,0
Required technologies are proven on industrial scale for the targeted products	1,2	1,8
Process does not require toxic or hazardous auxiliaries	2,0	1,0
The integrated concept does not generate additional waste that has to be treated	1,0	0,8
Application development		
Most of the selected applications are already existing	1,8	2,0
Products can be used in most of the selected applications	2,0	2,0
Products are referenced in most of the selected applications	1,8	2,0
Secondary products are referenced in the applications	1,4	1,6
Technical feasibility	**73,6**	**83,2**
Standard deviation	16,5	12,7

Technical feasibility

Statement	Biodiesel		
	PDO	Epi	Project average
Technical feasibility	**73,6**	**83,2**	70.7

Glycerine to 1,3-PDO
- merely an average case
- technology is considered as rather mature and benign
- main penalty comes from the significant downstream processing.

Glycerine to Epichlorohydrin (ECH)
- well above average
- high scores for the process feasibility
- worries mainly about safety issues (epichlorohydrin is toxic) and waste treatment.

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Commercial feasibility

Statement	Biodiesel	
	PDO	Epi
Project characteristics		
The integrated concept is leading to 1 new product	1,6	2,0
The product(s) can be used in several applications/markets	1,4	2,0
Market characteristics		
The integrated project addresses existing product/market combinations	2,0	2,0
The addressed markets are innovative (= open for new products/concepts)	1,4	1,0
The targeted markets are large enough to absorb the foreseen volumes	2,0	2,0
Competitive advantage		
Introduction of the new product(s) will lead to an economical benefit for the user	1,4	1,2
The new product(s) have functional benefits	1,6	1,0
There are specific benefits related to integrated concept compared to conventional processes	1,8	1,6
Social impact		
The new product(s) is an alternative to fossil-based products	2,0	2,0
The integrated concept is not in competition with food supply	2,0	2,0
The integrated concept does not require large quantities of fresh water	1,0	2,0
The integrated concept is leading to additional renewable energy production	0,4	0,4
The integrated concept is 'LCA positive'	1,6	1,6
The integrated concept improves the European competitive position in a global market	1,6	1,6
Regulatory impact		
There are no regulatory barriers affecting the market introduction of the product(s)	1,8	1,6
There is a supporting EU directive promoting the integrated concept	1,2	1,2
Commercial feasibility	**78,6**	**75,4**
Standard deviation	15,5	16,5

Commercial feasibility

Statement	Biodiesel		
	PDO	Epi	Project average
Technical feasibility	**78,6**	**75,4**	71,0

Glycerine to 1,3-PDO

- Commercially attractive project, especially regarding integration benefits and functional attributes (functionality of PDO-based polyesters)
- Some concerns related to water needs

Glycerine to Epichlorohydrin

- slightly above average
- driven by integration benefits and slightly better score on other statements.

SWOT-analysis 1,3-PDO

Strength:

• **High added value product** out of glycerine leading to more competitive biodiesel operation

Weaknesses:

• Technical issues: Fermentation based on glycerol **not proven at industrial scale yet**

• Economical issues: **Market for 1,3-PDO is limited** and depends on textile fibre development

• Strategic issues: Currently only 1 significant customer

Opportunities:

• **Future product diversification possible** (e.g. fatty acid esters of 1,3-PDO → lubricants)

Threats:

• Dependence on DuPont patent restrictions

• **Competition with PDO from sugars**

SWOT-analysis Epichlorohydrin

Strength:
• **Stable outlet** (price-wise) for glycerine towards 'bulk' chemical

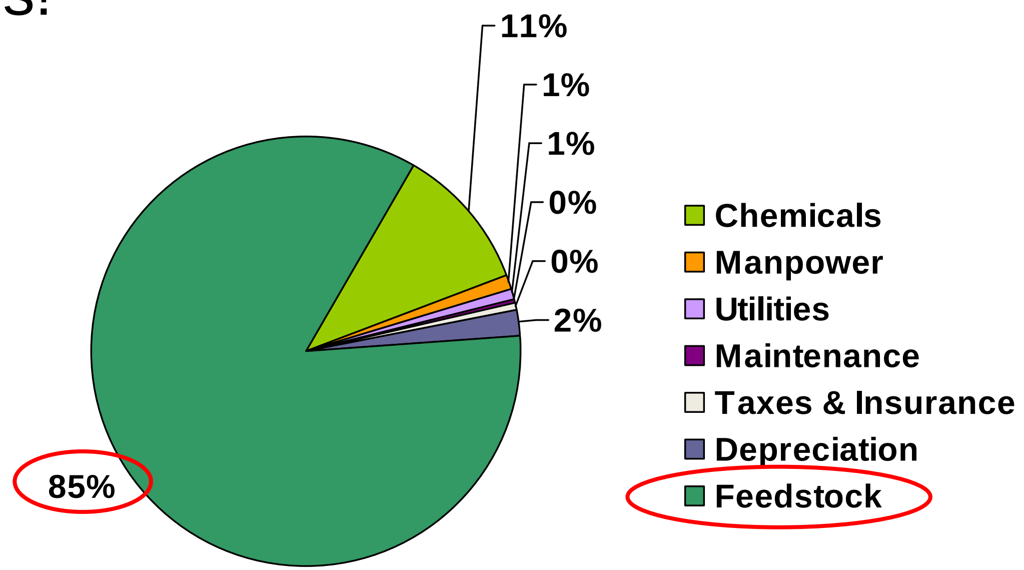
Weaknesses:
• Epichlorohydrin is a **toxic** product
• Investment cost: **large scale needed** ideally

Opportunities:
• Chemical modification of glycerol platform: **further conversion potential** to other products (glycidol, propylene oxide, 1,2-PG)

Threats:
•**Technology controlled by Solvay and Dow and operated at much larger scale**

Summary and conclusions

- Both integrated cases have good technical and commercial feasibility
- Both profitable, with slight advantage for EPI
- Larger scale needed to become more profitable
- > 80% of product cost comes from feedstock cost -> look for alternatives!



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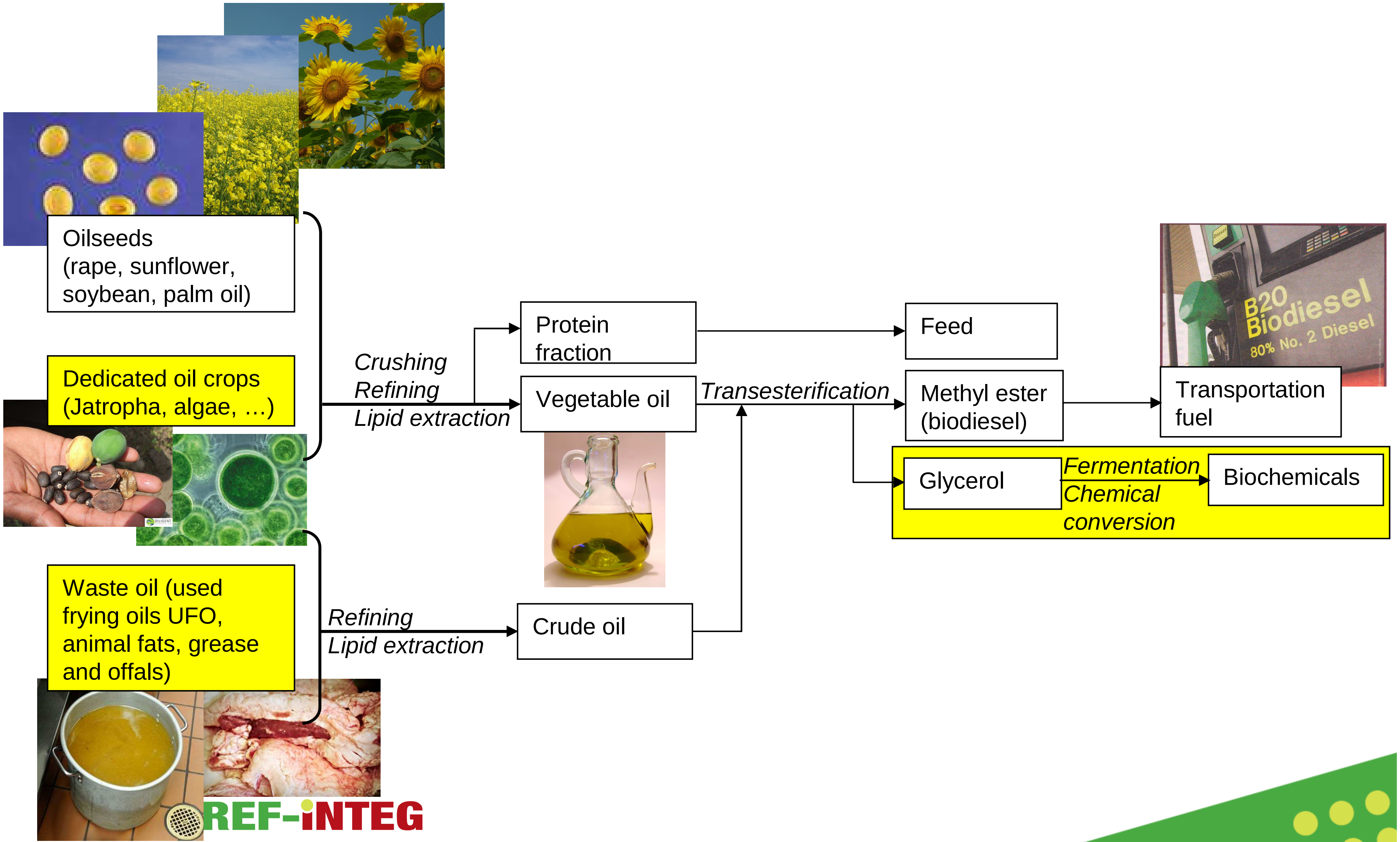
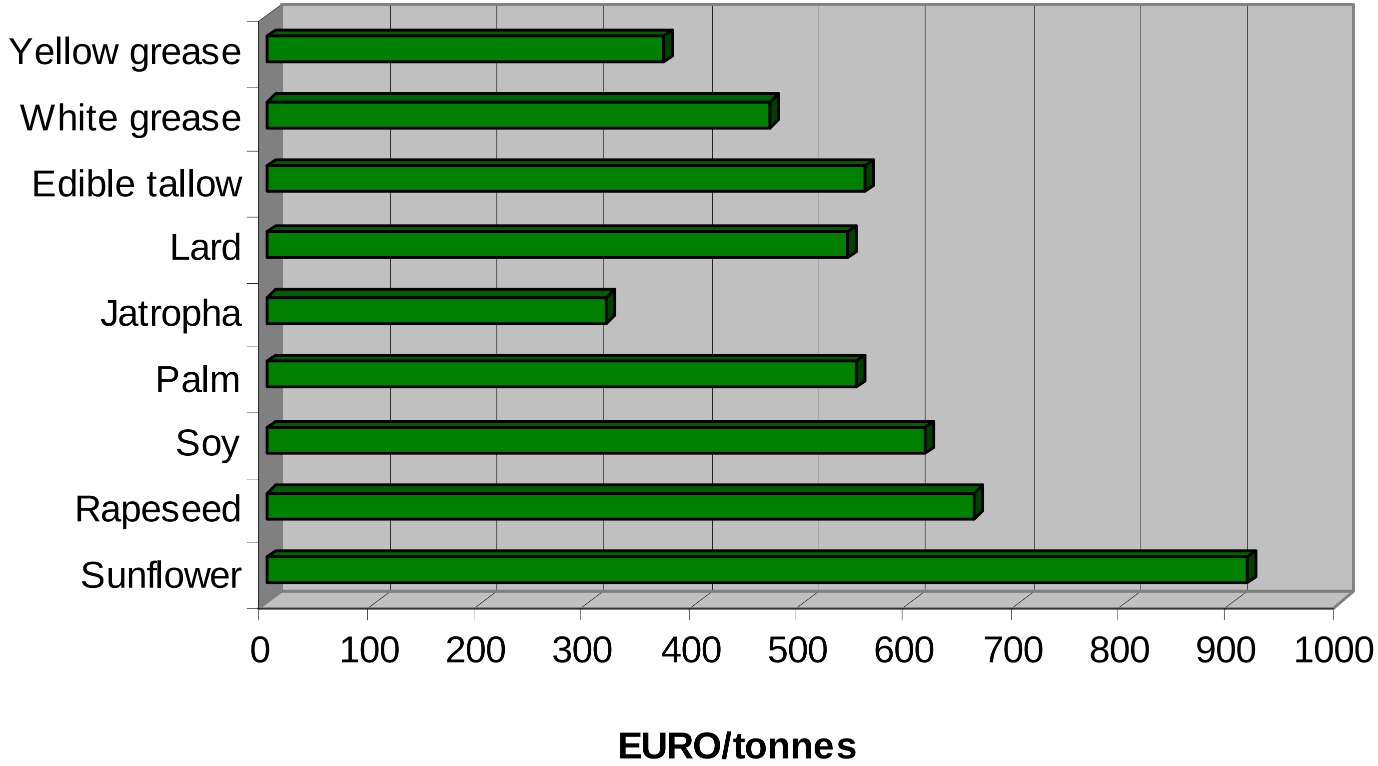
Alternative feedstock



Overview feedstock cost



Micro-algae oil: 3900 EUR/ton for cheapest algae in food industry

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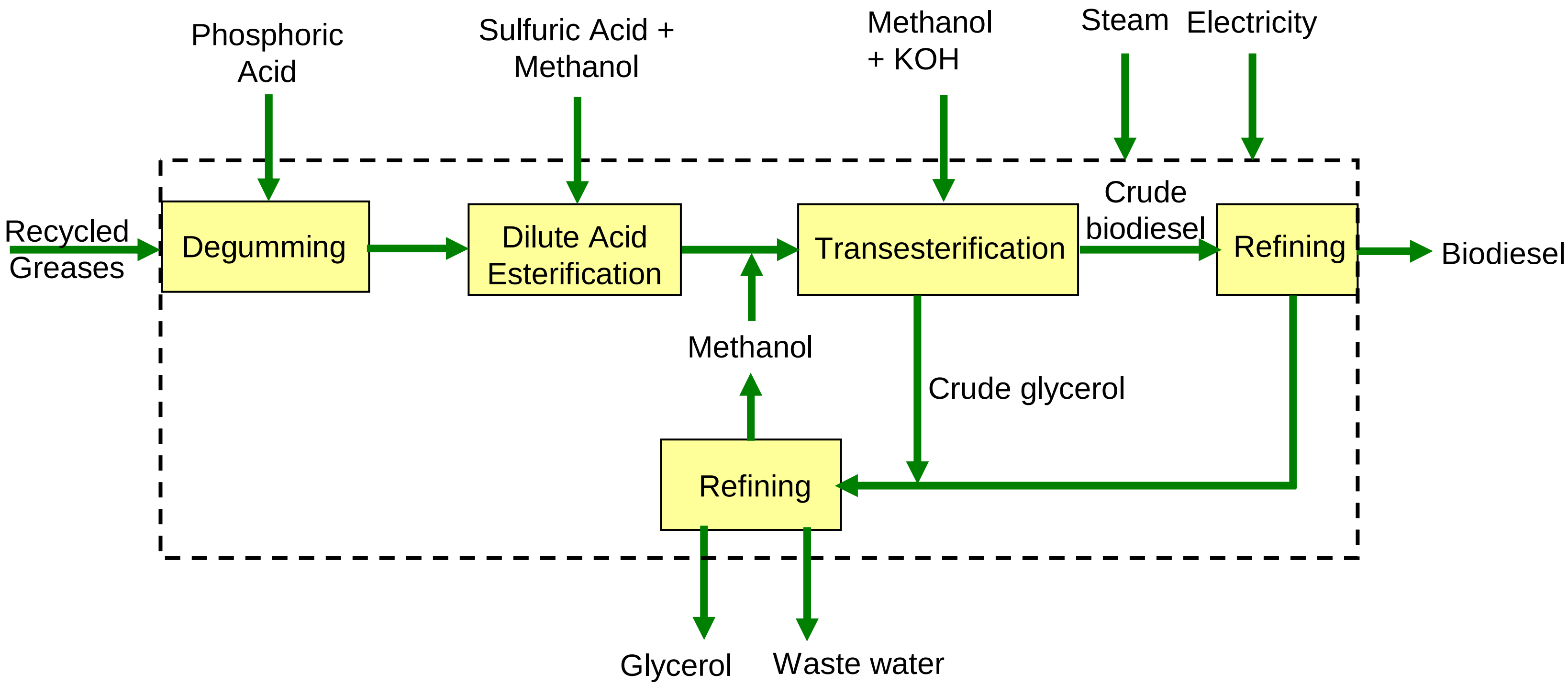
Feedstock type comparison

Animal fats	Seed oil
Less expensive	More expernsive
Higher sulfur	Lower or no sulfur
FFA 5-50% *	FFA< 5% *
Less available	More plentiful
Higher gel temp.	Lower gel temp
More stable	Less stable

Ciras, Iowa State University

*Free Fatty Acids: basic catalysts loose effectiveness and may react with free acids to form soaps that are very difficult to separate from end product

Biodiesel production from recycled greases



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Economics

	Nelson et al. (1994)	Noordam and Withers (1996)	Bender (1999)
Plant capacity	100,000 tonne/year	7800 tonne/year	10,560 tonne/year
Process type	Alkali-catalyzed continuous process	Alkali-catalyzed batch process	Alkali-catalyzed continuous process
Raw material	Beef tallow	Canola oilseed	Animal fats
Total capital cost	$ 12 million	Not reported	$ 3.12 million
Total manufacturing cost	$ 34 million	$ 5.95 million	Not reported
Biodiesel break-even price	$ 340/tonne	$ 763/tonne	$ 420/tonne

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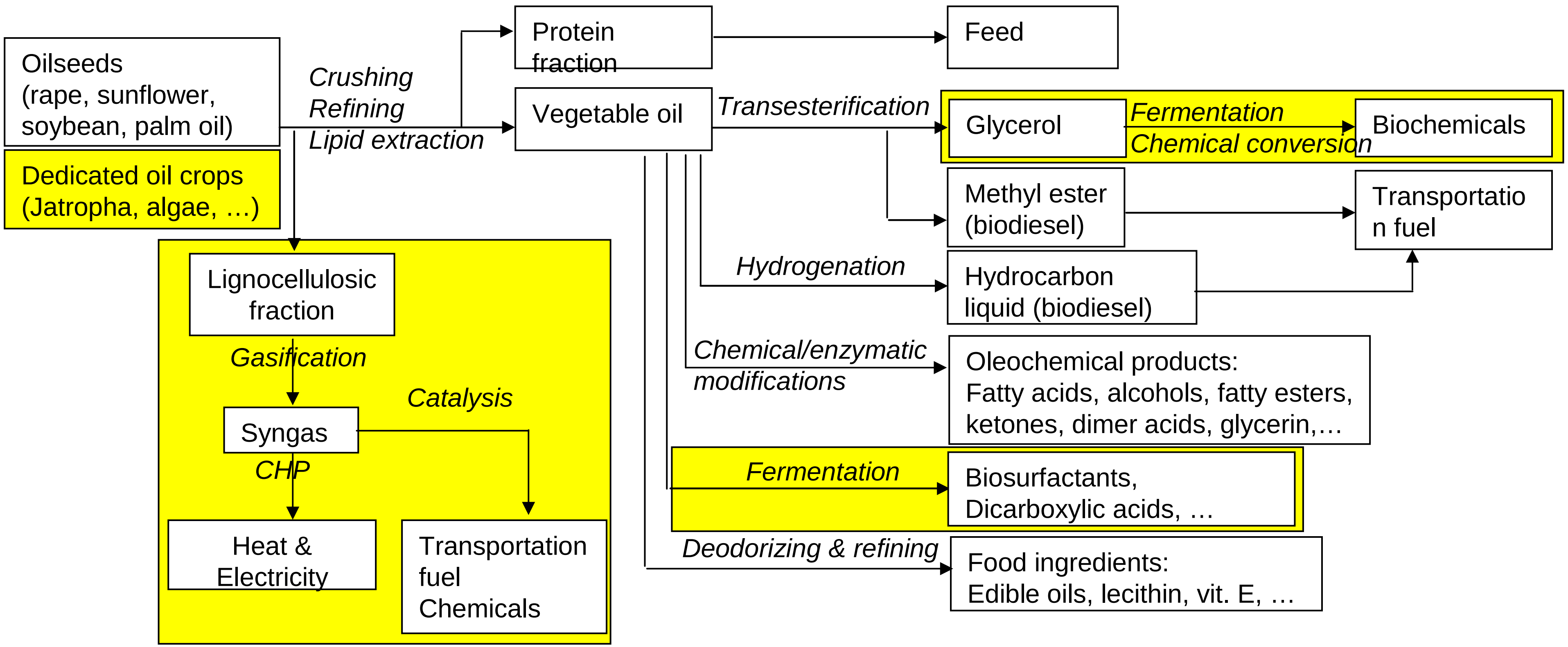
Further Biorefining Opportunities



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THANK YOU !

Contact

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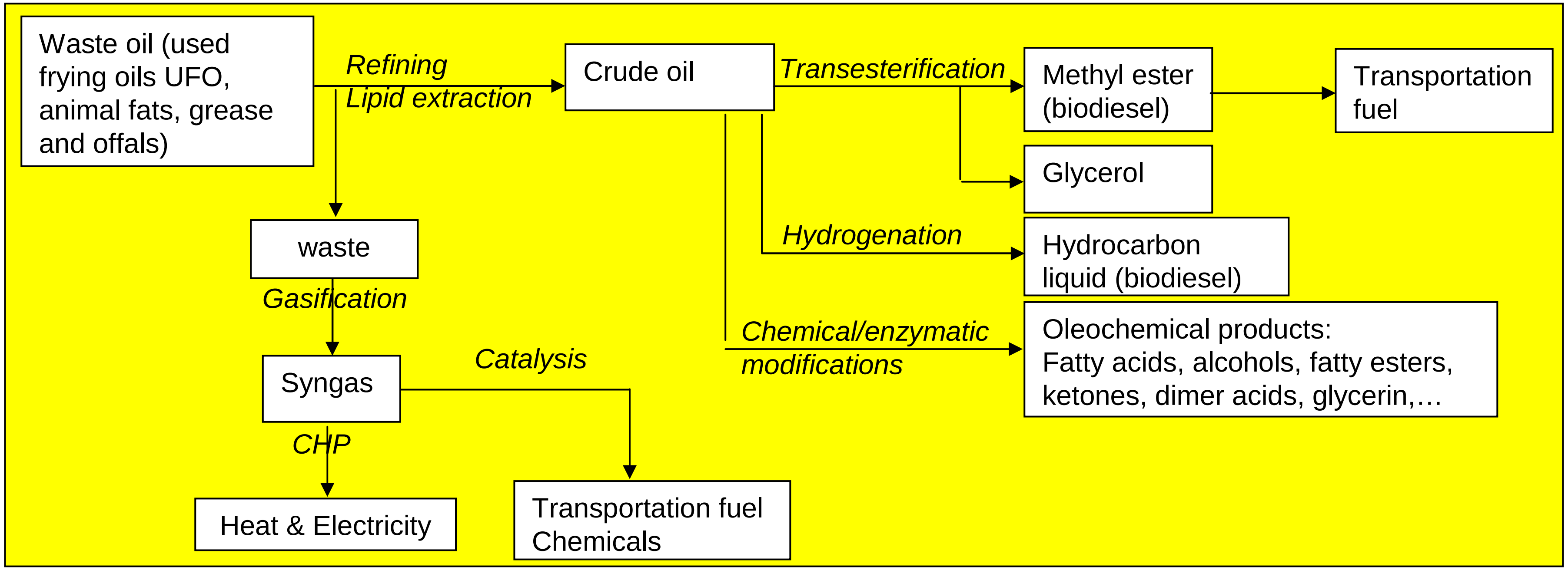
Waste Oil Biorefinery



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