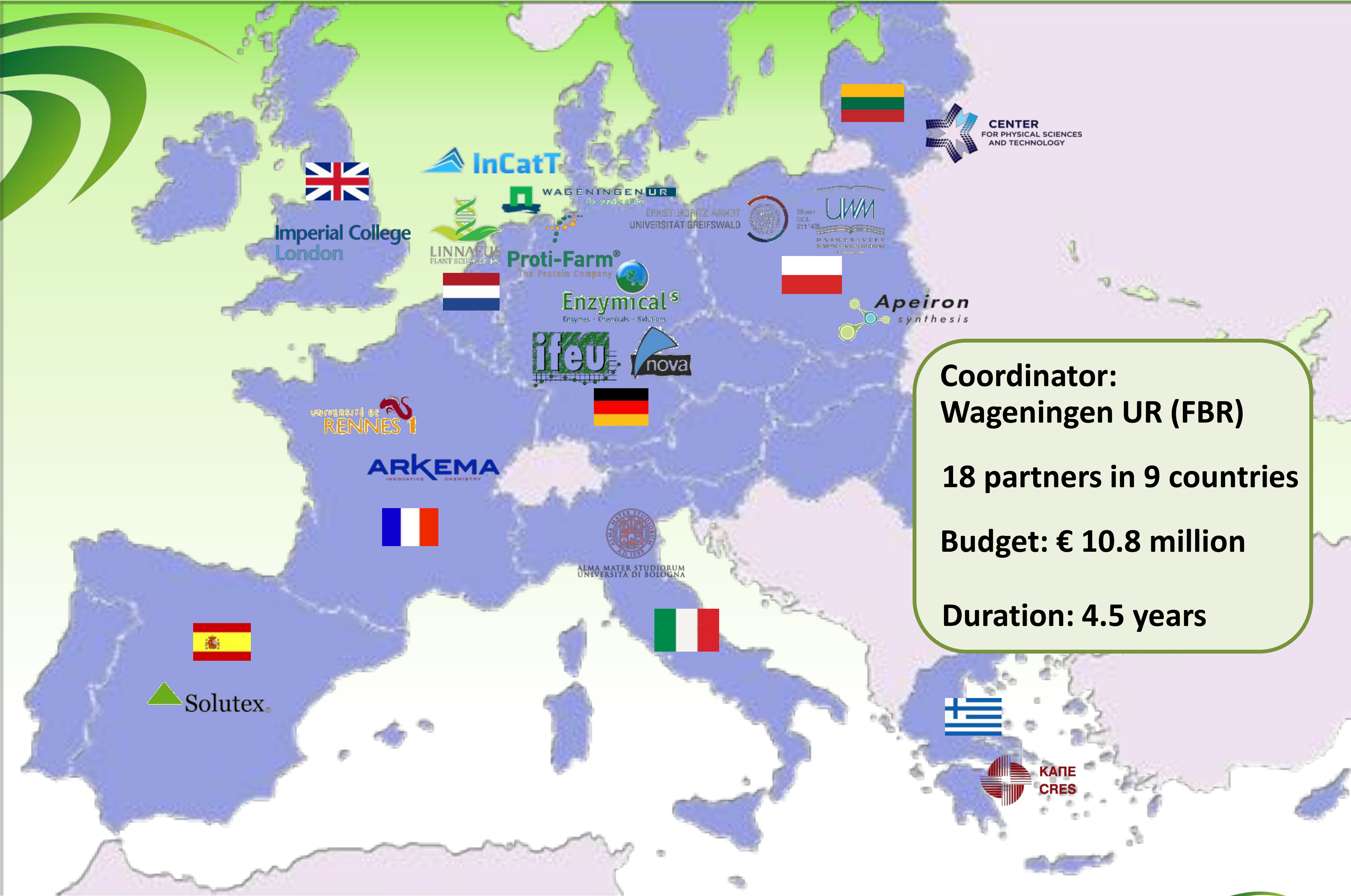
COSMOS: **C**amelina and crambe **O**il crops as **S**ources for **M**edium-chain **O**ils for **S**pecialty oleochemicals

Funded by the Horizon 2020 Framework Programme of the European Union

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL



Coordinator:
Wageningen UR (FBR)

18 partners in 9 countries

Budget: € 10.8 million

Duration: 4.5 years

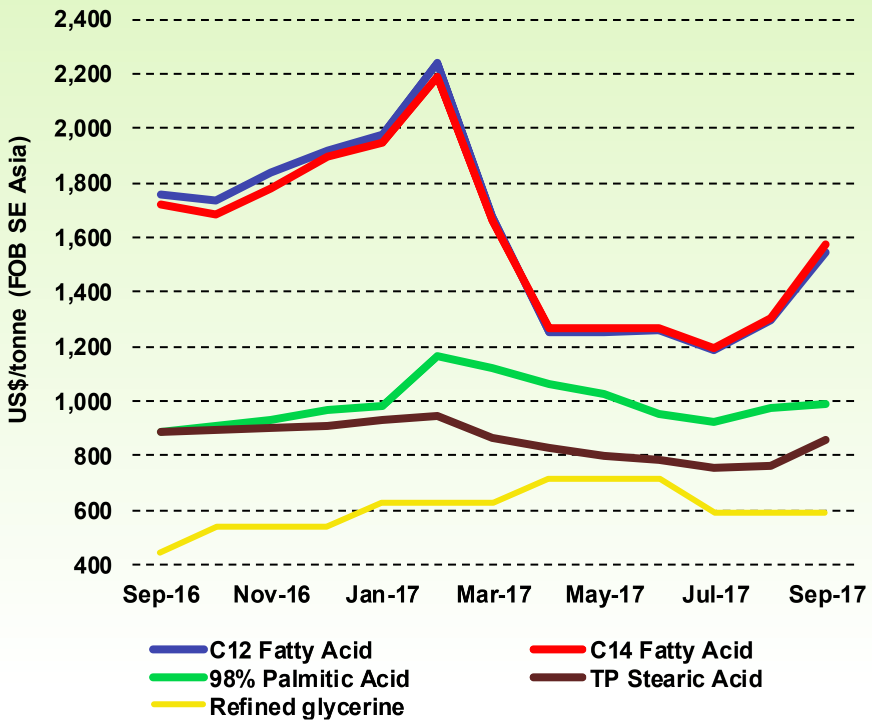
Background

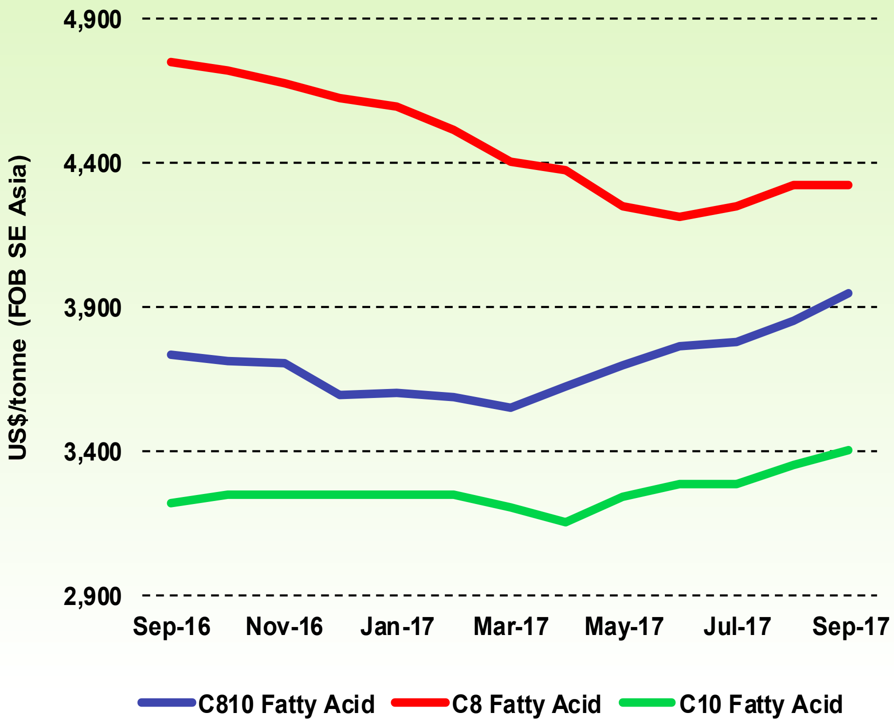
- Oleochemical industry relies predominantly on tropical oils:
  – palm, palm kernel, coconut, castor

- No European alternatives for tropical medium-chain fatty acids:
  – C8, C10, C12, C14

- Prices of these fatty acids higher and more volatile than those from more common oilseed crops (next slide)

Background





TP = Triple Pressed. Stearic Acid is commercial acid. C810 refers to the fatty acid cut. C8 and C10 are single chain length fatty acids. Caprylic is C8, Capric is C10.

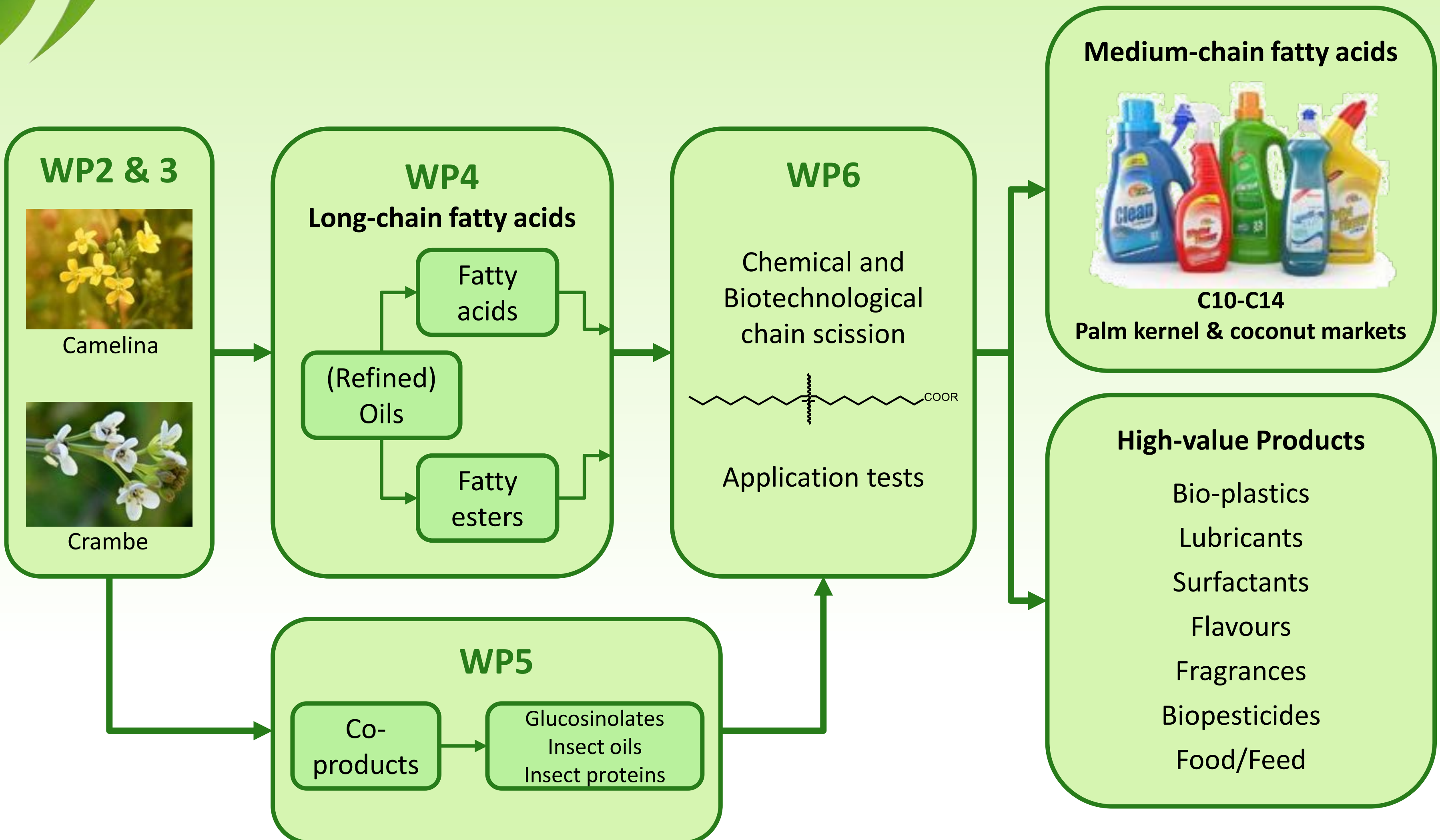
COSMOS: primary aim

- Reduce Europe’s dependence on imported tropical oils (palm kernel, coconut, castor) as sources for medium-chain-length oleochemical surfactants, lubricants, polymers and other high-value products, by:
  - turning camelina and crambe into profitable oilseed crops
  - creating and optimizing sustainable value chains

Camelina sativa

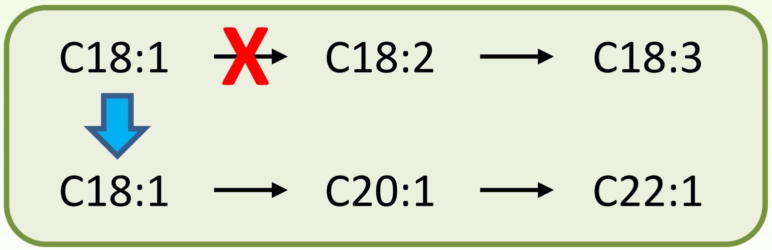
Crambe abyssinica

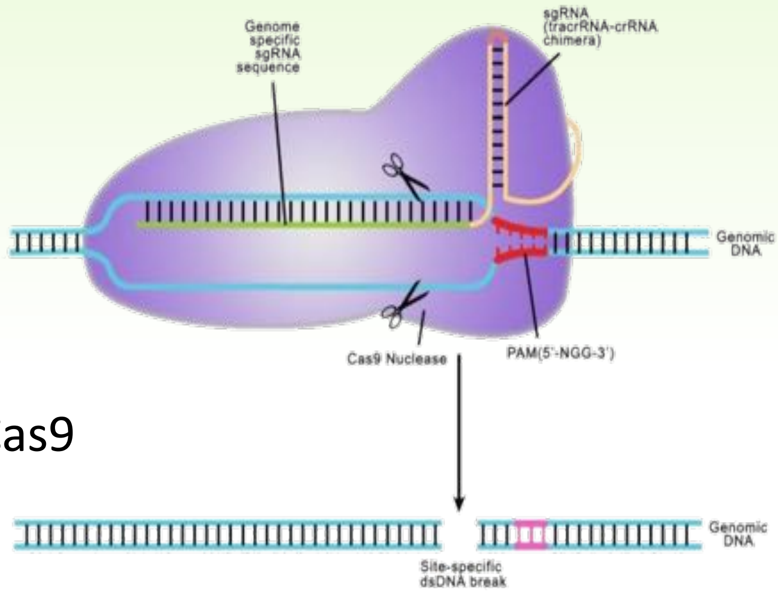
Approach


WP2 & 3
Camelina
Crambe
WP4
Long-chain fatty acids
Fatty acids
(Refined) Oils
Fatty esters
WP6
Chemical and Biotechnological chain scission
COOR
Application tests
Medium-chain fatty acids
C10-C14
Palm kernel & coconut markets
High-value Products
Bio-plastics
Lubricants
Surfactants
Flavours
Fragrances
Biopesticides
Food/Feed
WP5
Co-products
Glucosinolates
Insect oils
Insect proteins

WP2 – Plant breeding & genetics

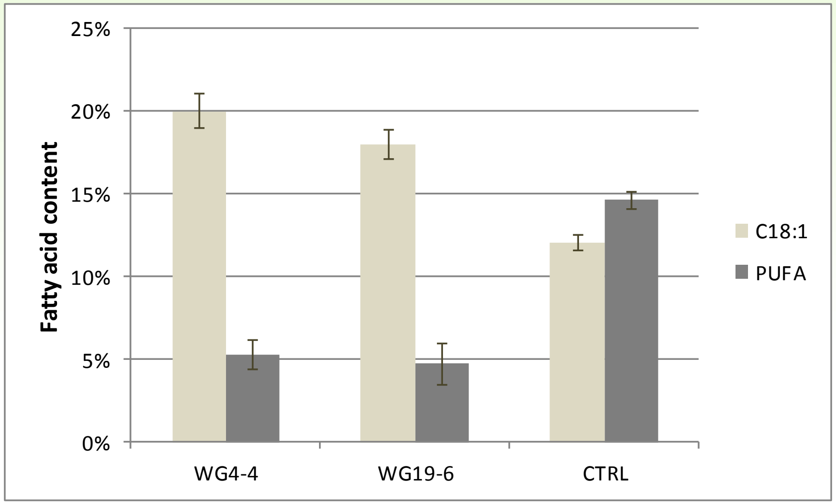
- Targets:
  - increase % of 11-eicosenoic acid (C20:1, *gondoic*) in camelina
  - increase % of 13-docosenoic acid (C22:1, *erucic*) and *oleic* (C18:1) in crambe
  - reduce content of anti-nutritional factors (glucosinolates, sinapines) in both crops

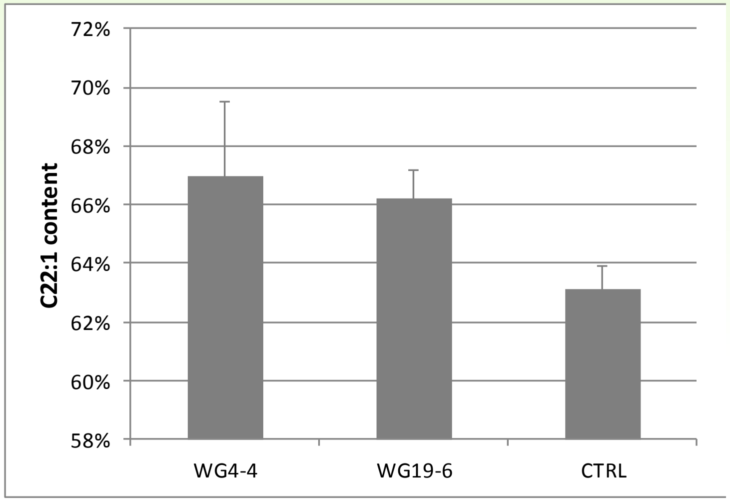




- Techniques:
  - site-directed mutagenesis: CRISPR/Cas9
  - random mutagenesis (EMS)

WP2 – Plant breeding & genetics



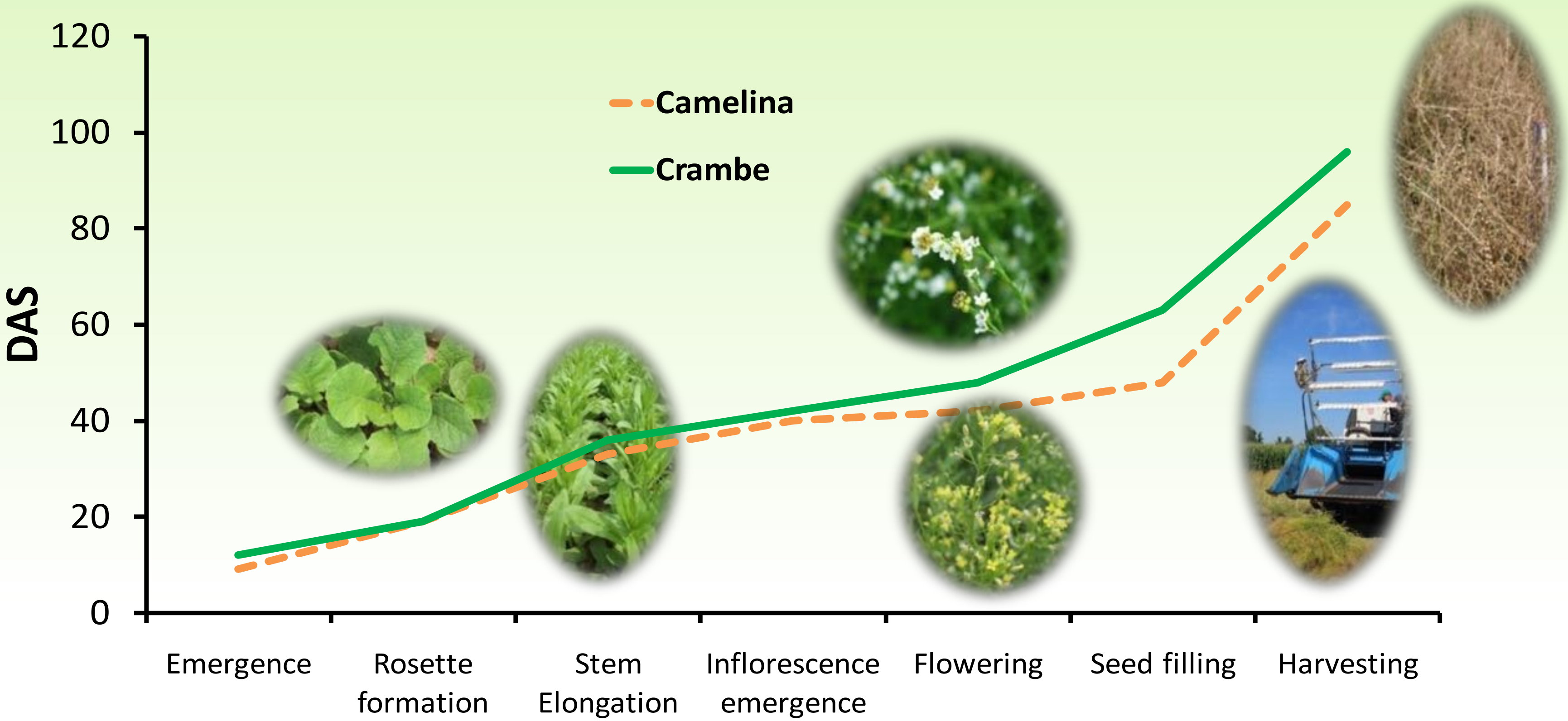


WP3 – Cultivation strategies

- Targets:
  - optimise crop and oil yield in various European climates: Italy, Greece, Poland, The Netherlands

Camelina harvest in Poland (August 2015)

WP3 – Cultivation strategies



Italy (Univ. of Bologna)

DAS: Days After Sowing

WP4 – Oil extraction and separation

- Targets:
  - use selective enzymes and physical techniques to separate individual MUFA in camelina and crambe oil
  - convert C18 PUFA to C10-C12 MUFA in genetically modified *Pseudomonas putida*

Oil pressing and extraction (subcontracting)

Fractionation and esterification of the oils

Solutex

Selective microbial FA chain size reduction

Wageningen University & Research

Enzymatic separation of long chain MUFA

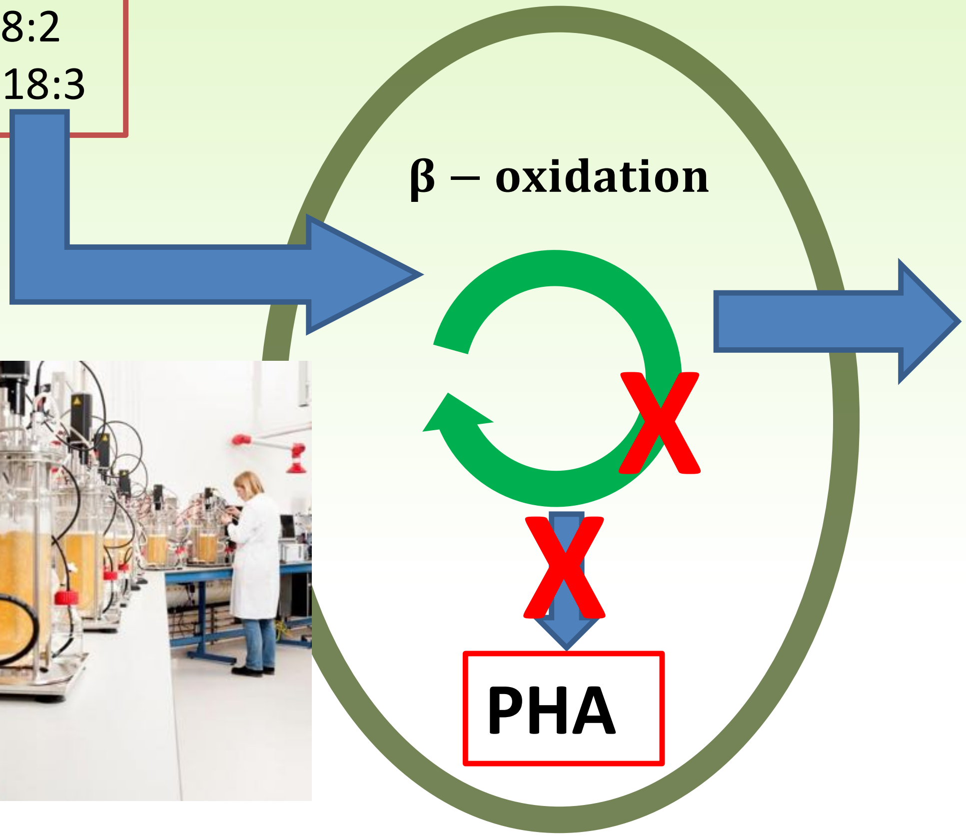
Enzymical

Ernst Moritz Arndt Universität Greifswald

WP4 – Oil extraction and separation

WAGENINGEN UNIVERSITY & RESEARCH

Linoleic acid C18:2
Linolenic acid C18:3



C12:2
C12:3
C10:1
C10:2

WP5 – 'Insect biorefinery'

- Targets:
  - find and use insect species able to convert crop side streams (straw, seed meal) to protein and fat
  - develop a refinery method to separate insect protein and fat

WP5 – 'Insect biorefinery'

Field survey Poland 2015

Meligethes, pollen beetle

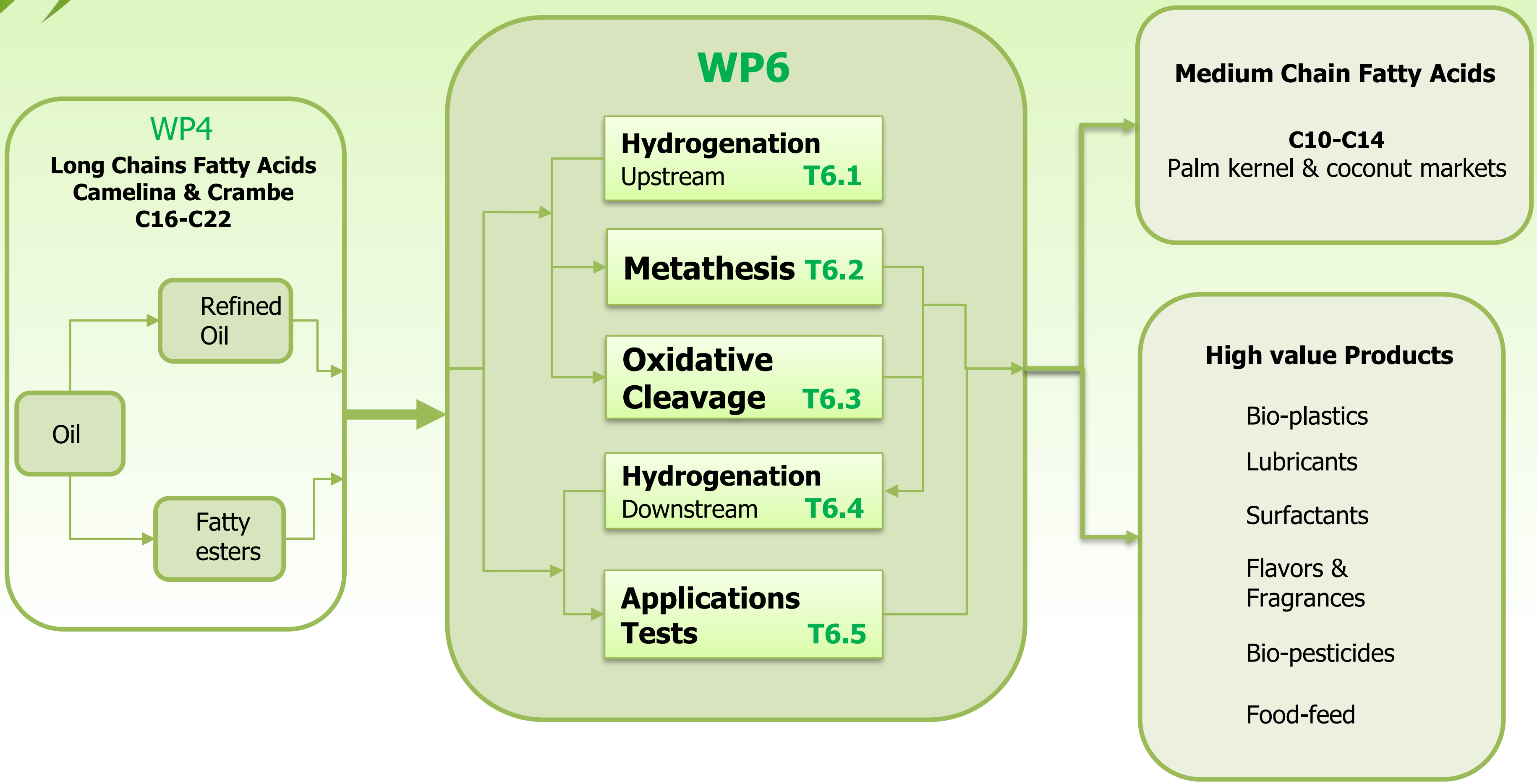
Ceutorhynchus, seedpod weevil

Plutella, diamondback moth

Phyllotreta, flea beetle

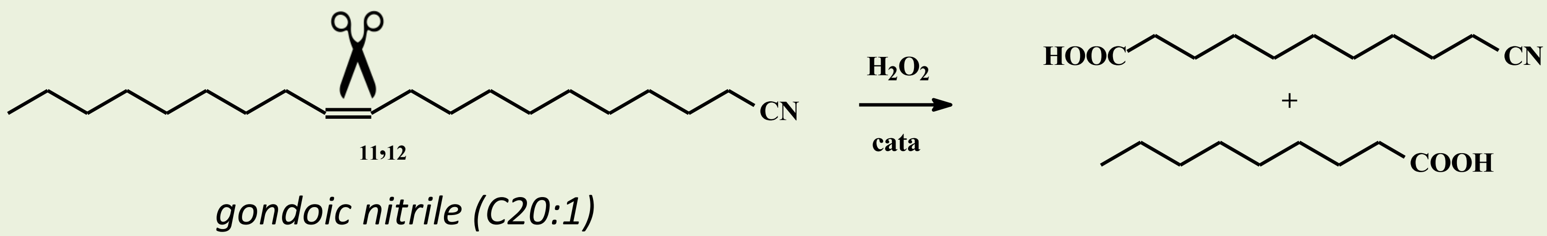
Chromatomyia, leafmining fly

WP6 – FA conversions and applications

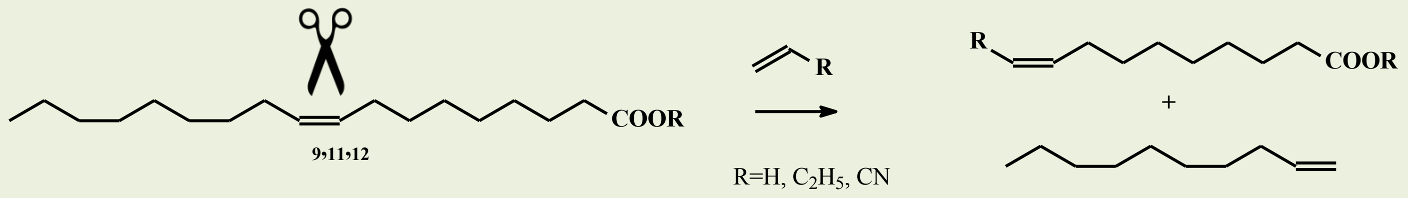


WP6 – FA conversions and applications

- Oxidative cleavage of MUFA:



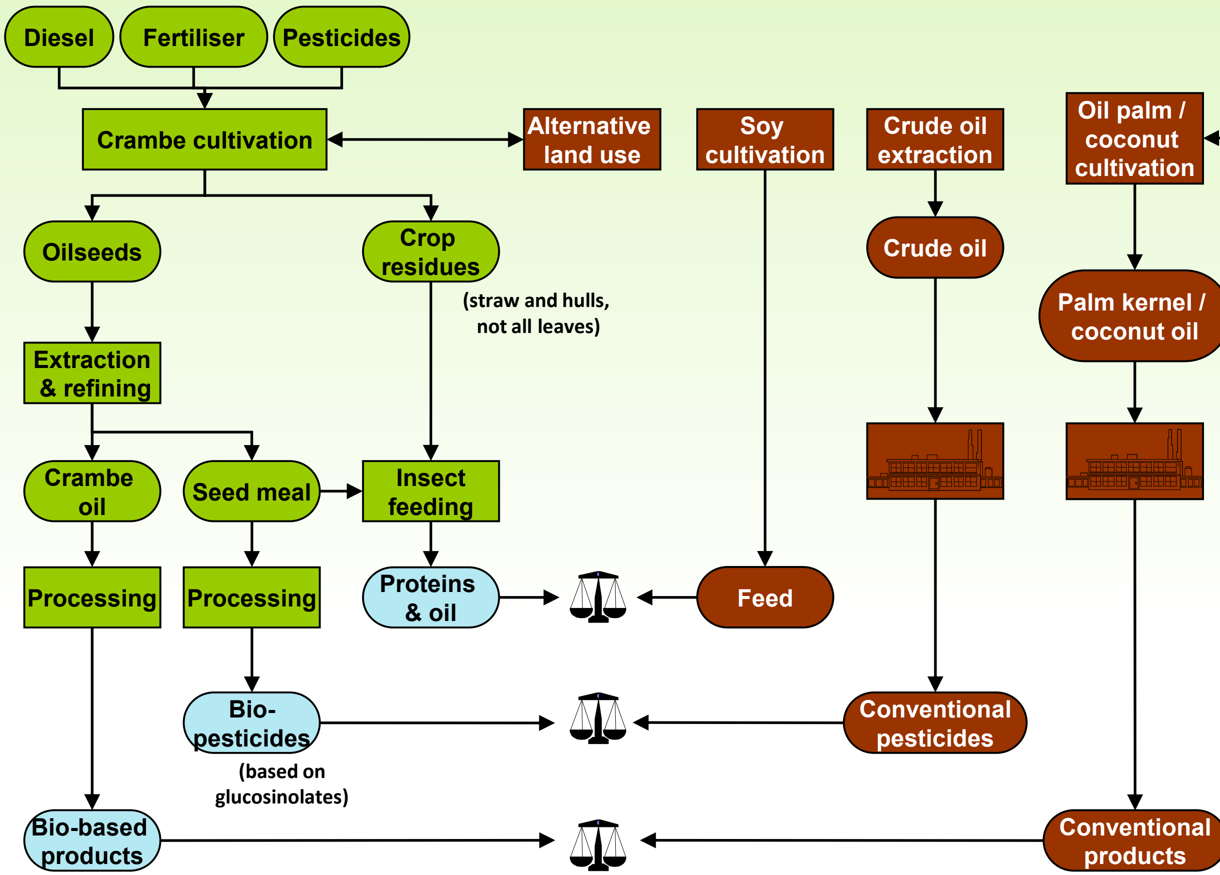
- Cross-metathesis (ethenolysis, butenolysis, 'acrylonitrilolysis'):



WP7 – Sustainability assessment

COSMOS Bio-products

Conventional products



Legend: (Intermediate) Product | Process | Marketable product | Reference system

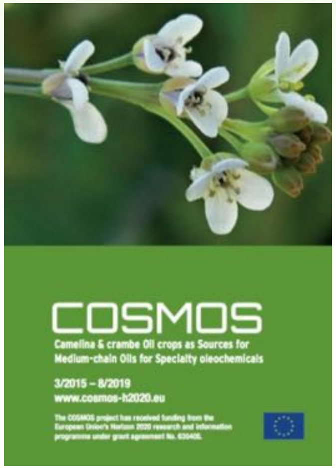
WP8 – Dissemination & Exploitation / IP

- Selection of output so far:
  - press release, project brochure, CRISPR/Cas leaflet
  - web site (http://cosmos-h2020.eu)
  - public project deliverables, available on website
  - several presentations at scientific conferences
  - scientific articles (agronomy, lipases, catalysts, lubricants)
  - two patents filed, one in progress


COSMOS

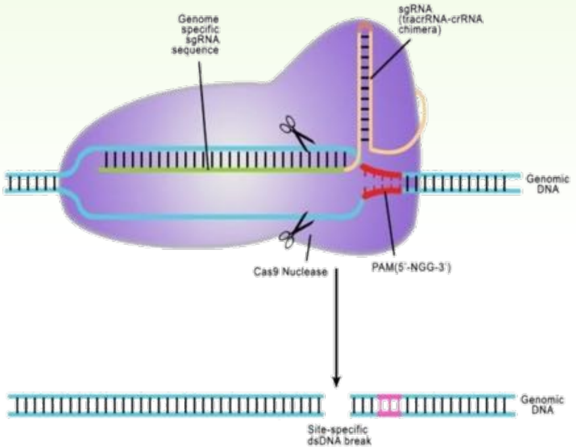
Press release

EU research project on underutilised oil crops kicks off:
COSMOS – Camelina & crambe Oil crops as Sources for Medium-chain Oils for Specialty oleochemicals



WP8 – Dissemination & Exploitation / IP

- Leaflet to communicate to the public on the CRISPR/Cas9 technology (WP2)
  - COSMOS promises ‘non-GM’ crops but uses CRISPR/Cas9
  - EU discusses whether it should be included in GM regulations
  - Random EMS mutagenesis (genetic material is removed, not added) is exempt from regulations
  - The end result of CRISPR/Cas9 crops is similar to that of EMS mutants
  - Argentina: non-GM crops
    Sweden: some crops GM, others non-GM



The COSMOS team

Thank you

rolf.blaauw@wur.nl

The COSMOS project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 635405.

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

Introduction to the Integrated Sustainability Assessment (WP 7)

Nils Rettenmaier, IFEU Heidelberg

Stakeholder workshop, Brussels, 9 October 2017

Funded by the Horizon 2020 Framework Programme of the European Union

COSMOS

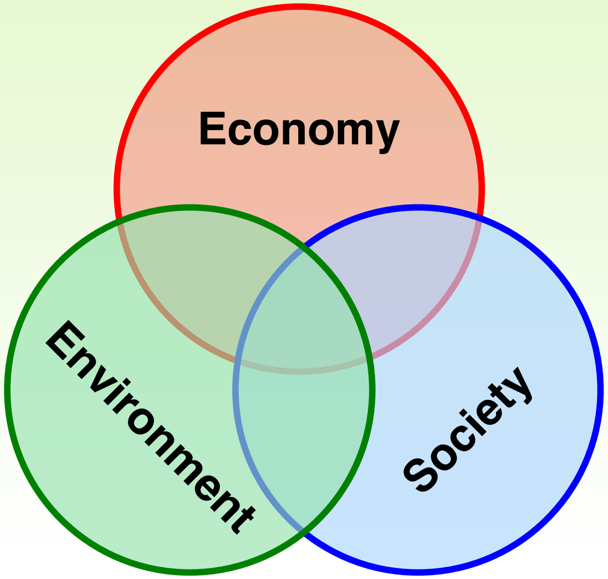
ADDING VALUE TO CAMELINA AND CRAMBE OIL

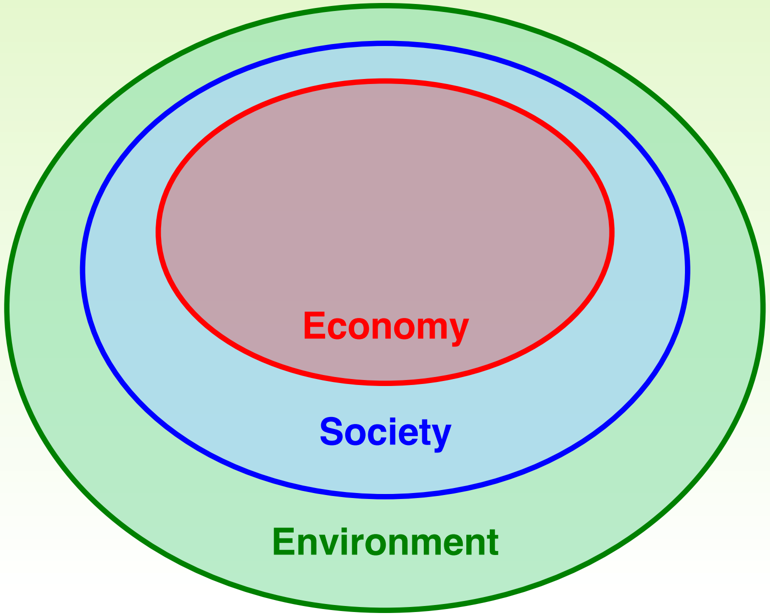
WP 7: Sustainability

Objectives

To deliver an integrated assessment of the sustain-ability of the entire value chains investigated in COSMOS and to reveal potential conflicts and synergies within and between the different pillars of sustainability.

The principle of sustainability



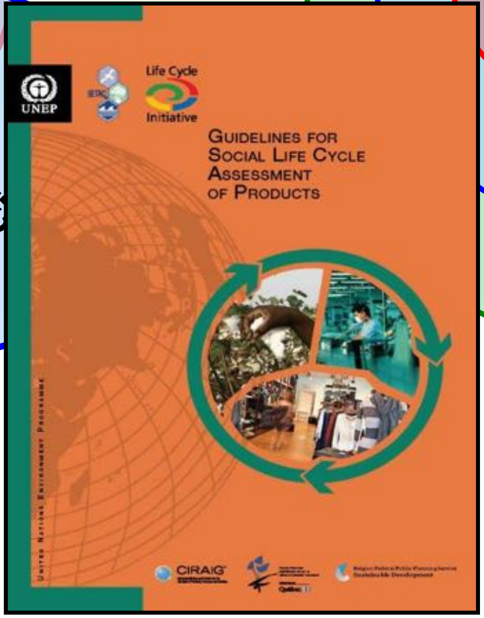


Assessing sustainability

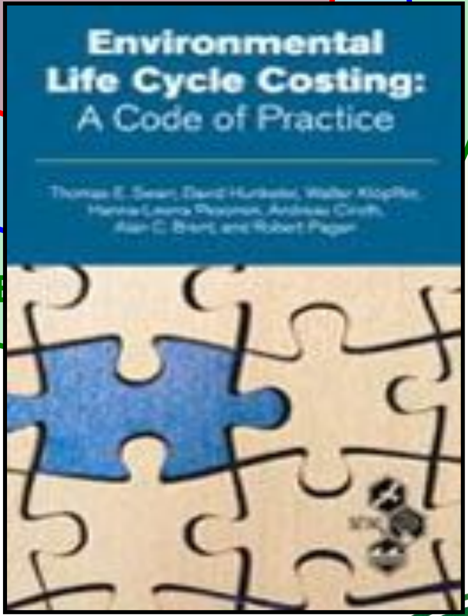
➔ **Including further ones such as for technological, legal and political issues**

Life Cycle Assessment (LCA)

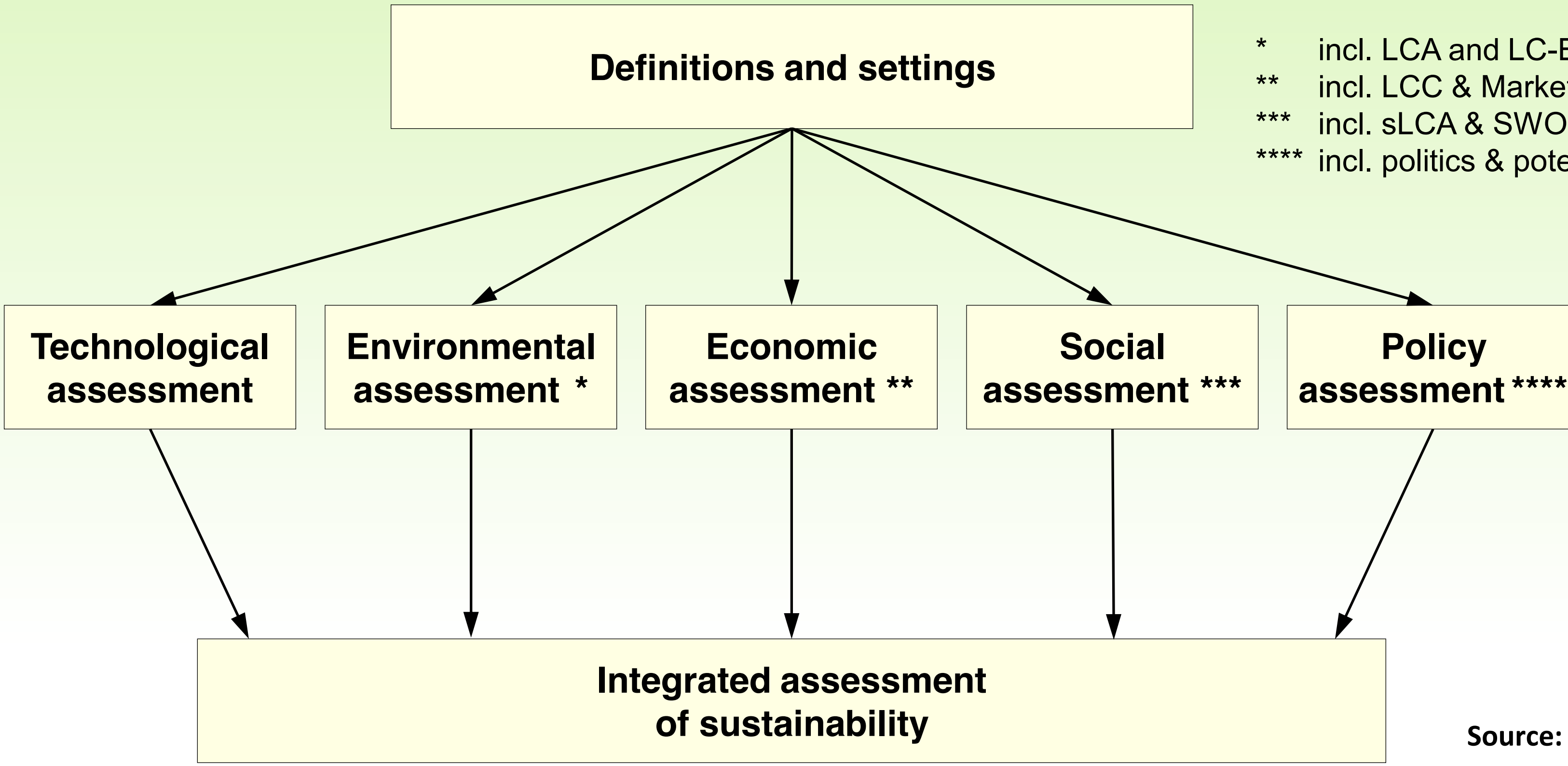
Social Life Cycle Assessment (sLCA)



Environmental Life Cycle Costing (eLCC)



Integrated life cycle sustainability assessment (ILCSA)



* incl. LCA and LC-EIA
** incl. LCC & Market analysis
*** incl. sLCA & SWOT
**** incl. politics & potentials

Source: IFEU

➔ **Successfully applied in many investigations since 2009**

ILCSA: Further reading

Applied Energy 154 (2015) 1072–1081

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Integrated life cycle sustainability assessment – A practical approach applied to biorefineries ☆

Heiko Keller *, Nils Rettenmaier, Guido Andreas Reinhardt

IFEU – Institute for Energy and Environmental Research Heidelberg, Wilckensstr. 3, 69120 Heidelberg, Germany

HIGHLIGHTS

- Integrated life cycle sustainability assessment provides ex-ante decision support.
- It extends LCSA by several features including a barrier analysis.
- A benchmarking procedure for result integration is presented.
- Practicability has been successfully demonstrated in five large EC-funded projects.

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ABSTRACT

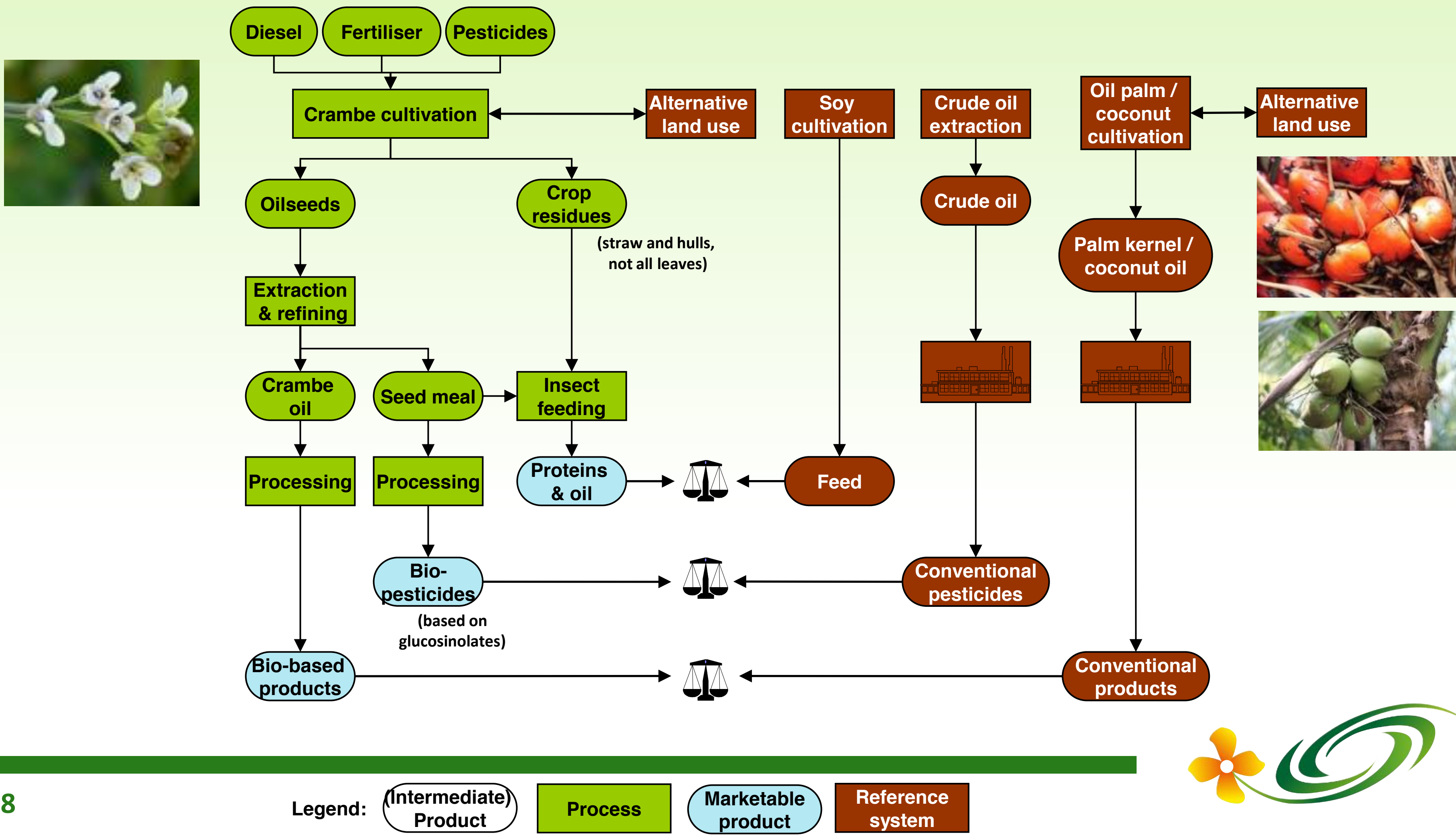
Politics and industry increasingly request comprehensive ex-ante decision support from a sustainability perspective in complex strategic decision situations. Several approaches have been introduced in the last years to increase the comprehensiveness of life cycle based assessments from covering only environmental aspects towards covering all sustainability aspects. This way, (environmental) life cycle assessment (LCA) has been extended towards life cycle sustainability assessment (LCSA). However, a practical application in ex-ante decision support requires additional features and flexibility that do not exist in the newly devised frameworks. Our methodology of integrated life cycle sustainability assessment (ILCSA) builds upon existing frameworks, extends them with features for ex-ante assessments that increase the value for decision makers and introduces a structured discussion of results to derive concrete conclusions

ILCSA: Exemplary results from BIOCORE

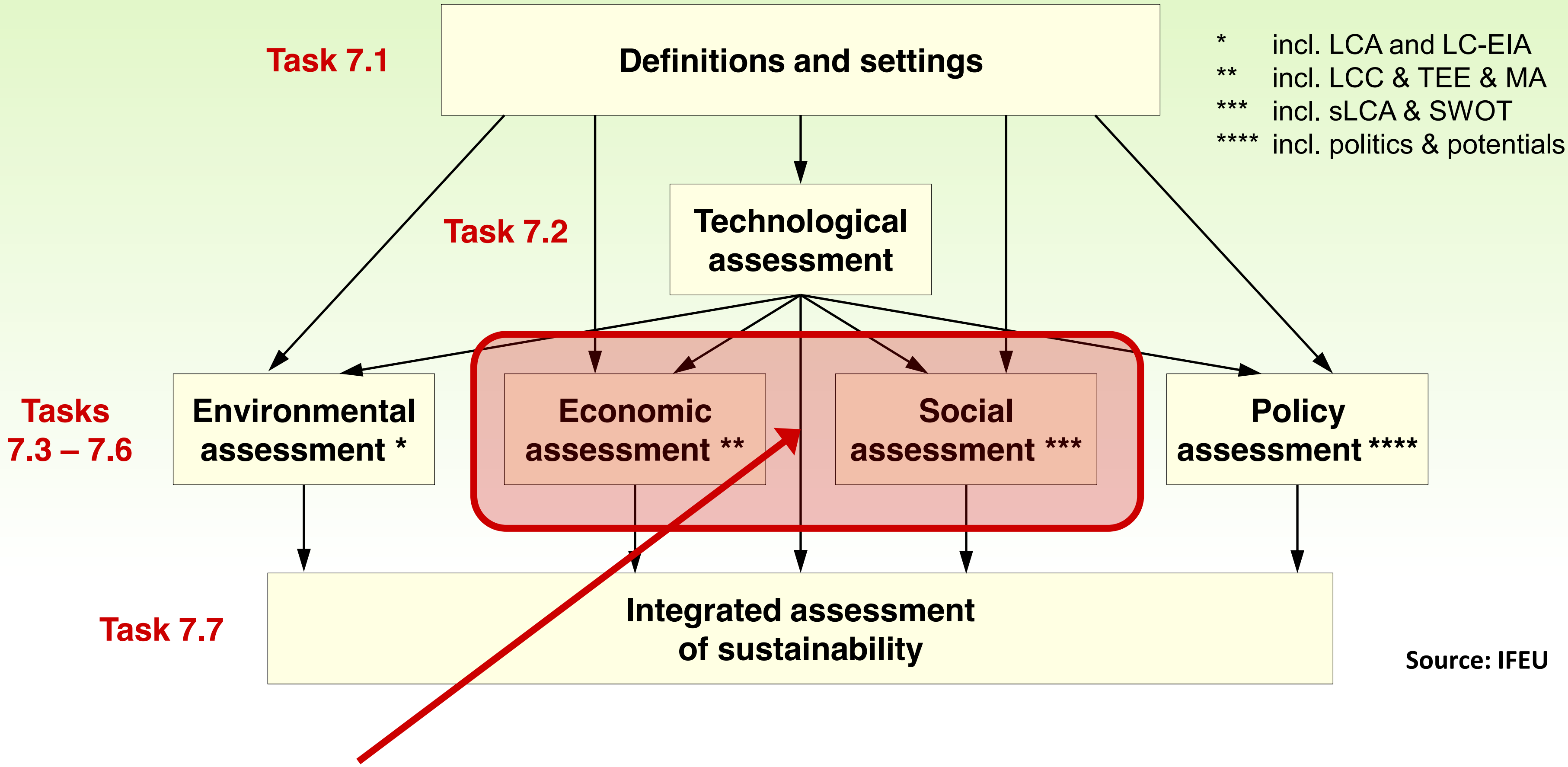
COSMOS: Life cycle comparison

COSMOS Bio-products

Conventional products



Integrated life cycle sustainability assessment adapted to COSMOS



Source: IFEU

Focus of today's workshop

The people behind WP 7

IFEU
Task 7.1
Task 7.3
Task 7.6
Task 7.7


Nils Rettenmaier


Guido Reinhardt


Tobias Wagner


F. Wellenreuther

CRES
Task 7.2


Myrsini Christou


Efi Alexopoulou

DLO
Task 7.1
Task 7.2


Rolf Blaauw

Imperial
Task 7.5
Task 7.6
Task 7.7


Rocio Diaz-Chavez

NOVA
Task 7.4


Stephan Piotrowski


Niels de Beus

Thank you !

nils.rettenmaier@ifeu.de

ifeu
INSTITUTE FOR ENERGY AND ENVIRONMENTAL RESEARCH HEIDELBERG

The COSMOS project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 635405.

COSMOS
ADDING VALUE TO CAMELINA AND CRAMBE OIL

COSMOS – WP2 – Modifying seed oil and meal quality

Camelina and Crambe Breeding and Genetics

Robert van Loo,
Wageningen Plant Research
Plant Breeding

Funded by the Horizon 2020
Framework Programme of
the European Union

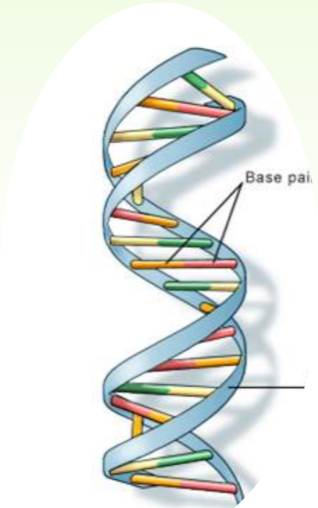
COSMOS
ADDING VALUE TO CAMELINA AND CRAMBE OIL

COSMOS – WP2 – Modifying seed oil and meal quality

Robert van Loo

Robert.vanloo@wur.nl

+31 6 53 72 67 69



H2020-COSMOS

- Development of new oil crops
- Tailoring crops to demand of oleochemistry
- Total crop use (also non-oil biomass)
- Substitution of EU-imports of vegetable oil
  - mono-unsatured short chain fatty acids (palm kernel, coconut)
- New oleochemistry (metathesis)
- Mutationa breeding and genome editing to improve oil profile and seed meal
  - EMS and CRISPR/CAS9 to knockout target genes

Two new oil crops

- *Camelina sativa*
- *Crambe abyssinica*
- *Brassicaceae*

Crambe abyssinica

- Seed yield 1500-4000 kg/ha
- Oil content > 38 %,
- Oil yield 600-900 kg/ha
- Erucic acid (C22:1) 60-65 %
- Too much C18:2 + C18:3
- Too much glucosinolates

Camelina sativa

- Seed yield 1500-3500 kg/ha
- Oil content > 40 %
- Oil yield 600-900 kg/ha

- High in C18:2+3 (linoleic +linolenic acid): 50 %
- High in C20:1 (gondoic acid): 15 %

Crambe erucic acid for erucamide and other products

Erucamide: slip agent in plastics
erucyl alcohol (C22:1 OH), behenic acid (C22:0 FA), behenic alcohol (C22:0 OH)

Camelina: Linnaeus Plant Sciences

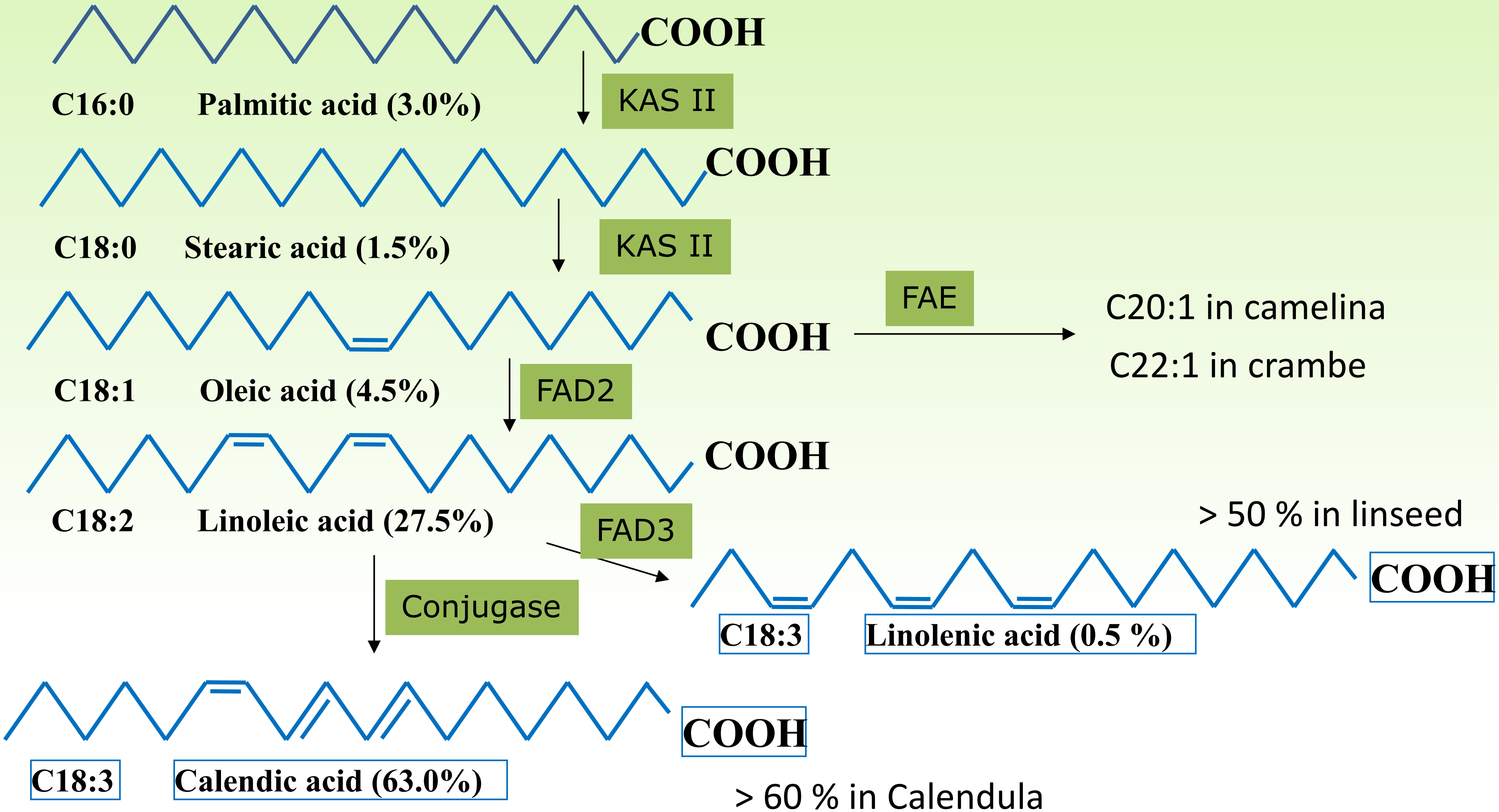
- Canadian company, daughter company in Wageningen
- in COSMOS: germplasm, PhD-student Jarst van Belle

Changing oil profile, improving seed meal

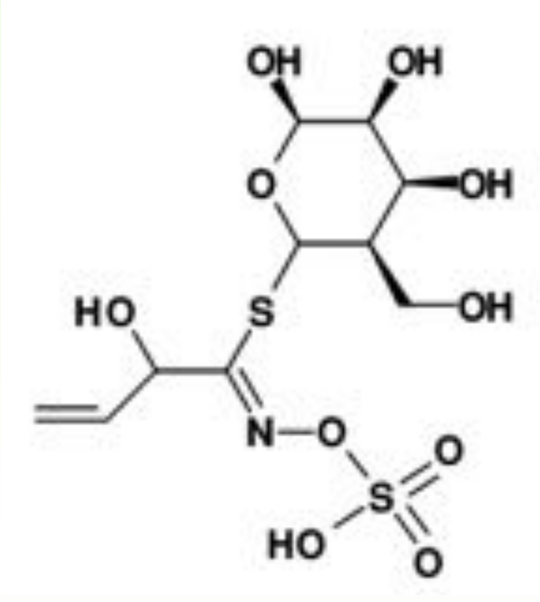
- Methathesis on poly-unsaturated fatty acids (PUFA)
  - gives a mixture of cleavages on all double bonds
  - PUFA < 10 % desired
  - *FAD2 should be knocked out*
  - higher level of C18:1, C20:1, C22:1 needed

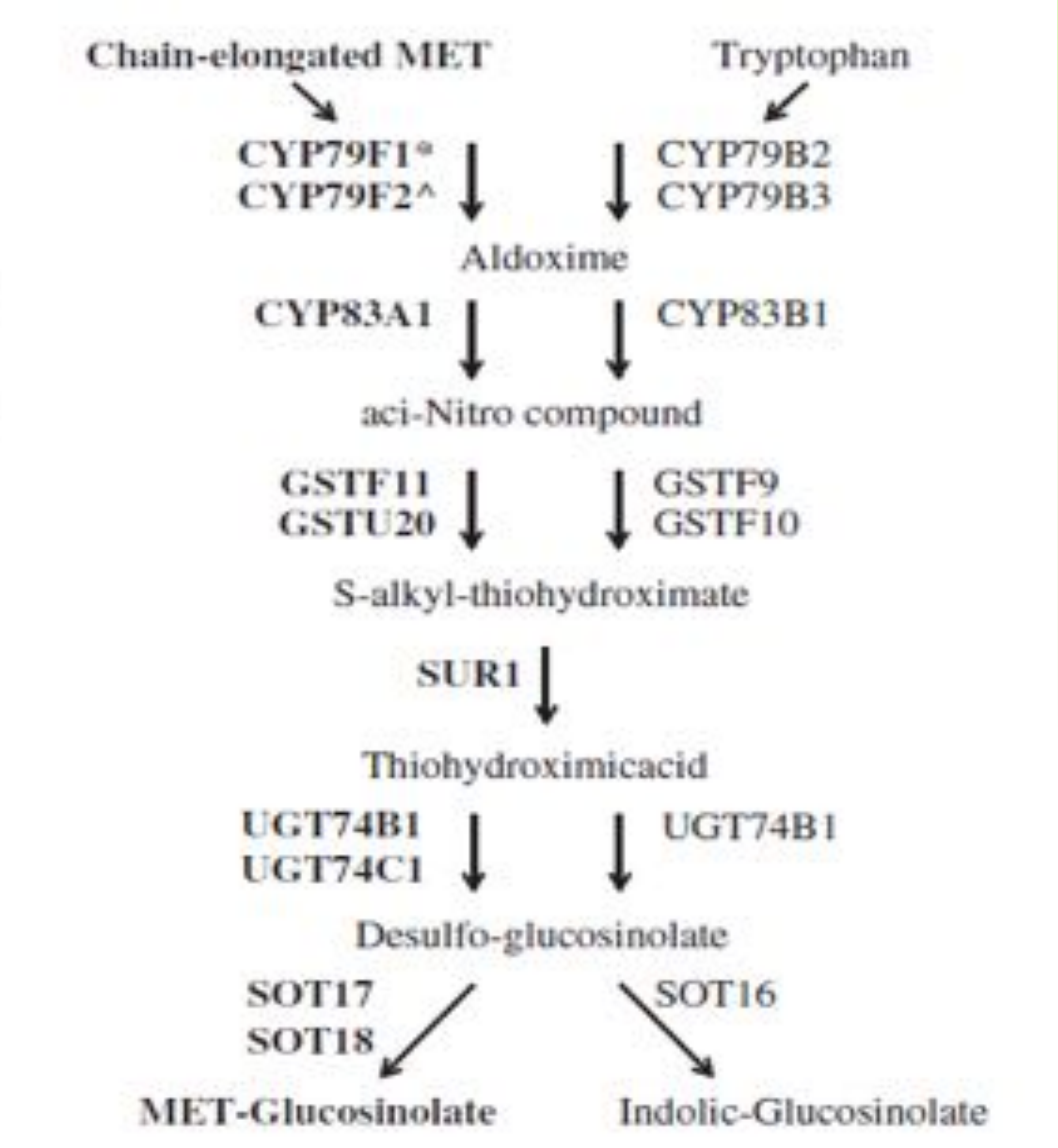
- Co-products should be higher value
  - *no glucosinolates, no sinapine*

Fatty acids in plants

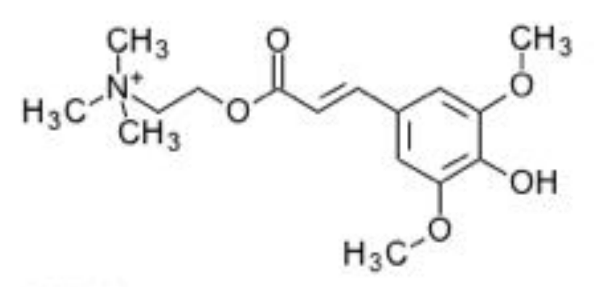


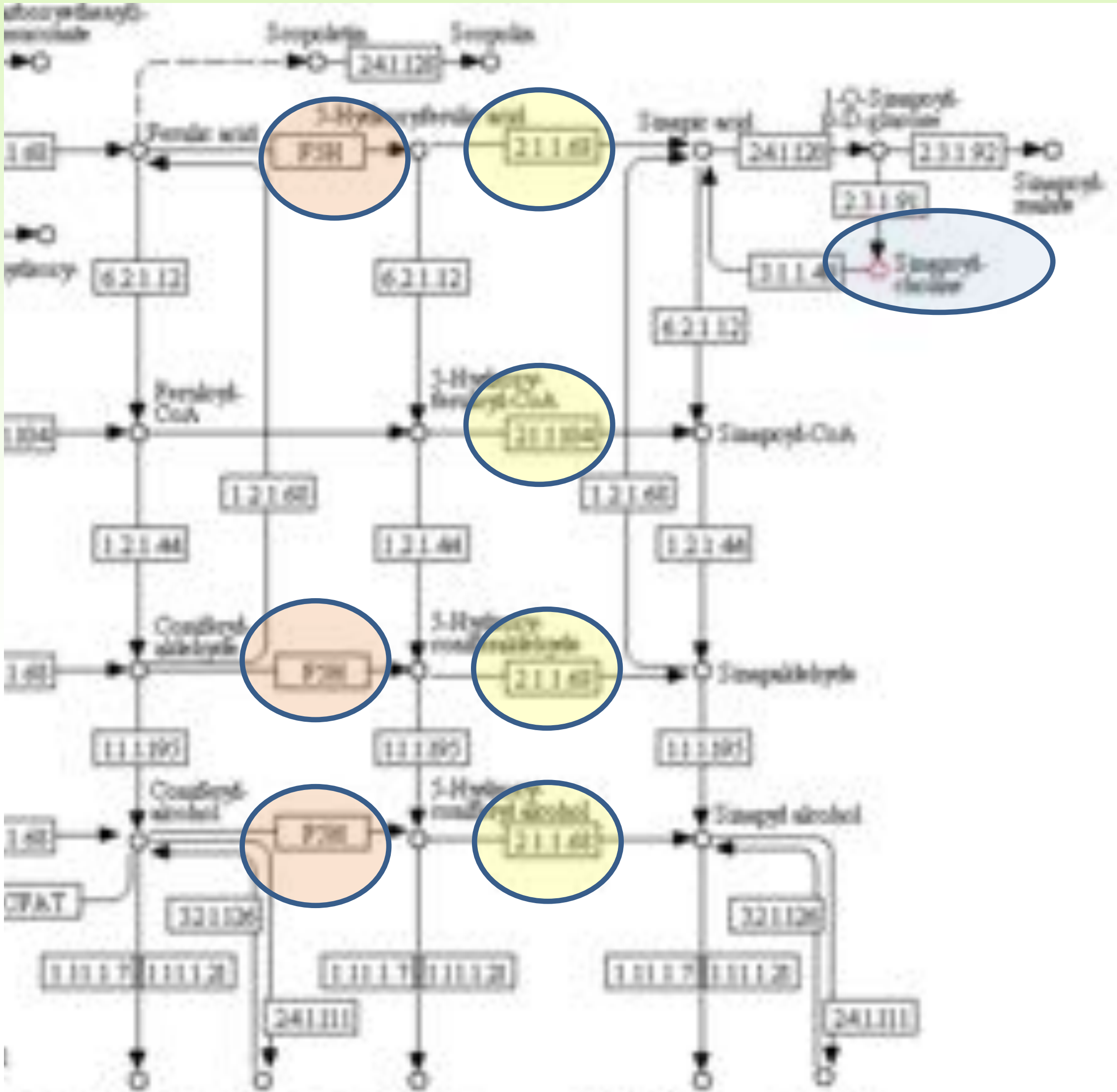
Knocking out glucosinolates in crambe



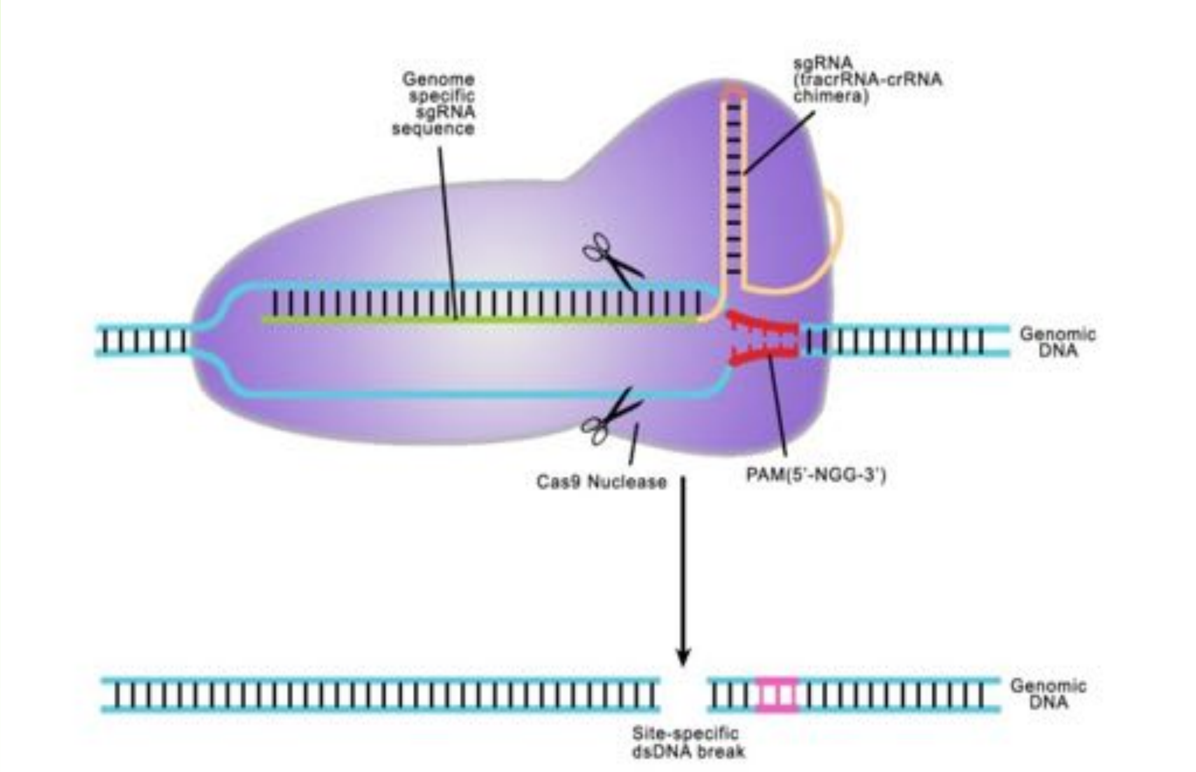


Knocking out sinapine





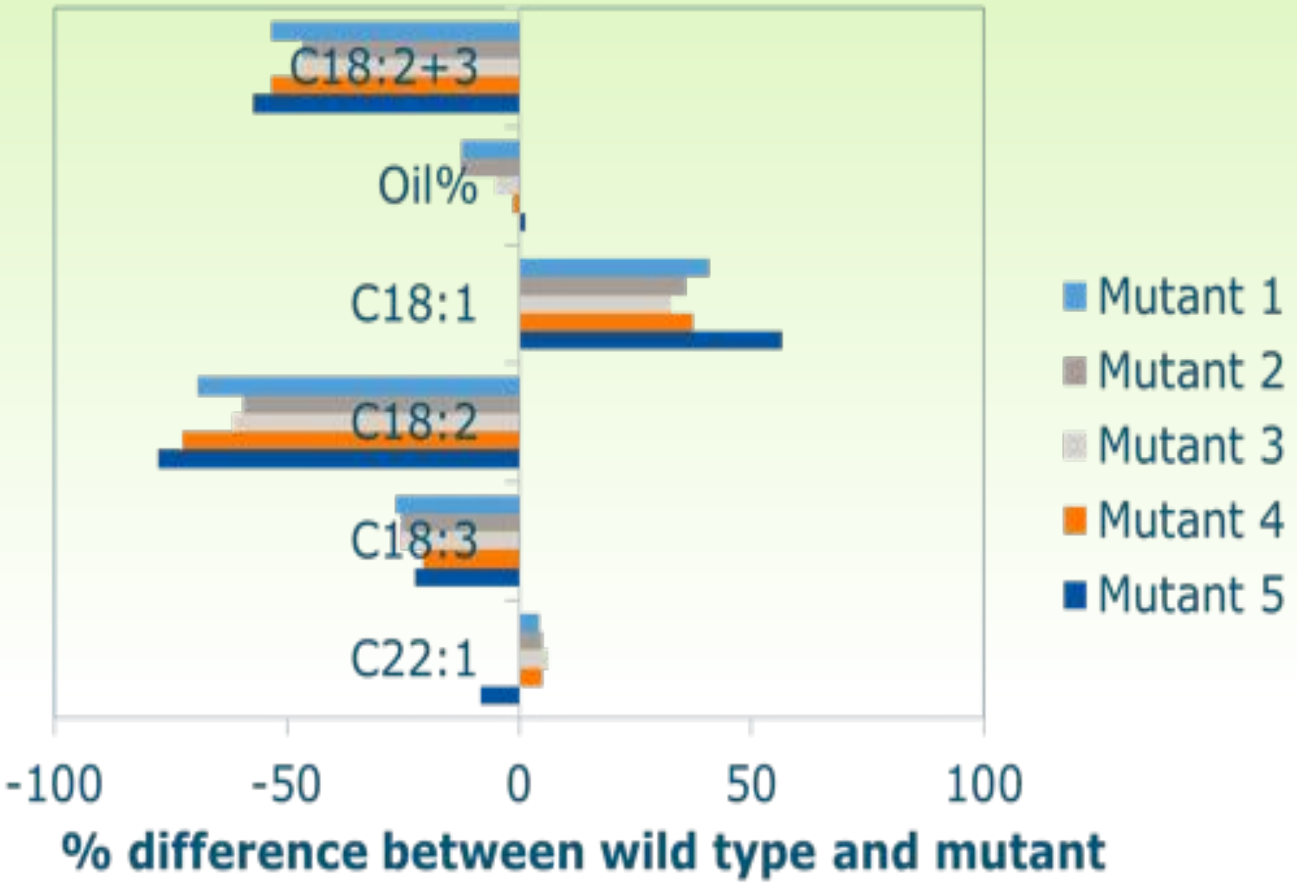
Genome editing: CRISPR/CAS9



Knocking out target genes or modifying their action

Targets
* lower poly-unsaturated FA, more C18:1, C20:1, C22:1
* less glucosinolates, sinapine

Task 2.2: Increasing mono-unsaturated fatty acid content in crambe (M1-M36) (DLO, LINNAEUS): FAD2-EMS-mutants



Field trial for seed production of EMS mutants of FAD2 in Crambe

- Mutant 1, 3 and 4 in Italy
- Mutant 1-5 plus Galactica in Netherlands
  - Now about 20 kg of each mutant line
  - Mutant lines are somewhat later flowering and maturing (unexpected) but not too late
  - Samples taken from 2 to 5 weeks after pollination and at maturity for oil % and FAME and RNA to test effects of mutations on expression of fatty acid pathway

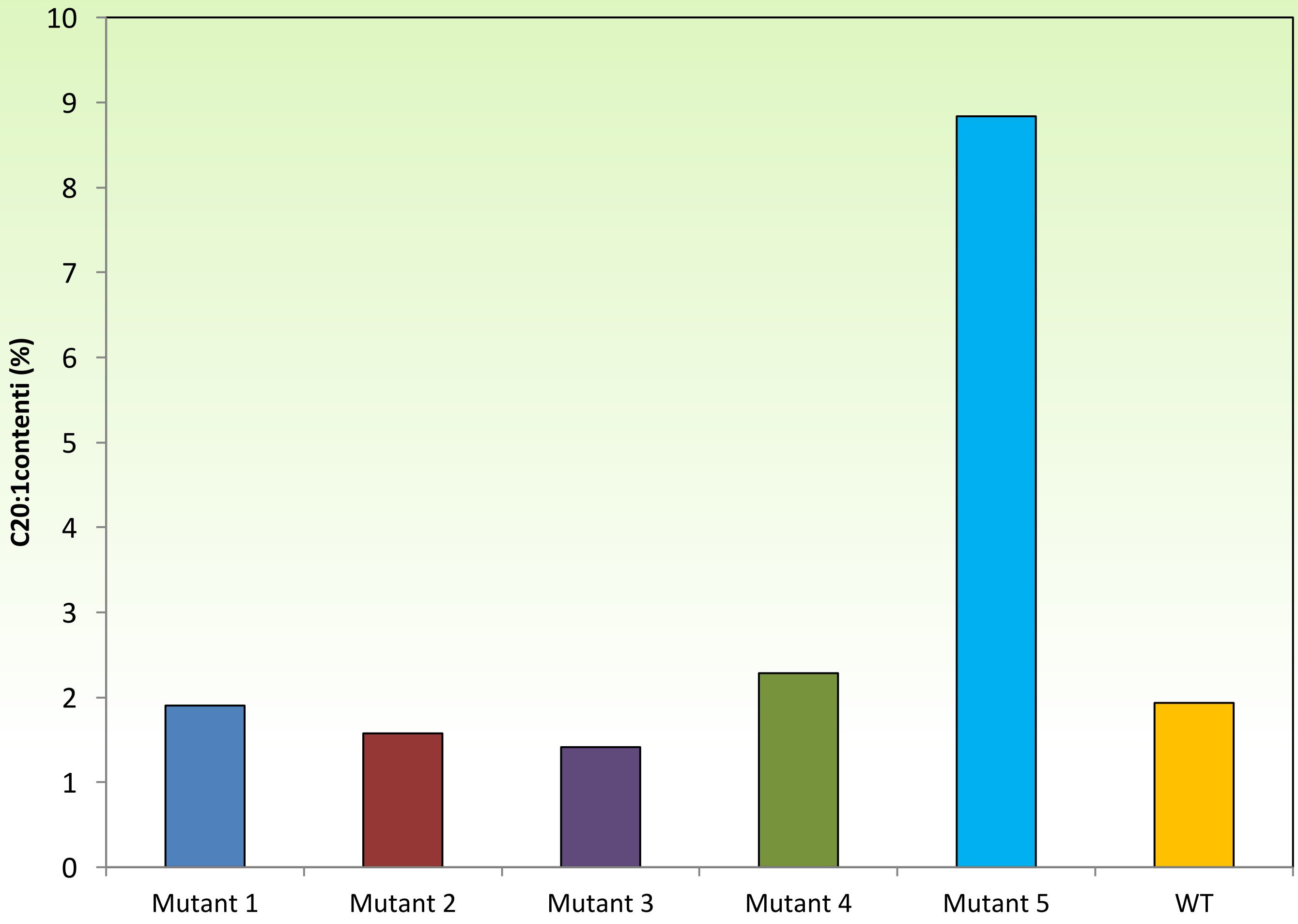
What will we have for you?

- Now already: Crambe varieties with
  - About same cost price as rapeseed oil
  - About 60-63 % erucic acid (C22:1)
  - About 35 % oleic acid (C18:1)
  - About 5 % C18:2+3 (PUFA) only
- Before end of COSMOS:
  - CRISPR mutants in crambe with low glucosinolates in seed meal
  - CRISPR mutants in camelina with low PUFA and increased C18:1 and C20:1 (gondoic acid)
  - CRISPR mutants in camelina with low sinapine in seed meal
- Industry can make pure monomers and polymers with these improved oil qualities and cost price will be lower due to higher value of seed meal

Discussion on regulation issues

- EMS mutants: no GMO regulation, fully safe and allowed
- CRISPR mutants: safety same as EMS mutants, but regulation issue not clear
  - GM needed currently to introduced the mutations but not transgenic end product ➔ EU regulation asks for strict GM rules
  - Possible to introduce CRISPR now (example in Sweden in potato) not using GM ➔ EU regulation will regard this as classical mutants which are not regulated

Task 2.2 FAD2-mutants crambe: C20:1 effect



Sustainable cultivation strategies (WP3)

Myrsini Christou, CRES

COSMOS Stakeholders Event, Brussels – October 9, 2017

Funded by the Horizon 2020
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the European Union

COSMOS
ADDING VALUE TO CAMELINA AND CRAMBE OIL

Contributors in this work

Myrsini Christou, Efthymia Alexopoulou

Andrea Monti, Federica Zanetti, Daria Righini

Mariusz Stolarski, Michal Krzyzaniak, J. Tworkowski, Jacek Kwiatkowski

Robert Van Loo

Jack Grushcow, Christina Eynck, Debbie Puttick

Objectives

To develop sustainable cultivation strategies for selected oilseeds (**camelina & crambe)** in order to optimize yields and oil content for the industrial needs.

Camelina (*Camelina sativa* L., *Brassicaceae*)

Why camelina?

- ✓ Non-food crop for the bio-based industry
- ✓ Annual crop, closely related to rapeseed.
- ✓ Grows on a variety of soils and climates
- ✓ Low input and drought tolerant
- ✓ Seed yields: 1.2 – 2.5 t/ha
- ✓ Oil content: 38-43%
- ✓ Oil characterized by 30-35% α-linolenic acid, 18-22% linoleic acid, 13-18% oleic acid and 13-17% of eicosenoic acid.

Camelina (*Camelina sativa* L. *Brassicaceae*)

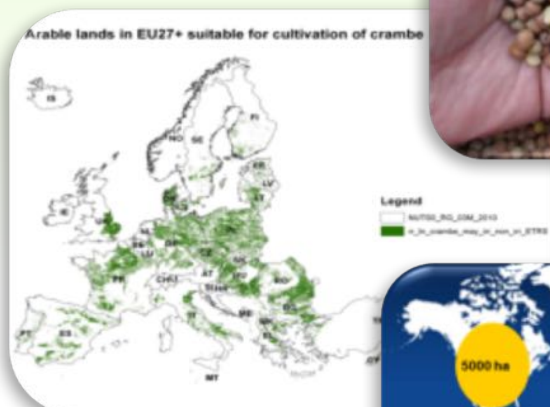
Advantages

- ✓ Short seasoned (<120 d)
- ✓ There are winter and spring types
- ✓ Very resistant to frost; seed germinates at ~ 5°C.
- ✓ Better shatter resistance than rapeseed
- ✓ Mechanized cultivation
- ✓ Helps spreading the workload since it can be seeded either very early in spring or in autumn/winter.

Constraints

- ✓ Does not thrive well when temperatures are above 25°C during flowering and seed filling
- ✓ Lack of registered herbicides

Crambe (*Crambe abyssinica* L, *Brassicaceae*)



Why crambe?

- ✓ Non-food crop for the bio-based industry
- ✓ Annual crop, closely related to rapeseed.
- ✓ Grows on a variety of soils and climates
- ✓ Low input and drought tolerant
- ✓ Seed yields: 1.2 – 3.5 t/ha
- ✓ Oil content: 30-40%
- ✓ Oil characterized by high erucic acid (C22:1) content (>55%)

Crambe (*Crambe abyssinica* L. *Brassicaceae*)

Advantages

- ✓ Tolerant to lodging and late season drought (depending on the variety)
- ✓ Not cross pollinated thus can be grown alongside with rapeseed

Constraints

- ✓ Cool season crop, highly sensitive to low temperatures at sowing and flowering
- ✓ Low genetic variability
- ✓ Crambe is susceptible to seed shatter if harvesting delays
- ✓ Competition with high erucic rapeseed but lower oil yield

Our trials

Aim to test of several agronomic practices to enhance sustainable crop yield and quality across a wide range of European climates, in small scale trials:

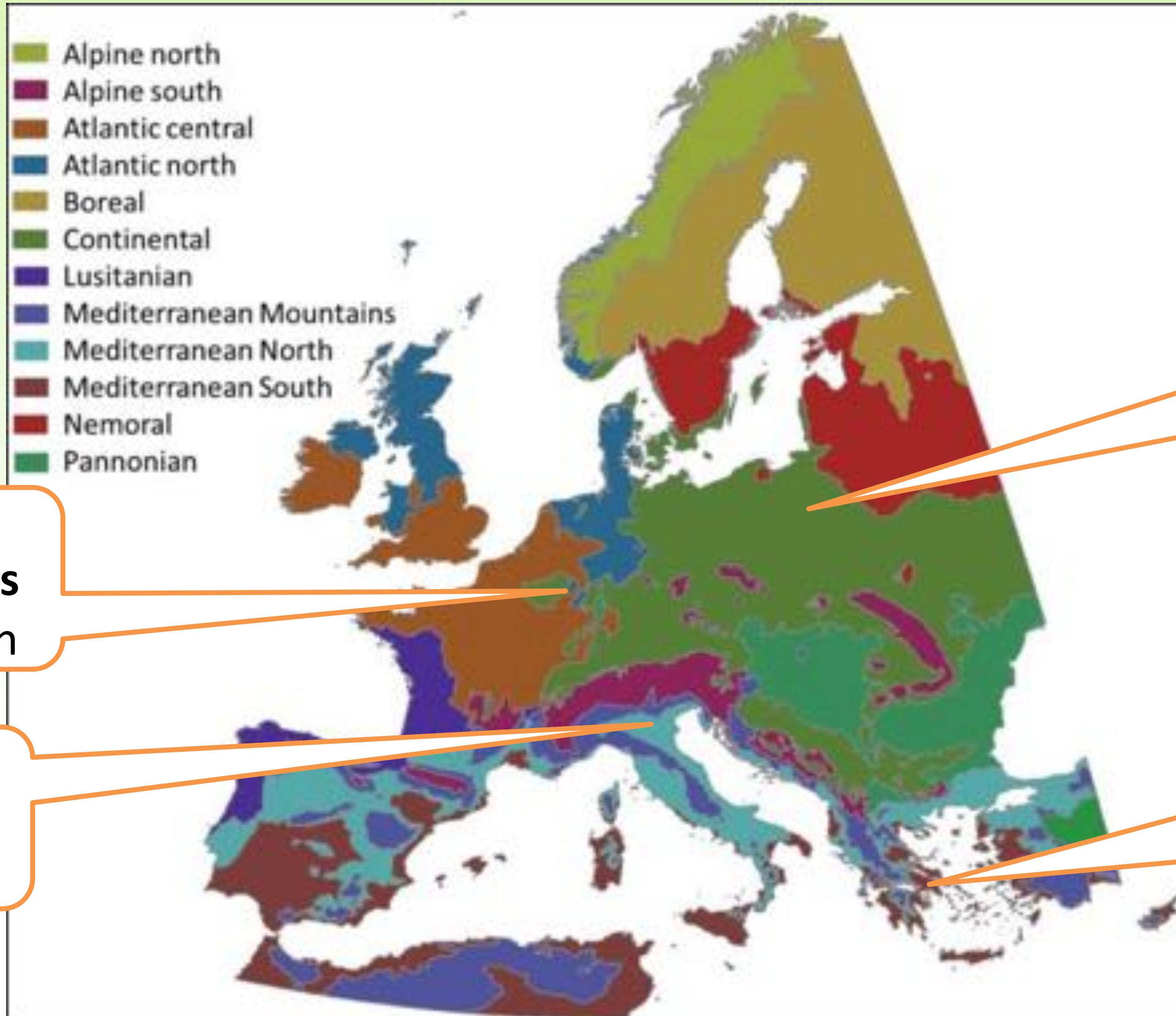
- **Screening**: To test several camelina and crambe lines
- **Sowing dates x densities**: To test different sowing densities and sowing dates
- **Fertilisation:** To test the effect of Nitrogen on yields and quality
- **Crop rotations**: To test the rotational effects of the selected crops on crop yield, nitrates and organic matter restitution of food crops. Monocultures are compared to different crop rotations: Cereal – Oil crops –Cereal/legume; Cereal – Oil crops (intercrop) – Cereal/legume; and monoculture

Our trials

Aim to test of several agronomic practices to enhance sustainable crop yield and quality across a wide range of European climates, in small scale trials:

- **Screening**: To test several camelina and crambe lines
- **Sowing dates x densities**: To test different sowing densities and sowing dates
- **Fertilization:** To test the effect of nitrogen on yields and quality
- **Crop rotations**: To test the rotational effects of the selected crops on crop yield, nitrates and organic matter restitution of food crops. Monocultures are compared to different crop rotations: Cereal – Oil crops –Cereal/legume; Cereal – Oil crops (intercrop) – Cereal/legume; and monoculture

4 Different locations - climate conditions



The Netherlands
Wageningen

Italy
Bologna

Poland,
Łężany

Greece,
Aliartos

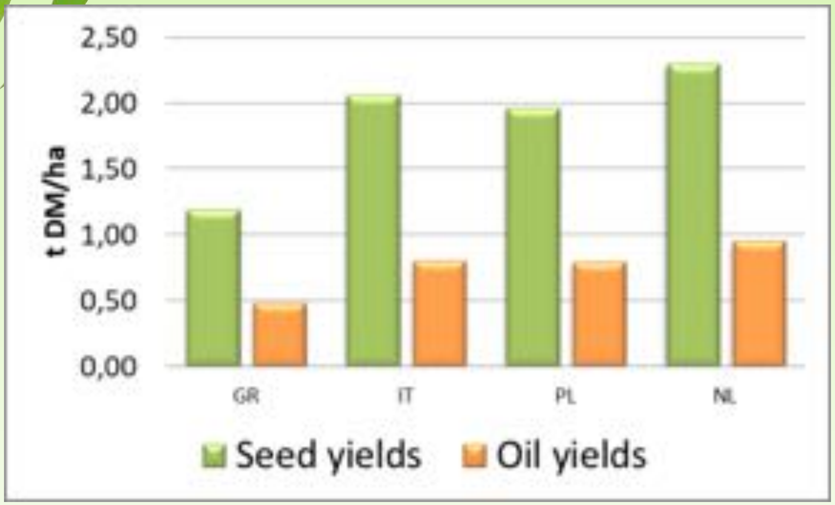
Screening trials

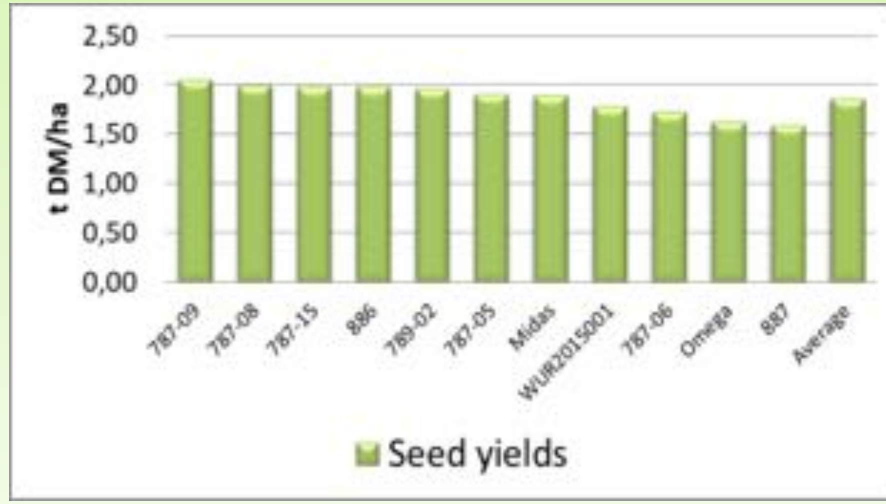
Camelina

Crambe

Screening trials

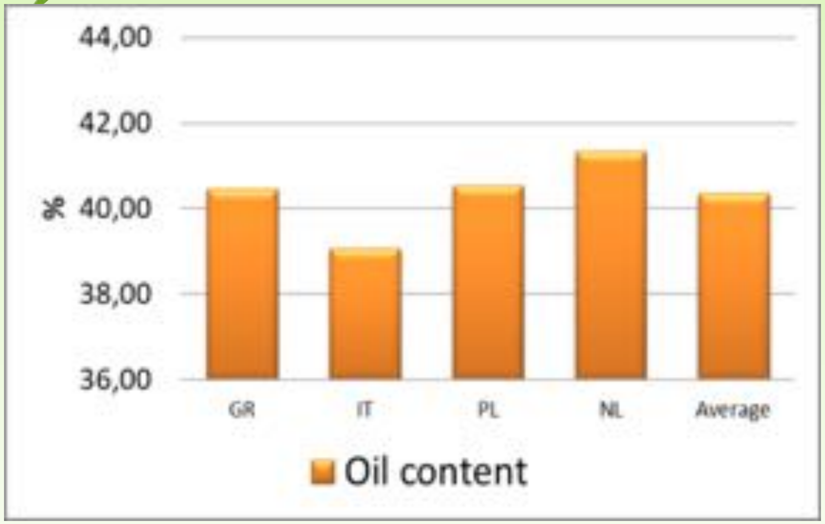
Camelina: Seed and oil yields

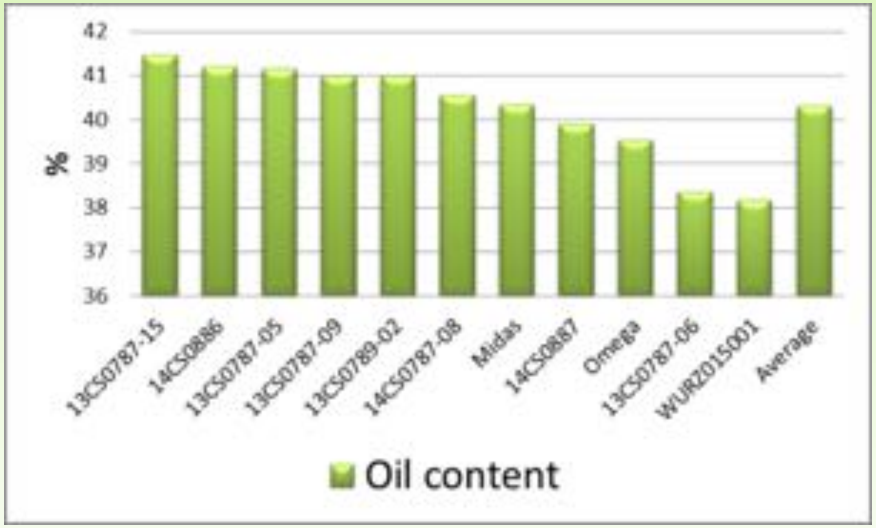




- ✓ Seed yields: 1.2 – 2.3 t DM/ha
- ✓ Oil yields: 0.5 – 1 t/ha
- ✓ Broadly adapted crop but some locations appear more suitable for camelina
- ✓ Higher yields in the Netherlands, followed by Italy and Poland. Much lower in Greece
- ✓ Oil yields varied significantly over locations and varieties
- ✓ The highest yielding varieties performed well in all locations

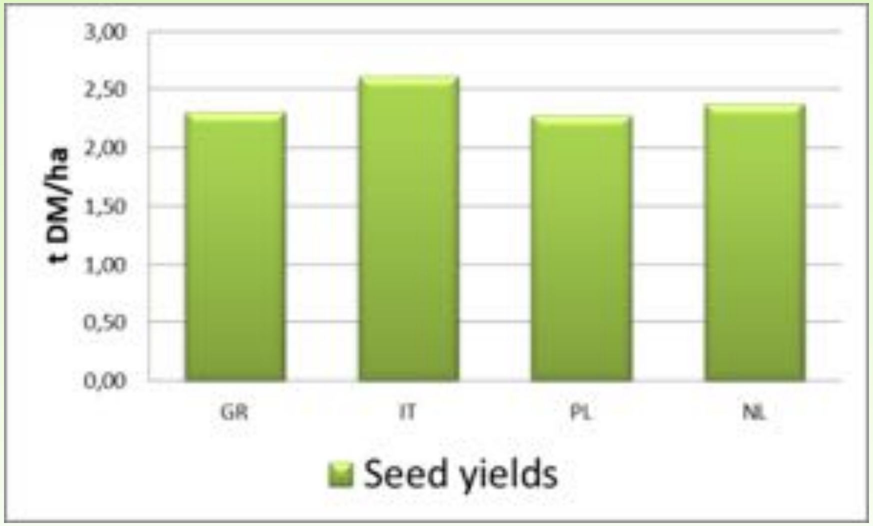
Camelina: oil content and fatty acid profile

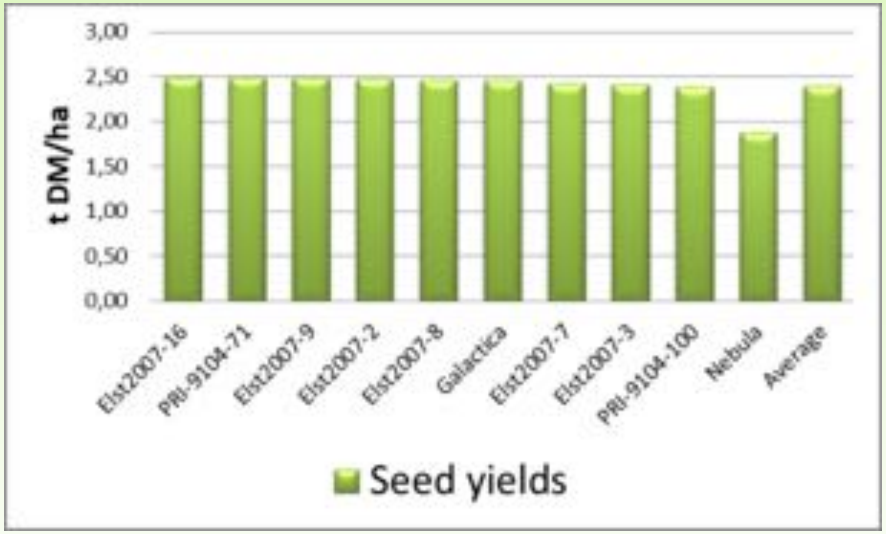




- ✓ Oil content: 39-41%
- ✓ Oil content and oil composition were significantly affected by environment and variety
- ✓ Low temperatures during seed filling period increase the α-linolenic acid content (C18:3)

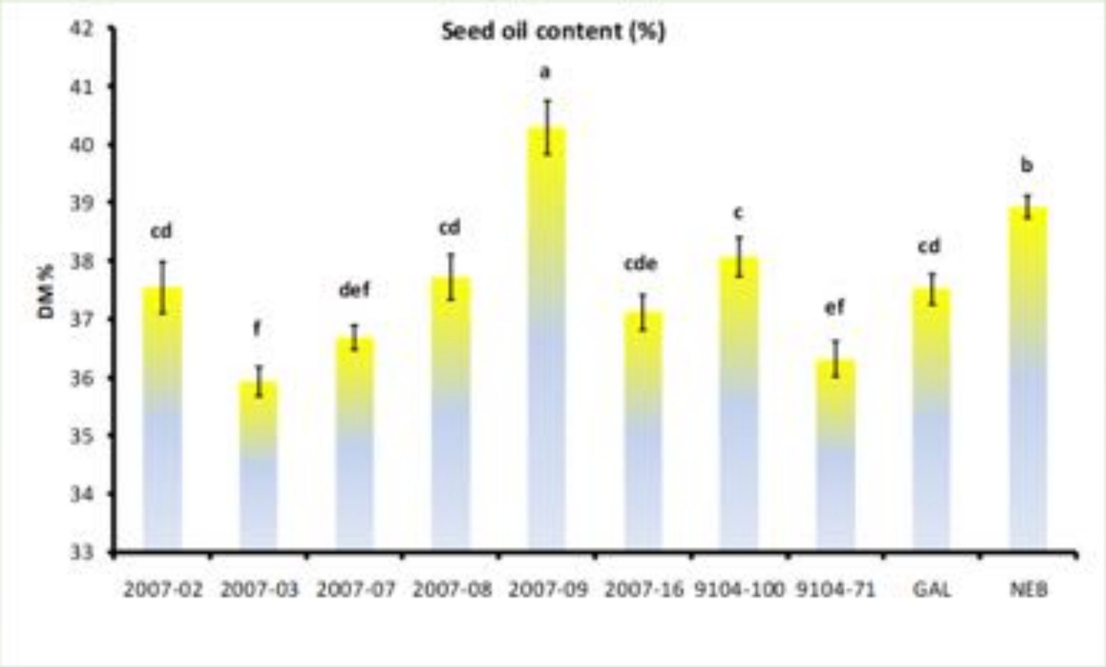
Crambe: Seed yields





- ✓ Seed yields: 1.0 – 2.6 t DM/ha
- ✓ Broadly adapted crop
- ✓ Seed yields were more or less stable across locations and varieties

Crambe: oil content and fatty acid profile



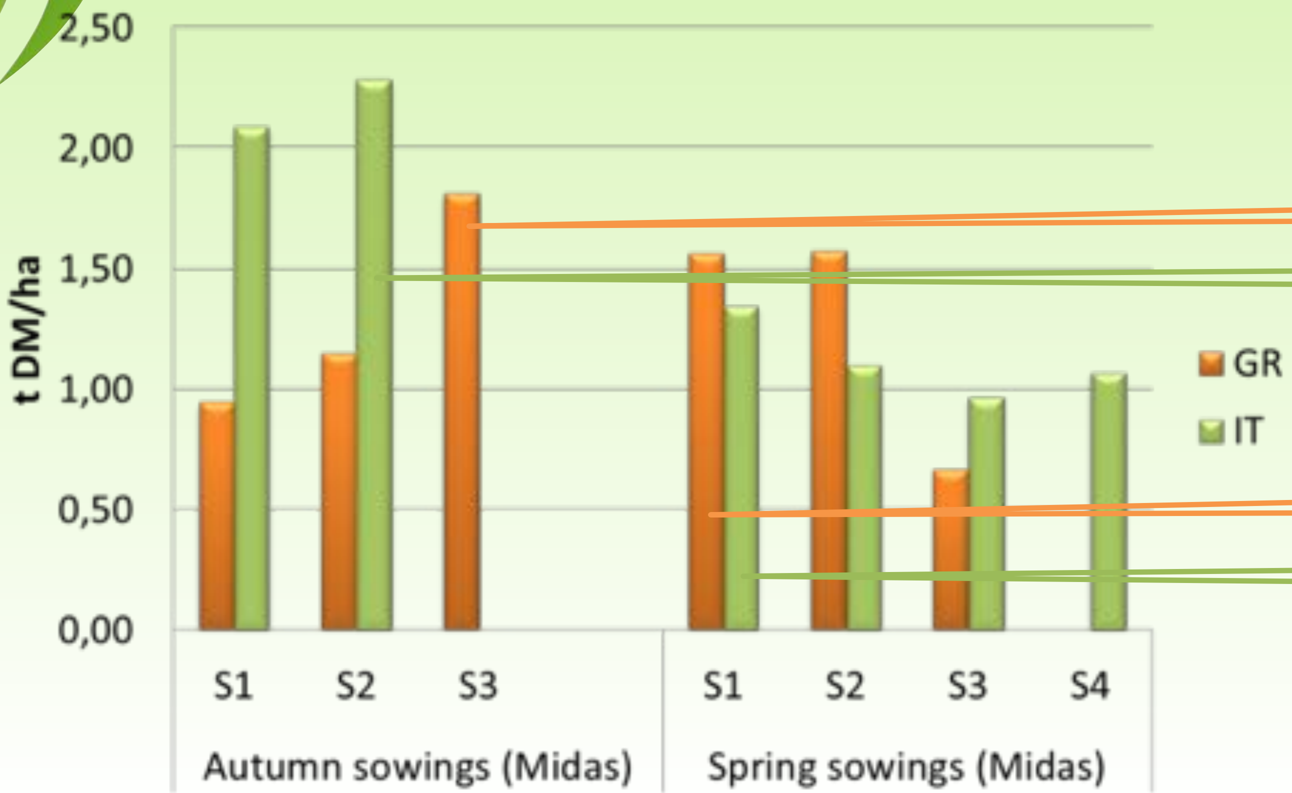
- Seed oil content was significantly influenced by location – higher in Poland.
- Differences among varieties were also significant
- However, oil composition of the tested varieties was very stable among cultivars and locations

Sowing dates x densities trials

Sowing dates x densities trials

Sowing dates x densities trials

Camelina: autumn vs. spring sowing



Autumn sowing times:

- **Greece**: **S1**=16/10, **S2**=08/11, **S3**=27/11
- **Italy**: **S1**=09/10, **S2**=26/10
- **Poland**: **S1**=21/09, **S2**=20/10

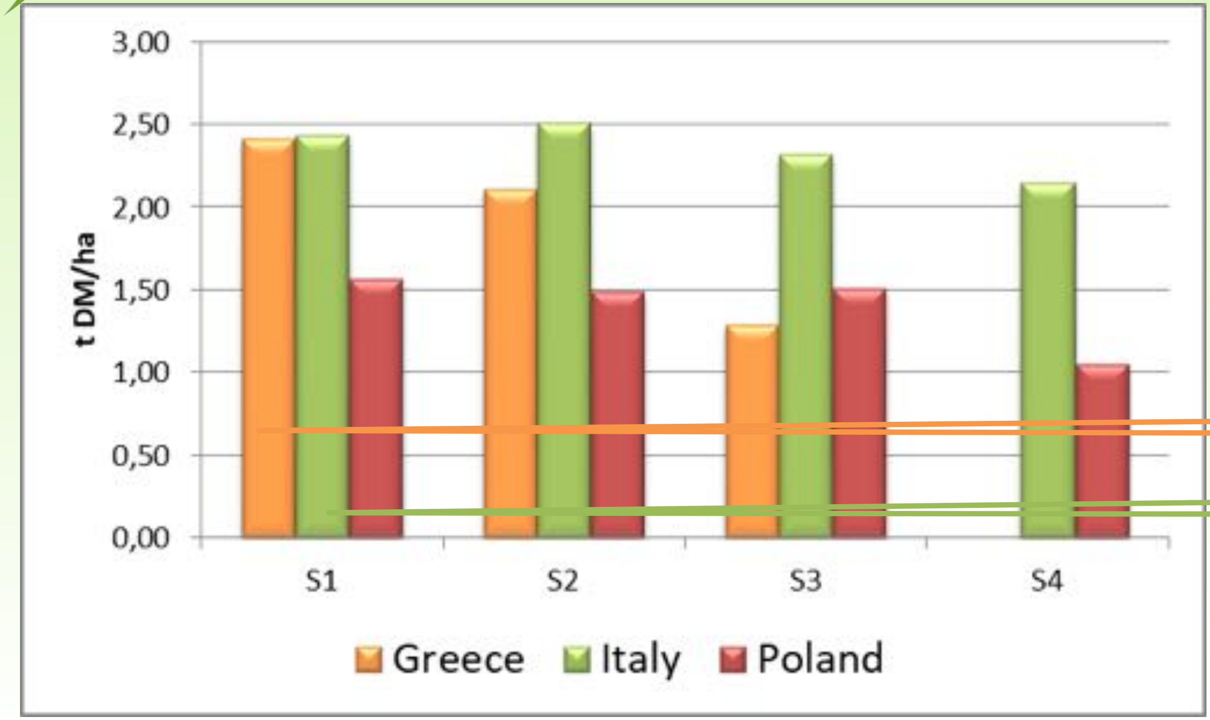
Spring sowing times:

- **Greece**: **S1**=4/3, **S2**=21/3, **S3**=5/4
- **Italy**: **S1**=12/2, **S2**=15/3, **S3**=30/3, **S4**=10/4
- **Poland**: **S1**=5/4, **S2**=15/4, **S3**=25/4, 5/5

✓ Camelina is higher yielding as a winter crop in Italy and Greece.

✓ In the environments characterized by mild winter, hot summer and early spring rainfall, a late autumn or early sowing seems to increase seed and oil yields.

Crambe: Spring sowing



Autumn sowing times:

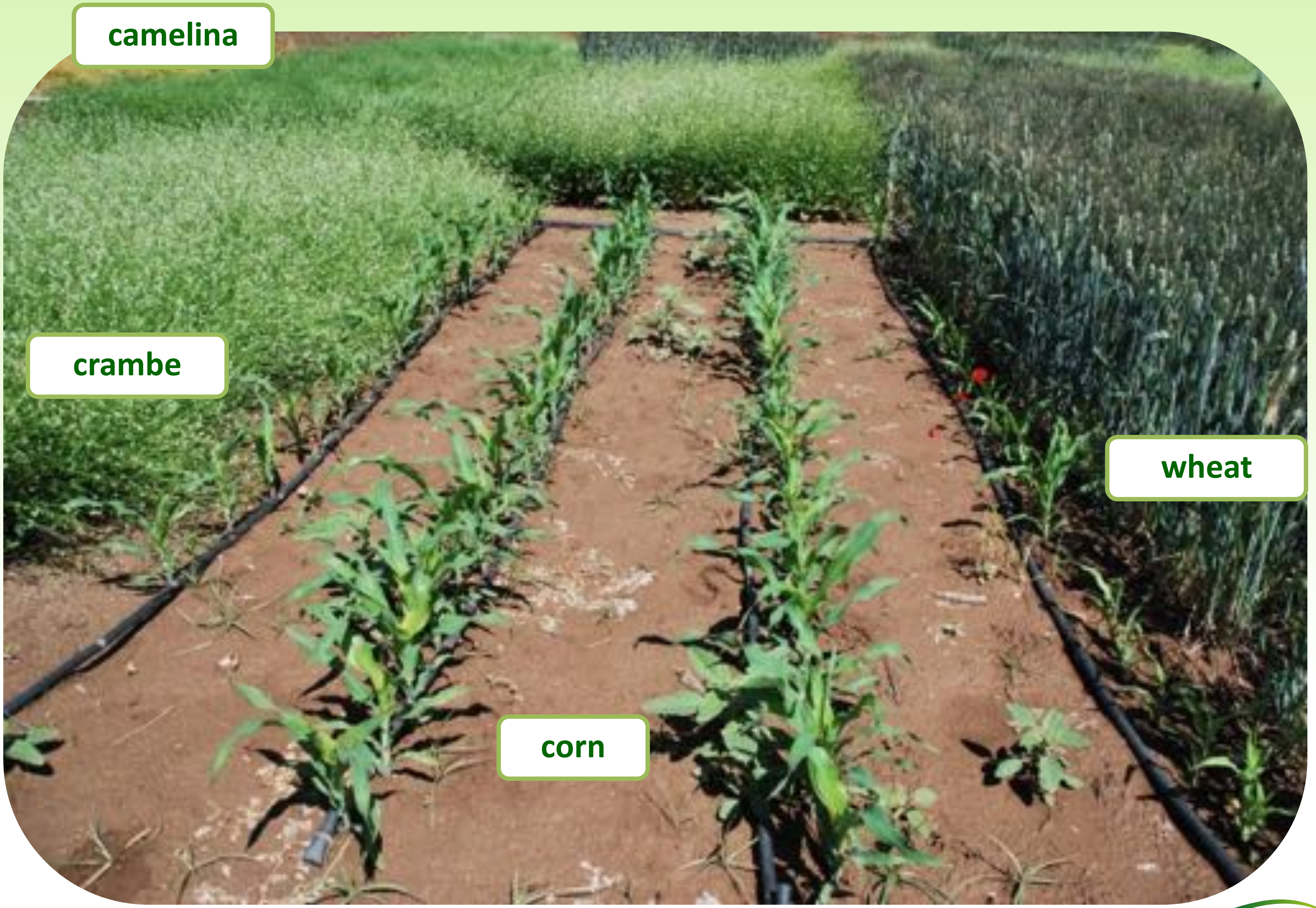
- **Greece**: **S1**=16/10, **S2**=08/11, **S3**=27/11
- **Italy**: **S1**=09/10, **S2**=26/10
- **Poland**: **S1**=21/09, **S2**=20/10

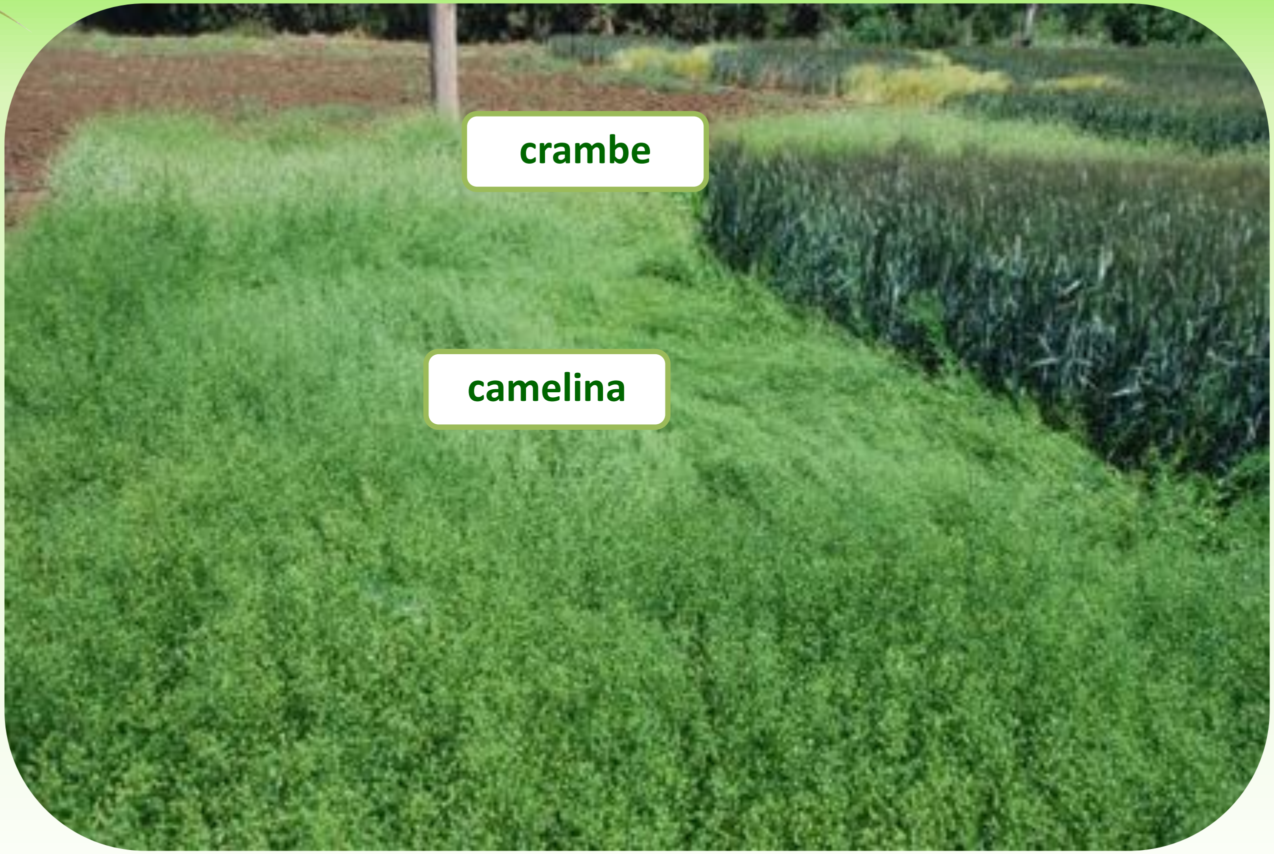
Spring sowing times:

- **Greece**: **S1**=4/3, **S2**=21/3, **S3**=5/4
- **Italy**: **S1**=12/2, **S2**=15/3, **S3**=30/3, **S4**=10/4
- **Poland**: **S1**=5/4, **S2**=15/4, **S3**=25/4, 5/5

- ✓ Crambe can be grown only as a spring crop
- ✓ Higher yields in Italy and Greece
- ✓ In the environments characterized by hot summer and early spring rainfall, early sowings increase seed and oil yields.

Crop rotation trials




crambe
camelina

Conclusions

- Camelina and crambe showed **good adaptability** to different environments
- Camelina performed better (higher seed yields and oil contents) in **mild-summer environments** (higher in the Netherlands, Italy), while crambe yields remained stable. Only seed oil content of crambe was significantly influenced by location (higher in Poland).
- **Late sowing in autumn** (for camelina) and **early sowing in spring (for both crops)** seem to increase seed and oil yields.
- The results are generally very promising to achieve a production target of 1 t/ha of oil.

Thank you for your attention!

Fore more information:
mchrist@cres.gr
http://cosmos-h2020.eu/

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

"Camelina & crambe Oil crops as Sources for Medium-chain Oils for Specialty oleochemicals"

The COSMOS project has received funding from the European Union's Horizon 2020 research and innovation program.

Grant agreement No. 635405

http://cosmos-h2020.eu/

WP 4. OIL EXTRACTION AND SEPARATION

Stakeholder Event

9th october 2017

Shila Ganguly Almenar

Funded by the Horizon 2020
Framework Programme of
the European Union

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

Participants

Solutex®
Delivering TailorMade Value

FOOD & BIOBASED RESEARCH
WAGENINGEN UR

Enzymical
Enzymes · Chemicals · Solutions

ERNST MORITZ ARNDT
UNIVERSITÄT GREIFSWALD
Wissen lockt. Seit 1456

WP4 targets

- Use physical techniques to separate individual MUFA in camelina and crambe oil
- Develop an enzymatic method to obtain oils enriched in long chain MUFA from camelina and crambe oil, by using selective lipases
- Convert C18 PUFA to C10-C12 MUFA in genetically modified *Pseudomonas putida*

Oil pressing and extraction (subcontracting)

Fractionation and esterification of the oils

Solutex – Delivering TailorMade Value

Selective microbial FA chain size reduction

FOOD & BIOBASED RESEARCH WAGENINGEN UR

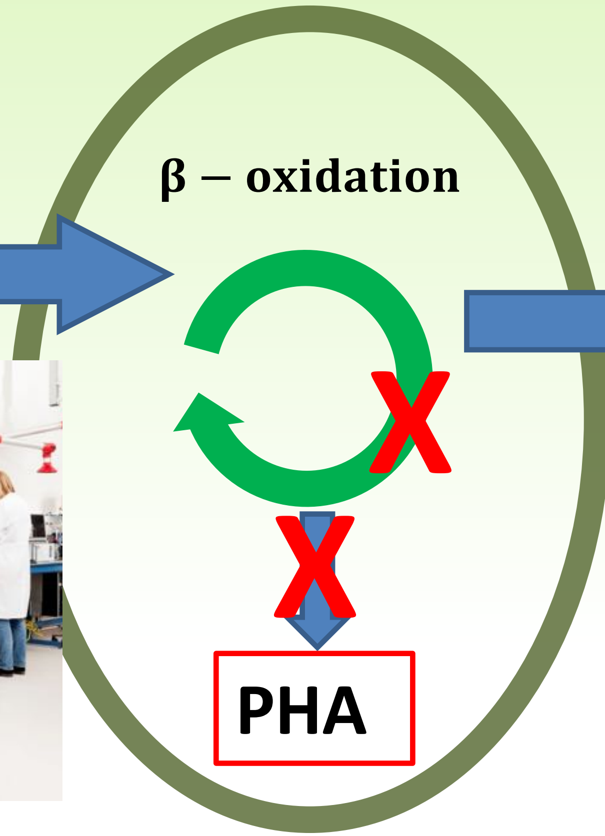
Enzymatic separation of long chain MUFA

Enzymical – Enzymes · Chemicals · Solutions

ERNST MORITZ ARNDT UNIVERSITÄT GREIFSWALD – Wissen lockt. Seit 1456

WP4. W.U: Oil extraction and separation

Linoleic acid C18:2
Linolenic acid C18:3

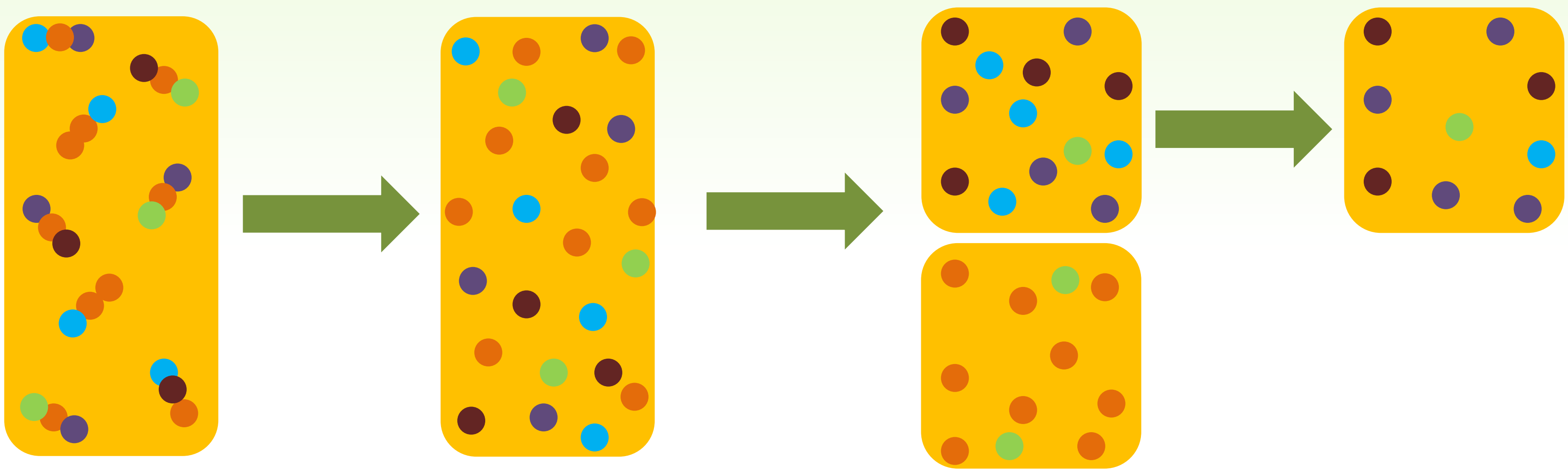


C12:2
C12:3
C10:1
C10:2

WP4. SOLUTEX: Esterification and physical fractionation

After performing a transesterification, using the most suitable separation techniques two fractions enriched in certain fatty acids are obtained.

An additional separation process can be performed to enrich the oil in various fatty acids.
Using enzymatical hydrolysis this oils obtained can be transformed to the FFA form.



RBD OIL

ESTERIFIED OIL

ENRICHED FRACTIONS

WP4. SOLUTEX: Esterification and physical fractionation

Solutex
Delivering TailorMade Value

Camelina oil

16% gondoic acid
52% PUFA

Fraction enriched in gondoic
46-50% gondoic acid
9-15% PUFA
Yield: expected to be improved

Fraction enriched in PUFA
0% gondoic acid
73-75% PUFA
96% C18 MUFA+PUFA
Yield: expected to be improved

Crambe oil

58% erucic acid
13% PUFA

Fraction enriched in erucic
77-79% erucic acid
5-6% PUFA
Yield: 40% (EE) 29% (FFA)

Fraction enriched in PUFA
0% gondoic acid
73-75% PUFA
96% C18 MUFA+PUFA
Yield:19% (EE) 15% (FFA)

WP4. Enzymicals: Enzymatic separation of long-chain MUFA

Enzymical(S)
Enzymes · Chemicals · Solutions

Techtransfer by Enzymicals

UniGreif

Cosmos Partner (Arkema) or CMO

Enzymical(S)
Enzymes | Chemicals | Solutions

A. **Scale-up of Lipase Production & Enzyme Immobilisation**
B. **Scale-up of selective enzymatic FFA enrichment process**
C. **Tech Transfer of Pilot Scale Application to COSMOS Project partners**

Next steps

Scale-up of oil transformation process and reaction conditions	Up to1L-scale

Next…
Reaction optimisation up to 1L-scale with improved lipase variants from UniGreif

4x parallel reactor system

Prepilot-Scale testing	multi-L-scale

Shila Ganguly: sganguly@solutex.es

Thank you for your attention

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

COSMOS: Camelina and crambe Oil crops as Sources for Medium-chain Oils for Specialty oleochemicals

WP5: Vegetative tissue and seed meal valorisation by insects

Arnoud Togtema

October 9, 2017, Brussels

Funded by the Horizon 2020 Framework Programme of the European Union

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

WP2 & 3

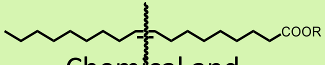

Camelina


Crambe

WP4
Long-chain fatty acids

- (Refined) Oils
  - Fatty acids
  - Fatty esters

WP6
(Bio)catalytic conversion & applications



Chemical and Biotechnological chain scission

WP5

- Co-products
  - Glucosinolates
  - Insect oils
  - Insect proteins

Medium-chain fatty acids

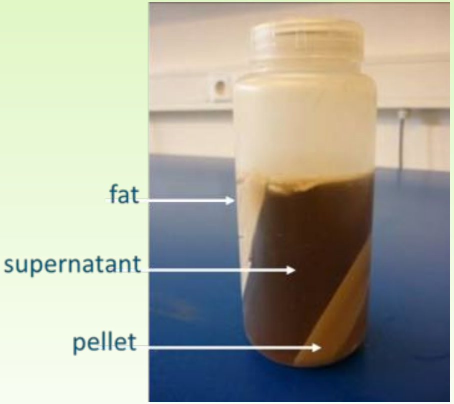
C_{10}-C_{14}
Palm kernel & coconut markets

High-value Products

Bio-plastics
Lubricants
Surfactants
Flavours
Fragrances
Bio-pesticides
Food/Feed

WP5 – Seed meal valorisation by insects

- Insect selection and rearing on seed meal diets (Wageningen Uni, Entomology)
- Insect refinery to obtain oils, proteins & other valuable biomolecules (Wageningen-FBR)
- Develop prototype for automated mass rearing of insects on side-streams + Implement Insect Biorefinery (Proti-Farm)
- Extraction of anti-nutritional compounds from seed meals (Glucosinolates) (Solutex)



Bioconversion of crop residues by insects

Camelina

	Press cake			meal							straw
	25	50	100	10	15	18	20	25	50	100	100
Acheta domesticus											
Alphitobius diaperinus											
Athalia rosae											
Delia radicum											
Hermetia illucens											
Pachnoda marginata											
Spodoptera exigua											

Crambe

	Press cake			meal							straw			
	25	50	100	5	10	15	18	25	50	100	12.5	25	50	100
Acheta domesticus														
Alphitobius diaperinus														
Athalia rosae														
Delia radicum														
Hermetia illucens														
Pachnoda marginata														
Spodoptera exigua														

Legend

- Performance equal/higher than control
- Performance lower than control
- Development impossible

Overview of performance scores per insect species and diet, using a traffic-light colour coding system. Scores are averaged over all parameters measured in each experiment

Conclusions

- Selection of best insect species: Black Soldier Fly;
- Mass-scale automated production system already in use for BSF (TRL 9)
- Pathway of straw bioconversion by insects not promising; not pursued further; to be deleted from economic assessment
- Mealworms, crickets and lepidopteran larvae found in the crops will be re-tested on seed meal from which glucosinolates have been removed.

Alphitobius diaperinus

Acheta domesticus

Heliothis viriplaca

Feed for insect mass-rearing: Proti-farm

Proti-Farm® The Protein Company

- Nutritional requirements of the animal
- Chemical composition of raw material
- Anti nutritional factors
- Cost price of raw material

=> Least cost formulation

Protein, energy, amino acids, vitamins….

Fiber, protein, fat, ash, minerals….

Glucosinolates ….

??

- Crambe & Camelina meal: vegetable protein source
- Negative effect on growth of Lesser Meal Worm
- Due to glucosinolates??
- Possibilities to remove glucosinolates
- Use of meal depends on price

Vegetable Oils Fatty Acids Profiles

CX:n (X=chain length, n=number of unsaturation or C=C bonds)

Oil	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0	C22:1
Rapeseed					4.5	2	57.5	23	11	0.6	2.3		
Soybean					9	4.5	25	49.5	11				
Palm Kernel	3.5	3	50.5	15.5	9	2	14.5	2.5		0.5			
Coconut	8	7	48	16	9	2	7	2					
Castor						3	87		11				
Camelina					6	2	15	18	35	1	19		1
Crambe					2.4	0.8	17.9	8.3	5.7	0.5	4.2	2.1	55.9
Black Soldier Fly Larvae		0.7	51.2	8.5	10.5	1.1	12	9.5	0.6	0.2			

Composition BSF-larvae dry mass based:
±40% Crude protein
±28.5% Crude fat

Thank you

- The COSMOS project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 635405.

- The COSMOS slides reflect only the author's view. The Research Executive Agency of the European Commission is not responsible for any use that may be made of the information it contains.

Funded by the Horizon 2020 Framework Programme of the European Union

COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

WP6: (Bio)Catalytic conversion and applications

Cosmos Stakeholders Event

Brussels – October 9, 2017

Jean-Luc Dubois - Jean-Luc Couturier (Arkema)

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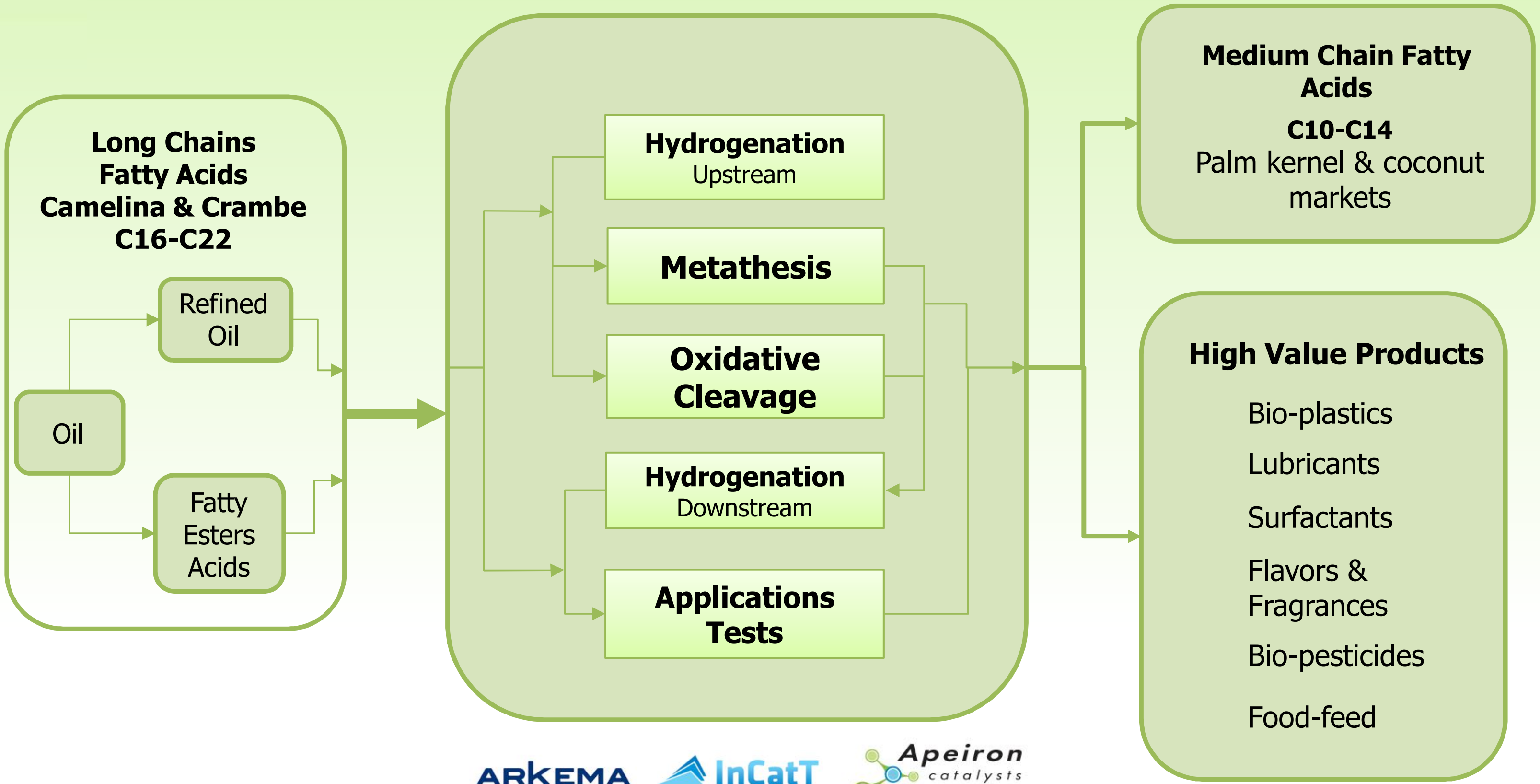
the European Union

COSMOS
ADDING VALUE TO CAMELINA AND CRAMBE OIL

Catalysis in Cosmos



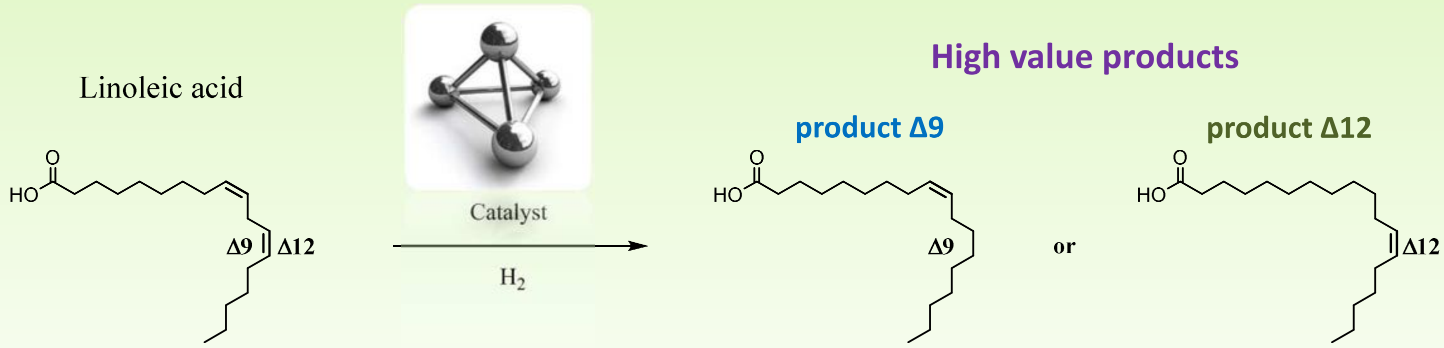
ARKEMA InCatT Apeiron catalysts

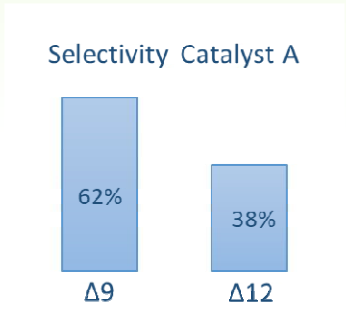
UNIVERSITÉ DE RENNES 1 CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

Position selective hydrogenation

Selective hydrogenation of linoleic acid into only one position-isomer MUFA (Δ9 or Δ12) using transition metal catalysts

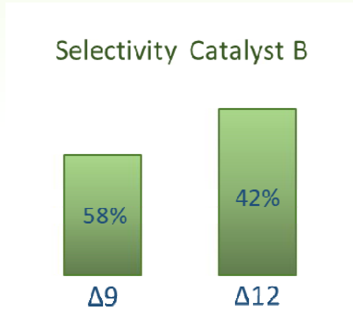
High value products





Excess in product Δ9

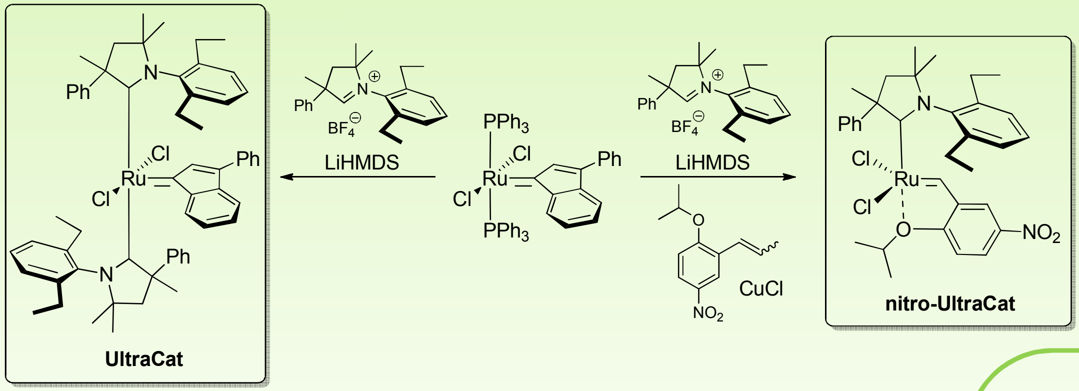
Selective formation of product "on-demand"



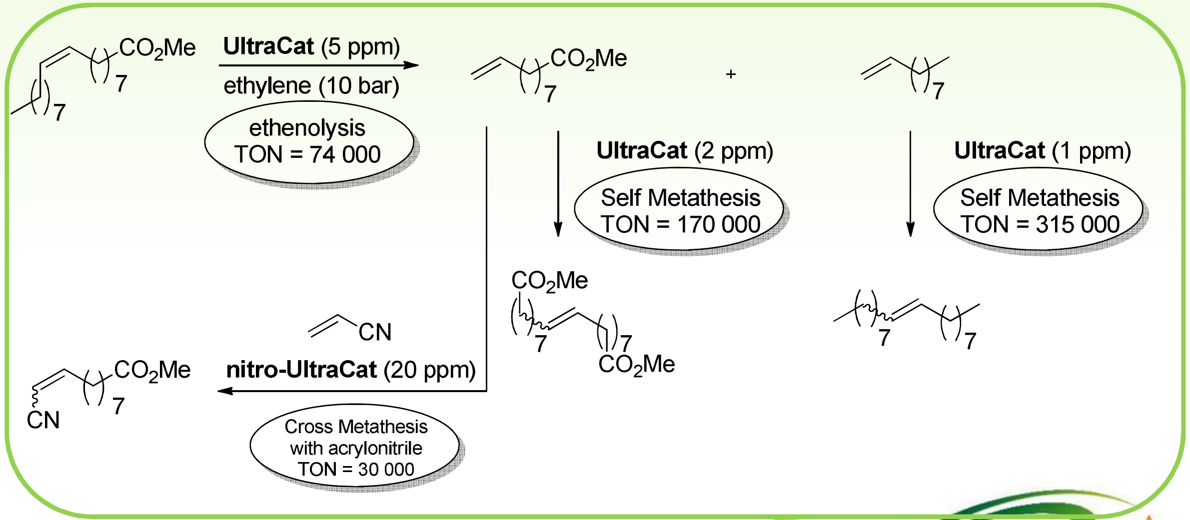
Excess in product Δ12

Metathesis

UltraCat catalysts family: unprecedented versatility



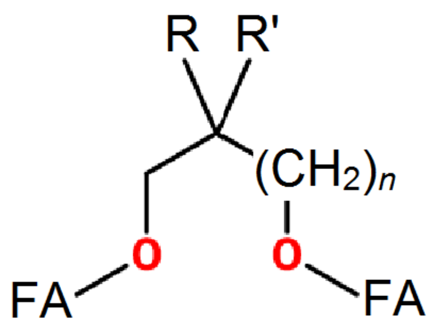
Apeiron synthesis



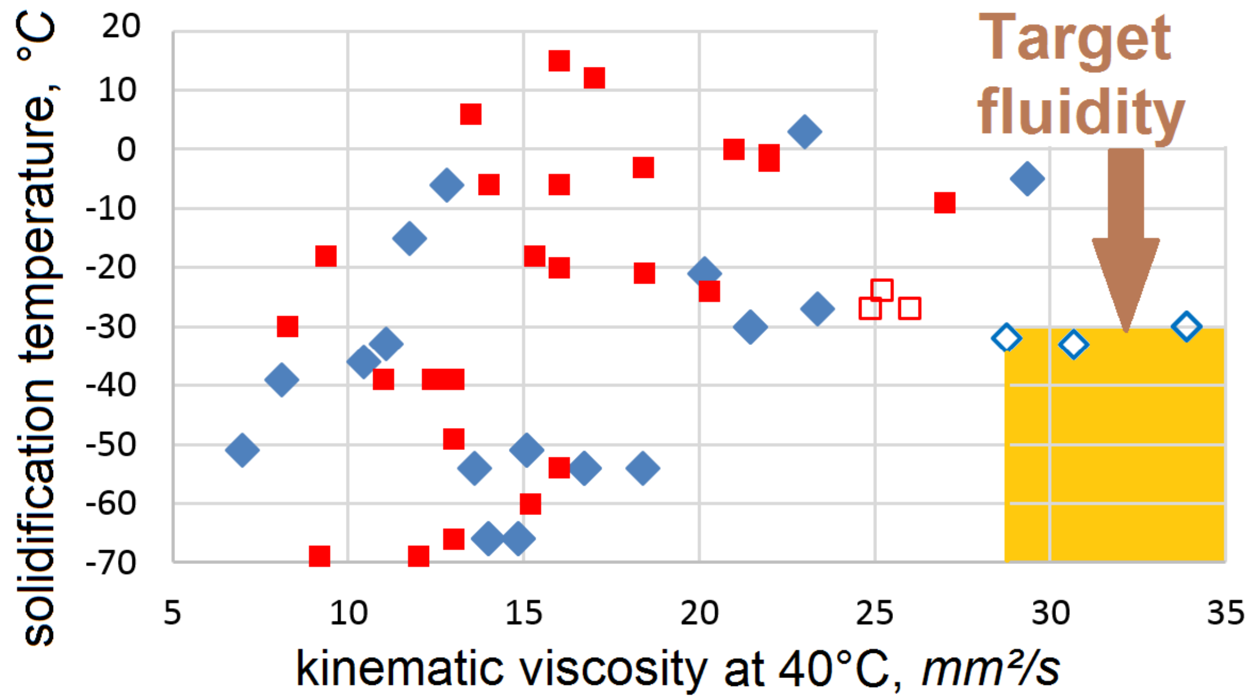
1. *WO 2017/055945*
2. R. Gawin, K. Skowerski et al., *Angew. Chem. Int. Ed.* **2017**, *56*, 981.
3. *R. Gawin, K. Skowerski et al., ACS Catal.* ***2017****, 7, 5543.*

New biobased lubricants

- Crambe & Camelina oils can be converted into Hydraulic Fluid basestocks (better than mineral oils):
  - lower volatility, excellent biodegradability, good low temperature fluidity, oxidative stability
  - excellent lubricity and Viscosity Index: expected lower temperature of operation in a hydraulic system
- Over 30 polyol esters synthesized and evaluated for fluidity: solidification (“Pour point”) and viscosity at 40°C
- Target: Hydraulic Fluid viscosity grade ISO VG32 – often used for heavy duty equipment, e.g. excavators



	R=H	R=C_2H_5
MCFA	■	◆
oleic a.	□	◇



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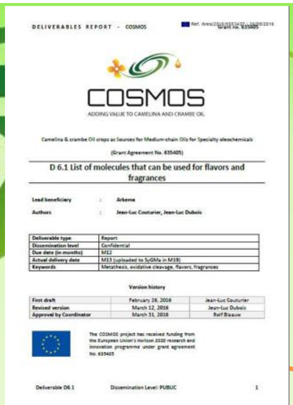
https://www.ebooks.ktu.lt/eb/1385/chemistry-and-chemical-technology-proceedings-of-the-international-conference/



Flavors and Fragrances

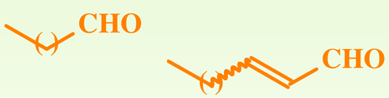
Public deliverable D6.1

Camelina & Crambe
Fatty Acids / Esters

Cross-Metathesis

Oxidative Cleavage

Aldehydes

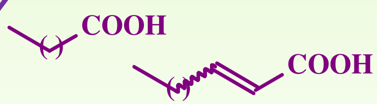


Hexanal
Nonanal
Decanal
Undecanal
Dodecanal
Tridecanal

2-Pentenal
2-Octenal
2-Undecenal

Green, floral, citrus, orange, rose, apple, grape, lemon, lime, melon peach, spicy, herbaceous, fruity…

Acids

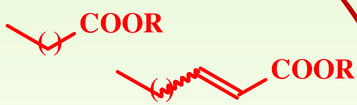


Hexanoic acid
Nonanoic acid
Decanoic acid
Undecanoic acid
Dodecanoic acid
Tridecanoic acid
Tetradecanoic acid

2-Octenoic acid
9-Decenoic acid

Cheese, fatty, waxy, sour, oily….

Esters



Methyl hexanoate
Methyl nonanoate
Methyl decanoate
Methyl undecanoate
Methyl laurate
Ethyl laurate
Methyl 2-octenoate

Ethereal, pineapple, coconut, nutty, fruity, floral, green…

Nitriles

Decanenitrile
Dodecanenitrile
Tetradecanitrile
9-Undecenitrile

Fatty, citrus, fresh, orange, green floral, fruity…

Contacts

jean-luc.dubois@arkema.com

jean-luc.couturier@arkema.com

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 635405.

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COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

Socio-economic and policy Assessment
COSMOS workshop
October 9, 2017

Dr Rocio A Diaz Chavez
Centre for Environmental Policy
Imperial College London
(r.diaz-chavez@imperial.ac.uk)

Funded by the Horizon 2020 Framework Programme of the European Union

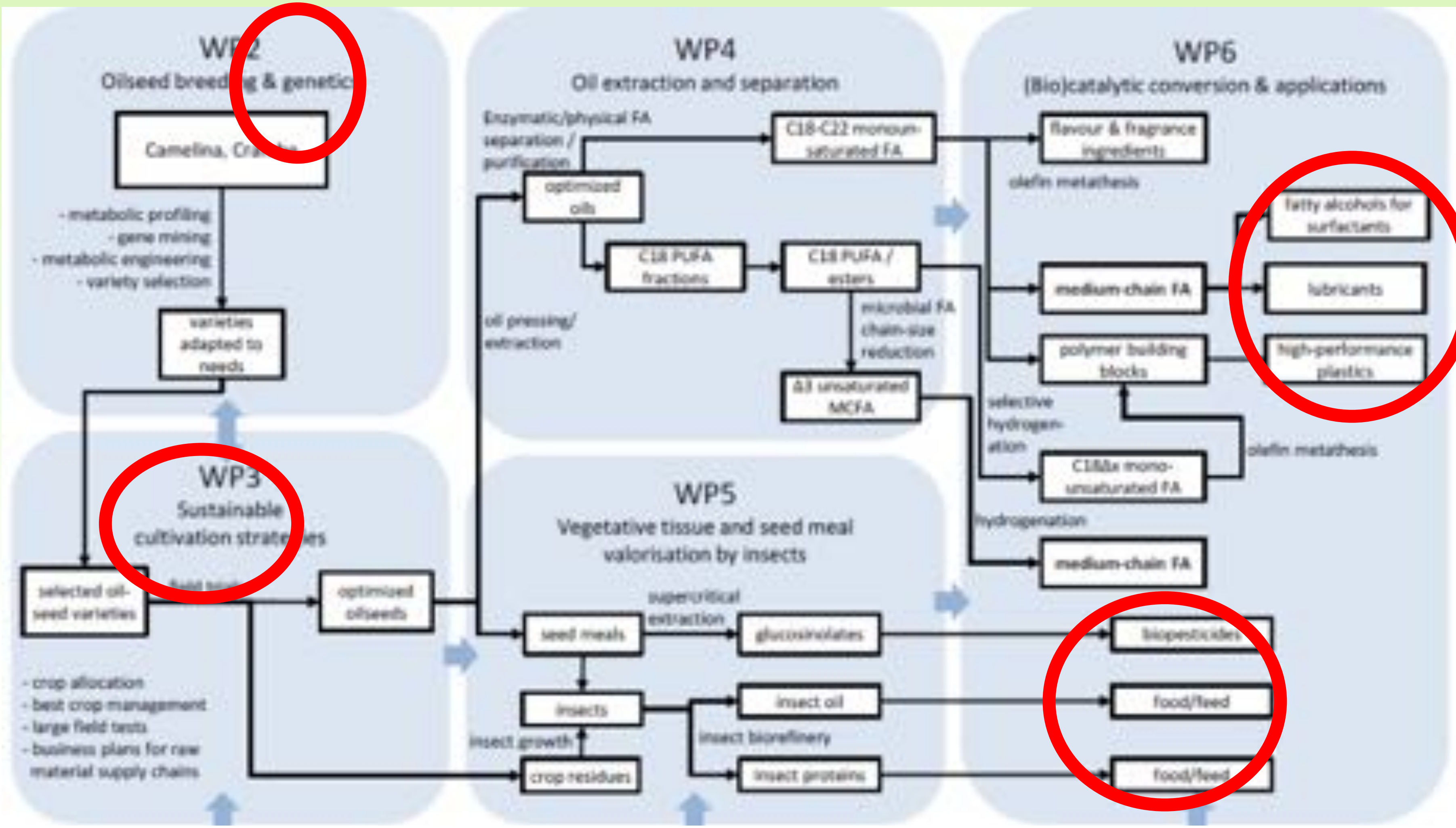
Imperial College London

COSMOS
ADDING VALUE TO CAMELINA AND CRAMBE OIL

Socio-economic objectives

- Social assessment: level of acceptability and the level of market diffusion of new technologies and the social implications associated with the COSMOS value chains.
- An analysis of strengths, weaknesses, opportunities and threats (SWOT) with stakeholders to analyse perceptions regarding the products and activities related to COSMOS.
- Policy assessment:
  - Including biomass potential analysis in Europe.
  - Policy frameworks and their effectiveness along the COSMOS value chains and strategies for requirements of technologies, raw materials and special interests of stakeholders

COSMOS



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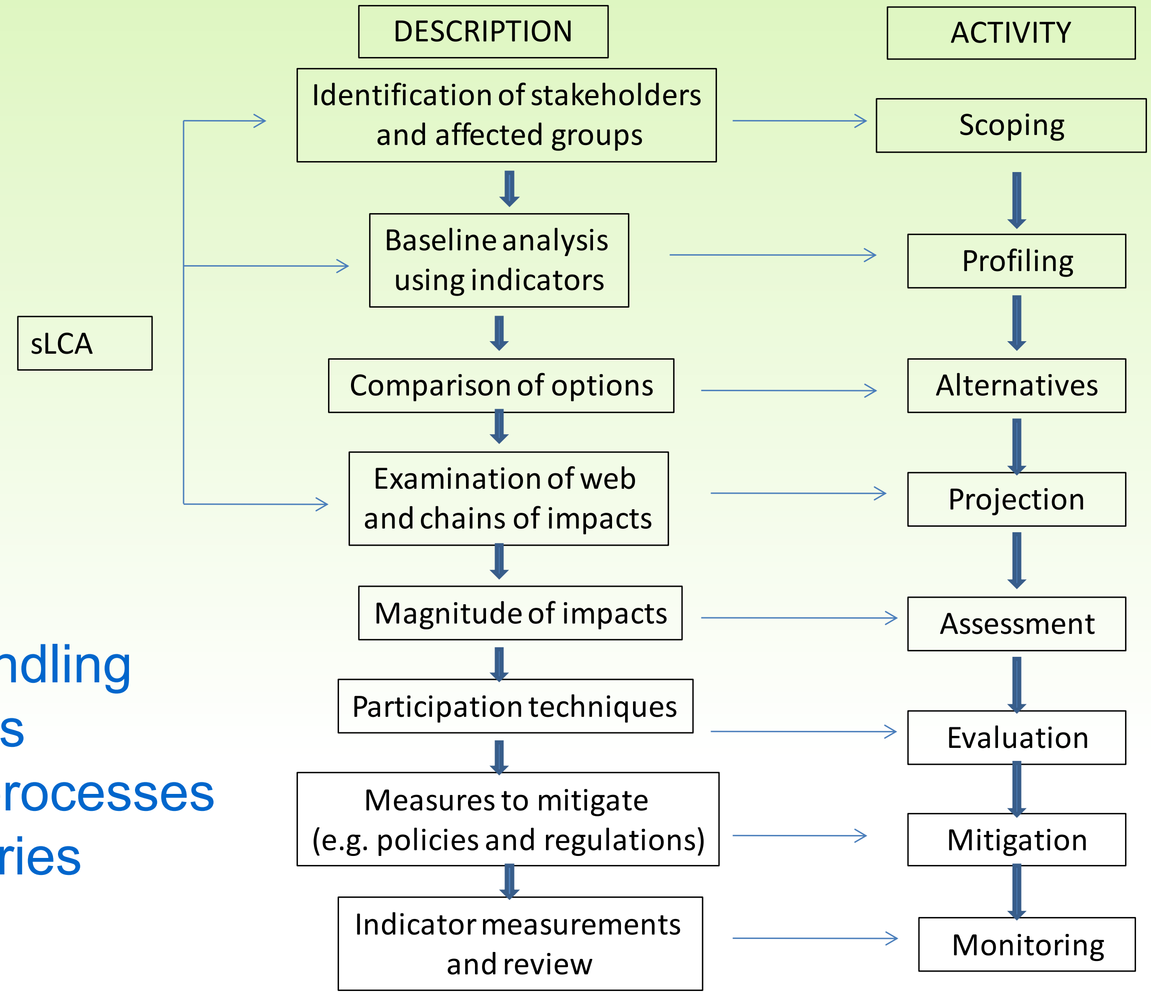
Adapted social impact assessment



sLCA limitations

Boundaries

Methodology of co-product handling

Definition of reference products

Foreground and background processes

Determine stakeholder categories

(Diaz-Chavez, 2012)

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Key variables and sustainability indicators

- **Production and availability of feedstock**
  - Biomass surplus
  - Willingness to shift cropping patterns
  - Role of panchayat in deciding cropping patterns
- **Employment**
  - Limitation to employment opportunity
  - Openness in exploring and taking non-agricultural activities
  - Working conditions in the competing industry
  - Willingness to work in bio-refinery
  - Strength of labour union
  - Child labour issues; etc
- **Health, environment and food security**
  - Health impacts due to working conditions in competing industries
  - Impacts on food security due to presence of a bio-refinery
  - Environmental, water related, land related stress in the area related to industrial activities; etc.
- **Rural development**
  - Improvement in physical infrastructure due to industrialization
  - Would bio-refinery improve infrastructure
- **Research and development**
  - Extent to which investments in R&D activities in clean/bioenergy is needed
  - Extent to which R&D activities have happened in clean/bioenergy
- **Other issues related to political, legal and economic barriers**
  - Current barriers in terms of political and administrative hurdles in setting up of a new bio-refinery
  - Creation of new economic opportunities for the locals

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Case studies

Figure 8 - Highlight of Gelderland Province in the Netherlands (Source: Central Intelligence Agency. (2016))

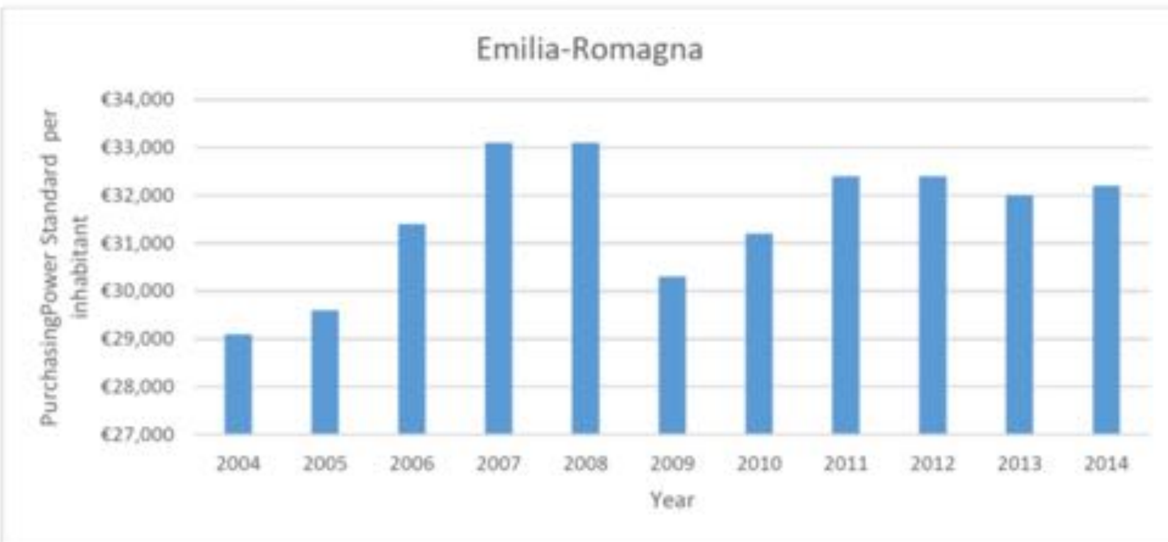
Figure 9 - Highlight of Warminsko-Mazurski Province in Poland Source: Central Intelligence Agency. (2016)

Figure 11 - Highlight of Attiki Province in Greece (Source: Central Intelligence Agency. (2016)). Greece

Figure 10 - Highlight of Emilia-Romagna Province in Italy (Source: Central Intelligence Agency. (2016)). Italy

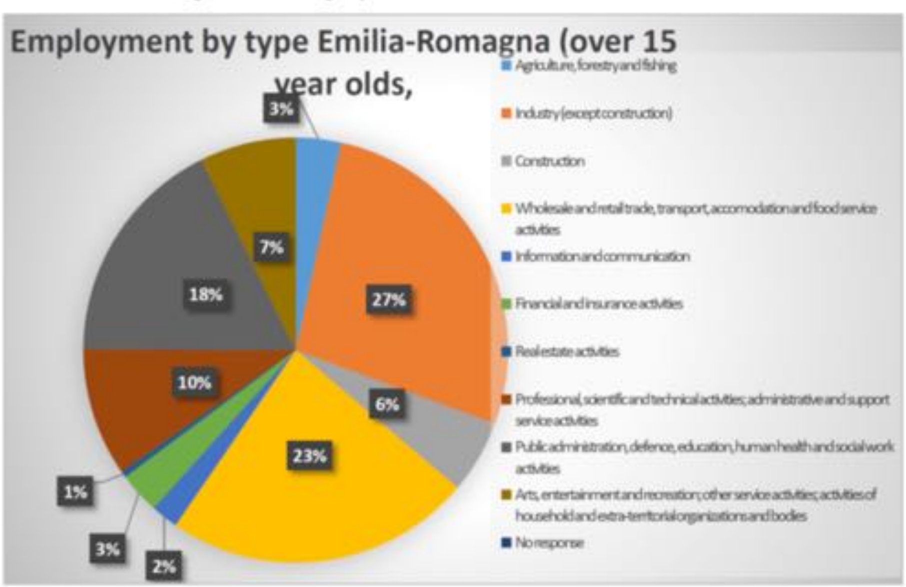
Examples indicators

Indicator 1.0 – GDP - purchasing power per inhabitant

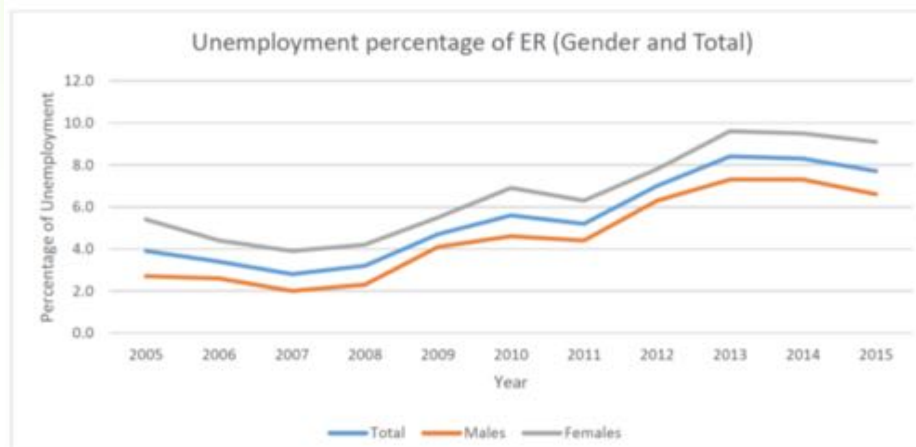


(Olad Habad,2016)

Indicator 1.1 – Population Employment Structure

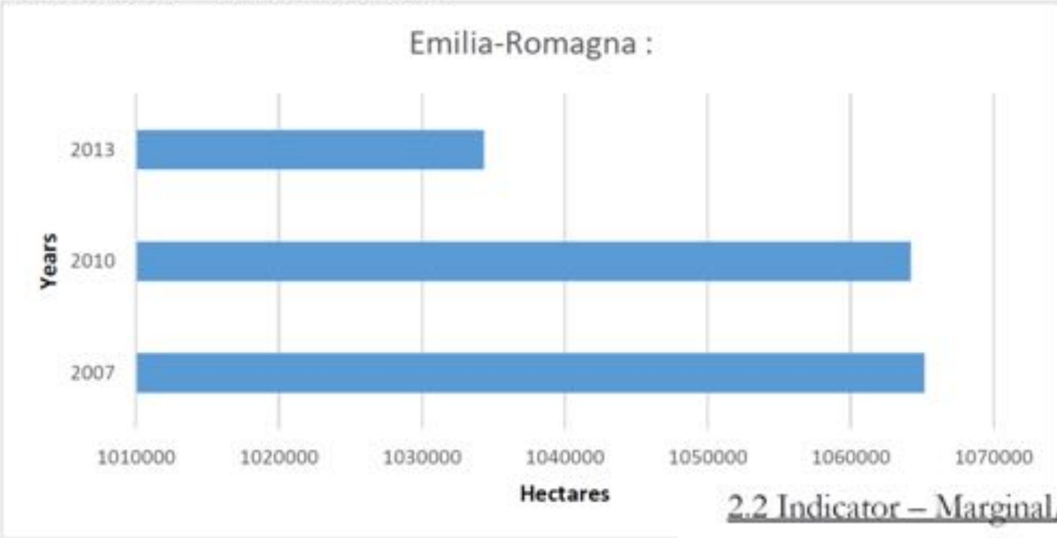


1.3 Indicator – Unemployment

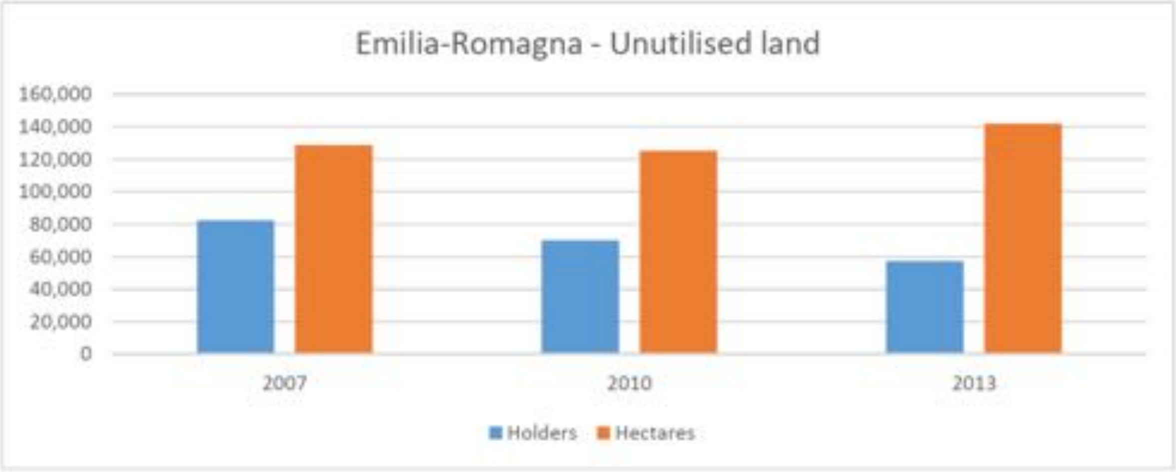


Examples of indicators

2.1 Indicator – Utilised land area



2.2 Indicator – Marginal/degraded/unutilised land



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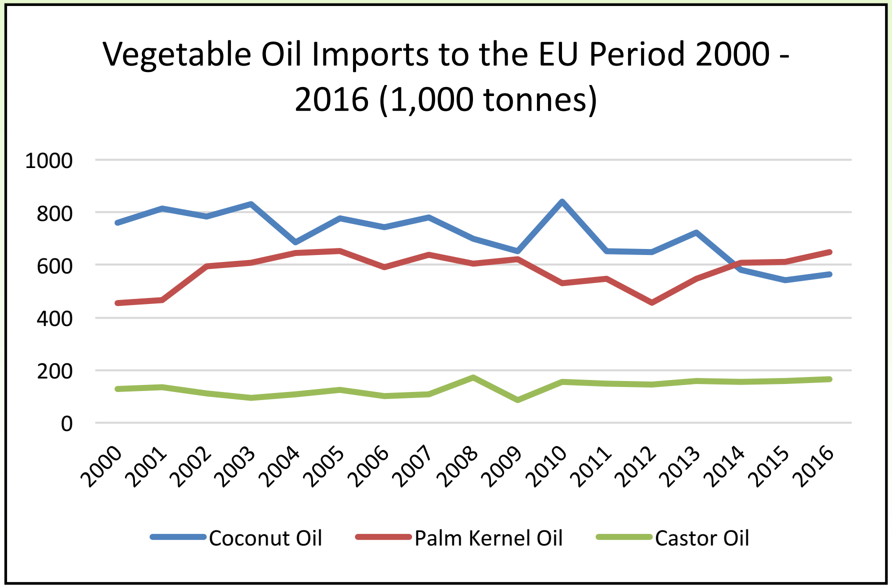
The Demand of Vegetable Oils (*coconut oil, Palm Kernel Oil (PKO), and castor oil*) in the EU

- The demand of coconut oil, palm kernel oil (PKO), and castor oil remained stable – tend to increase.
- The import of coconut oil to the EU reached **542 MT** in 2015 (Fediol, 2017)
- There was an increase of PKO import **from 529 MT** in 2010 to **610 MT** in 2015 (Fediol, 2017)
- Castor oil remained stable since 200o. In 2015, its import to the EU reached **160 MT** (Fediol, 2017)



(Ivan Tumpak, 2017)

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Assessment of coconut oil in the Philippines

Approximately **24 million people** of the Philippines, one-third population, directly and indirectly, rely on the coconut industry (Fujii, 2005).

Employment

- 3 mio coconut farmers and workers
- 1.55 mio farmers representing 11 million people throughout the country

Economy

- Contributed to 64% of global coconut oil requirement
- The industry earns USD 800 mio/year (5% of GDP)

Social and Environmental

- Its farmers are the poorest in agriculture communities
- Monoculture farming; and the aging of trees makes it less productive, leading to expansion

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Assessment of Palm Kernel Oil (PKO) to Indonesia

Employment

- The industry absorbed 1.7 – 2 mio and provided benefit to approximately 6 mio people (Sheil, 2011)
- High number of workers, but high turnover
- Increase standard of living

Economy

- Along with palm oil, PKO industry contributed to 1.5 – 2.5% GDP.
- The farmers and workers have the highest income among agriculture communities.
- Alleviate financial worries but many unfair cases

Social and Environmental

- Massively contributes to environmental problems, such as soil erosion, air pollution, and deforestation
- Land acquisition' feuds
- Biodiversity degradation including orangutan cases

As the world's largest producer, Indonesia mainly produces PKO in Borneo and Sumatra with total volume of 3328.6 (1000 MT) in 2014 (FAO, 2017).

Assessment of castor oil in India

As the world's largest exporter and producer, India produced 1.42 mio tonnes castor oil in 2015.

Employment

- Many workers shifted to other remunerative crops due to bad condition

Economy

- Not significantly contributes to the economy but important to the producing areas' economy
- As the leader, India can manage the price

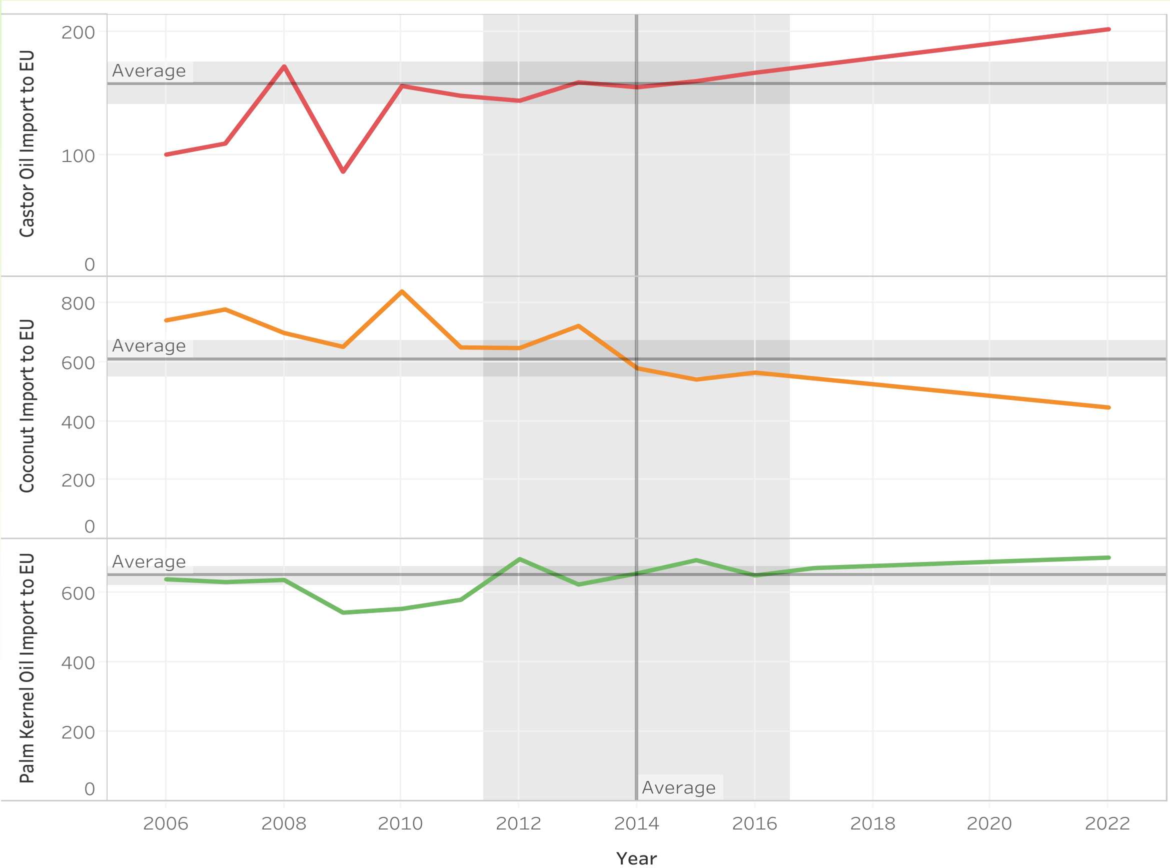
Social and Environmental

- Detox-plant as its ability to absorb toxin and heavy metal in the soil
- No cases in health-related

Scenarios

- Reduction of imports 5, 10 and 15% were analysed.
- Less demand of PKO would not affect its export performance in Indonesia
- The EU are not able to limit the import of vegetable oils since the transition to bio-based economy in still in the early stage
- Coconut oil might be the most affected due to its high dependency to the EU's market
- Castor oil might be affected since the EU is also its biggest market

Forecast of production



Data from FEDIOL 2017

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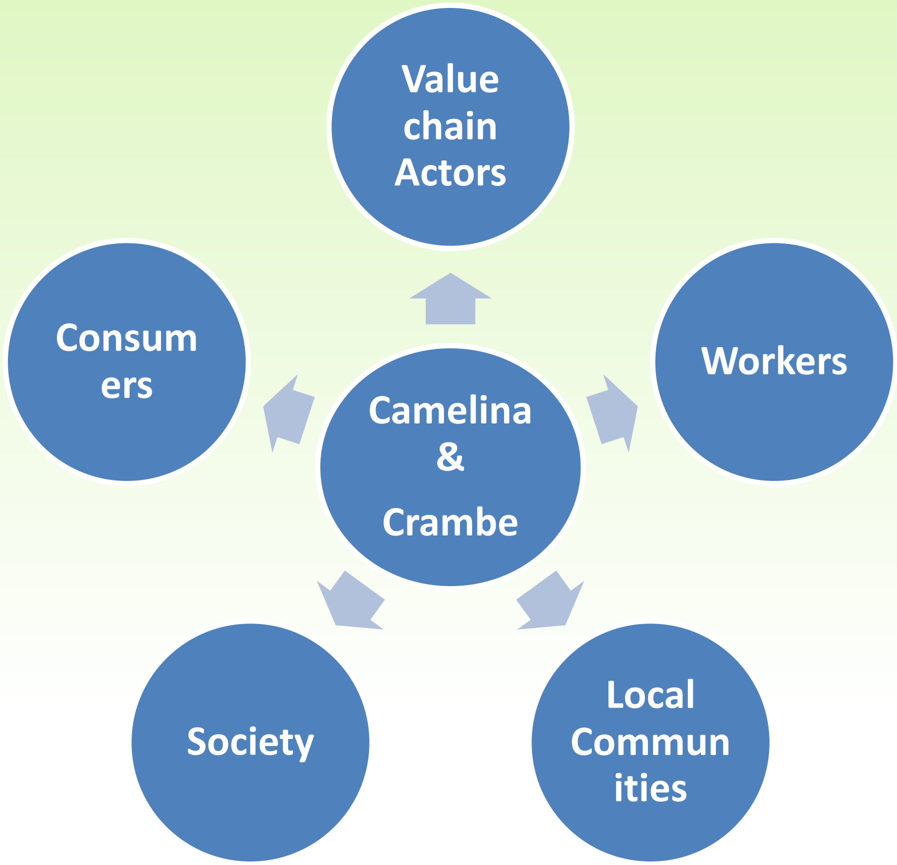
Stakeholders' Views

- The import reduction might lead to the increase of PKO
- The EU needs to look for more productive crops
- There would be an uphill struggles in biofuel industry in EU
- Lack of revenue to the importers (company)

Supply Chain Stakeholder Diagram



Socio-economic assessment framework consists of a stakeholder-based impact categories.
Key impact categories include:

- **Working conditions**
- **Health and safety**
- **Governance**
- **Community infrastructure**
- **Human rights**

(Kaili, 2017)

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GREECE CASE STUDY: STAKEHOLDERS INTERVIEWS

Stakeholder Categories	Interviews (#)
National Government	3
Regional Government & Consulting	1
Industries & (Industry & Research)	4 & (1)
Farmer/Agronomists Unions	3
Academia/Research	3
NGOs	
National	1
Private (with research and e-commerce activities)	1

- 17 interviews. Some of the stakeholder interviews covered more than one category (Company and Research Laboratory together for example)

(Vassilis Skianis, 2017)

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STAKEHOLDERS INTERVIEWS KEY POINTS

- No familiarity with camelina or crambe plant.

- Strong familiarity with rapeseed, but mainly for the edible oil production for human consumption.

- Greece has significant revenues from the production of first-generation energy crops in general (mainly sunflower and first-generation –edible oil - rapeseed production). But nowadays, there seems to be a downward trend.

- Evidence has shown that energy crops are very suitable for crop rotation (especially with wheat)

- Positive attitude towards testing and cultivating new crops such as crambe and camelina, as long as there is respect on the environment.

STAKEHOLDERS INTERVIEWS KEY POINTS

- Positive attitudes towards reducing dependency on imported oils.

- In some cases, with regards to land use, it was highlighted that priority should be given on agricultural production

- Some stakeholders stated their preference on indigenous plant species over imported ones.

- Contract farming (contracts between industries and farmers for the supply of the production) is the key element for a successful implementation of new crops especially from farmers side.

- Some stakeholders (mainly from industries) highlighted that there is a **lack of infrastructure and equipment** for the production of non-edible oils.

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FARMERS' SURVEYS

- Most of energy crops cultivation takes place in Central & Northern Greece
- We conducted 12 surveys with farmers mainly across these regions.
- In particular: Central Macedonia (4 surveys), Easter Macedonia & Thrace (3 surveys), Central Greece (3 surveys), Athens (1 survey)
- 11 surveys were completed anonymously.

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FARMERS' SURVEYS KEY POINTS

- Cultivated land ranged between 12.5 ha and 728 ha. In most cases, farmers were both owing and leasing land.

- With regards to crops, most of the farmers were cultivating wheat, sunflower, cotton and legumes. Other crop types included: fruits and vegetables, sugar beet, medic and crambe.

- Half of the farmers declared monthly income less than 1500 euros.

- some farmers have or had produced "energy" crops (mainly rapeseed and sunflower), whereas other farmers mentioned that they would be willing to cultivate new plants such as crambe and camelina in the future.

- Main reasons for being negative towards cultivating alternative crops: lack of land availability (small-scale farming) and lack of appropriate equipment, small-scale farming

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CASE STUDY POLAND: SURVEYS FOR STAKEHOLDERS

Mariusz Dubicki, 2017

Category	Quantity	comments
Government/Policy makers and enforcement (National, regional, local), considering Environmental, agricultural, industry, other.	3	- Warmia and Mazury agricultural advisory center - Regional government Stawiguda - Warmia and Mazury Marshall Office
Industry (vegetable oil industry, biofuels, chemicals, other,)	3	- ChemProf chemical consulting - LOTOS Oil industry - Feed industry
Agricultural industry (seed providers, equipment)	3	- John Deer sales representatives - regional seeds producer - Crops and grants agroconsulting
farmers ‘s representatives/associations	3	- Consulting association - Food and feed association - Farmers association
NGOs	3	NGO’s (in agriculture)
Academics	3	Scientist from University of Warmia and Mazury in Olsztyn, (formerly agricultural and technical academy)

KEY POINTS

- Most of the respondents see the importance of the reduction the EU's dependence on import oils for the oleochemical industries.
  - Increasing the activity of EU farmers
  - Development of the EU economy
  - Independence of the EU
- High number of the respondents has knowledge on camelina and crambe and its profitability
- Respondents made point that the effectiveness of these crops and profitability is important to start any negotiations on growing these plants and to increase activity of the industry in this sector
- Respondents pointed out that vegetable oil industry could be a good oportunity for rural development of the region, new jobs and ecomony development
- Most of the respondents pointed out that both oil industry and camelina and crambe are not well known
- There are some local, regional and national regulations supporting the bioecomony sector, but there are only few known by the respondents. Most of them do not know about any regulation in the bioeconomy sector

Surveys for farmers

- Most of the surveys were conducted in Warmia and Mazury Region
- Some of them were conducted at Lublin province
- During june and july almost non of the farmers wanted to go through the surveys, because of the high crops season
- August and September were most effectiveness month for surveys
- There were about 25 invitations for the survey for farmers
- 17 farmers agree to go through the survey
- 6 farmers are or were inthe past growing oil crops (rapeseed and sunflower)
- Non of the farmers grow camelina or crambe
- 2 farmers were growing vegetables and fruits
- 1 farmer was growing grasses for grants purpose
- The rest of them were growing different cereals (including farmers that are or were growing oil crops)

KEY POINTS SURVEYS FOR FARMERS

- Average salary per month is 1500-2400 EUR
- Most of the farmers do not know camelina and crambe at all
- Those who pointed out that were growing oil crops in the past were interested in growing alternative crops under certain conditions: effectiveness of the crops and market demand
- Some of the farmers see the opportunity to grow camelina and crambe on marginal or abandoned land
- Camelina and crambe could be the opportunity for new farmers' activity and oil industry development (new jobs, rural development)
- Most of the farmers do not want to grow alternative crops such as camelina and crambe, because of lack of knowledge of the plants and too low market demand on those plants
- Most of the farmers do not know about possibility of use of marginal or abandoned land
- Most of the farmers have no problem with genetic modification (transgenic)

CASE STUDY ITALY: STAKEHOLDERS' INTERVIEWS

Stakeholders	Number	Sector/s
INDUSTRY	3	Agriculture, food and feed industry, energy and biofuels, biotechnology
RESEARCH	3	Academic and scientific research centres working in agriculture
FARMERS'REPRESENTATIVES	3	Food and feed, biofuels
NGOs/CIVIL ASSOCIATIONS	1	Food and feed and biofuels
PUBLIC SECTOR (REGIONAL GOVERNMENT)	2	Regional/local authority

(Marco de Nigris, 2017)

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KEY POINTS

1. Most respondents see independent oil production as beneficial because of:

- Job opportunities
- Environmental performance (the EU has more advanced regulations than other regions)
- Independence and price stability

2. Most respondents have some familiarity with camelina and crambe and believe their production (mainly camelina) is beneficial because of:

- Biofuels production
- Camelina is good for rotation with wheat which is very common in the region

3. Main barriers:

- More research needed to have a more detailed knowledge of yield and related profitability
- Prudence of farmers in developing new crops, more certainty and production chain needed

4. Different opinions on incentives' implementation; they might be useful in the first phase, to increase producers' confidence, but must be supported by effective yield and demand creation.

5. Respondents generally favourable to insects related production, though this must be supported by strong evidence of their convenience, to face cultural barriers and environmental concerns

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Farmers' surveys key points

- Farmers did not generally know camelina and crambe
- Most farmers apply rotation, with many different cultivations, among which: forage, corn, beetroot, tomatoes, wheat
- Generational gap on openness to new cultivations (young owners are more open)
- Main barrier is the newness of the product, which tends to prevent to 'take the risk'. More experience and verified confidence on yield and profitability is needed.

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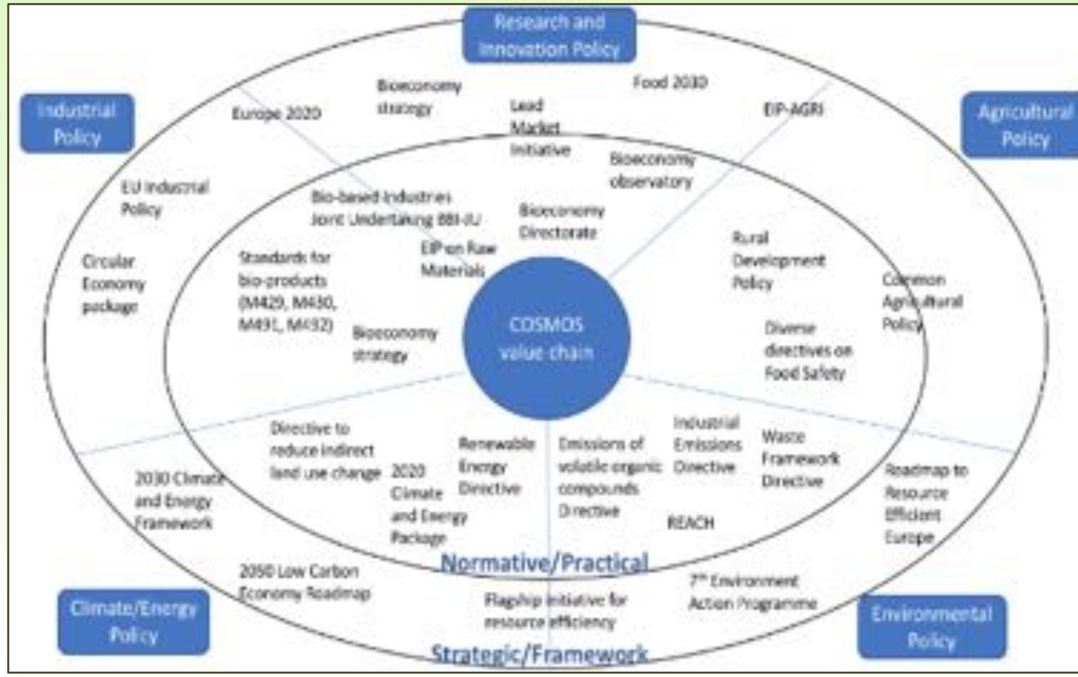
Policy assessment Methodology

1. Broad mapping of all bioeconomy policies in the context of the EU
2. Assessment of EU policies relevant to the COSMOS value-chain
3. Extended analysis to global and national level



Mapping of bioeconomy policies in the EU

Contribution from M.Sc. Ute Thiermann

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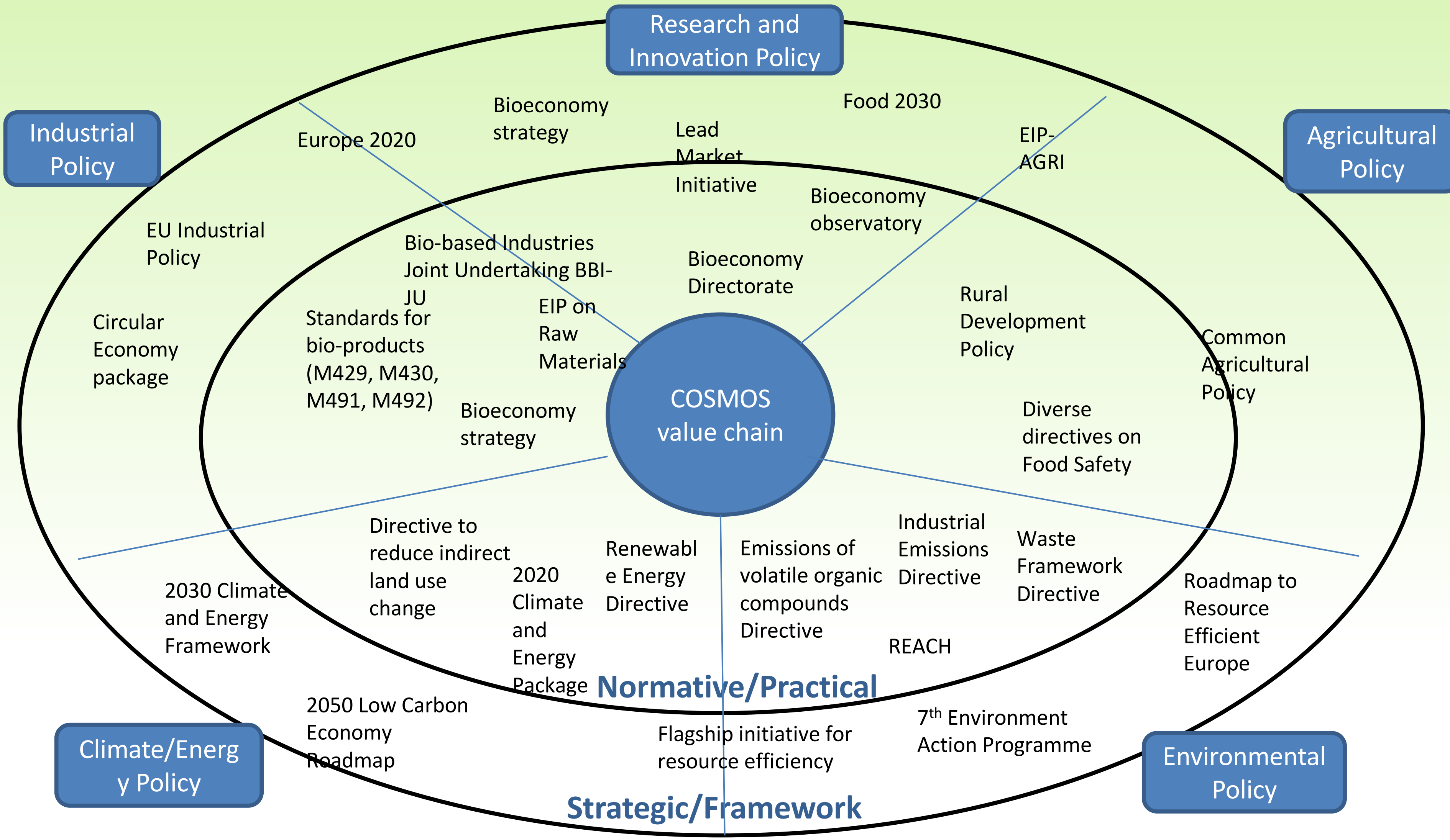

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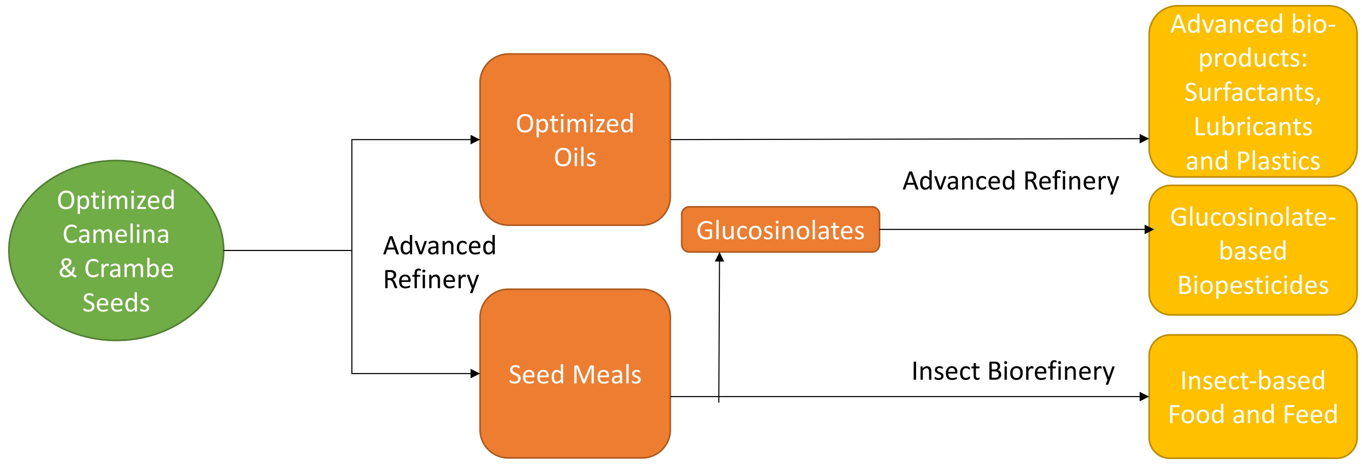
Key policies in the COSMOS value-chain



Raw material	Transformation	End-Products
Overarching frameworks: Europe2020, Circular Economy, Climate&Energy, Bioeconomy Strategy		
• Common Agricultural Policy • Renewable Energy Directive • Food Safety Regulation (GMO) • Sustainability Criteria	• Research&Innovation Policy • Waste&Emissions Regulations • Chemicals Regulation (REACH) • Food Safety Regulation (Insects)	• CEN Standards • Public Procurement • Consumer awareness& Labelling
	• Financing Instruments	

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The assessment in a nutshell

- **Significant progress** has been achieved regarding the development of the **bioeconomy** globally, in the EU, and in EU Member States.
- **COSMOS** is **both outcome of bioeconomy policy actions** in the EU, as well as could be an **important driver** for progressing and shaping those.
- Great **expectations lie on the sector** in order to bring **rural development** to remote regions in the EU, to create employment opportunities and to become a global **industrial leader**.
- There **exists a plethora of policy initiatives and publications** listing the great variety of policy and market barriers for the establishment of an independent innovative bio-industry, and of the necessary and available policy tools to overcome them.
- Implementation of policy actions seems to **progress steadily, but slowly**. Several **key areas are still awaiting policy action** that would favour the implementation of a sustainable bioeconomy in Europe.

Key policy challenges & recommendations

General	Feedstock production	Transformation	End-products/market	Access to finance
The **EU Climate strategy** should incentivise and reward non-energy related industries for actions that target climate mitigation. Thorough implementation/further revision of the **EU Bioeconomy Strategy** is key for developing the bio-industry.	**EU agricultural policy** awards crop diversification and sustainable practices, but also should promote feedstock for bio-based industries. **Food safety regulation** related to **GMO** needs to be clarified quickly to promote innovation in the agricultural sector. **Differentiated treatment** between biomass uses, favouring bioenergy applications. Better integration needed to promote the cascading use of resources. **Sustainability standards** are still confusing, while also varied for the different feedstock uses.	Several regulations and directives exist to control **emissions, waste and chemicals**. The **ETS** should allow bio-materials to count towards GHG emissions reduction targets in the industrial sector. **Vegetable oil refineries** are subject to strict emissions levels. The recent concept of **insect-biorefineries** depends on advances in regulations around food safety related to insect use in food/feed but mainly on acceptance	A large number of **standards for the bio-products sector** has been developed. There is lack of or little action around **labelling, public procurement and awareness raising**. Bio-products would benefit from a good reputation and **GreenPremium prices**.	Research projects often do not transit into reality, as **commercial-scale applications struggle to find funding** (public&private). The **strategic use and communication** of **financing programs** at EU and MS level need to be improved, to **leverage** more private capital.

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CRISPR: Zoom on Food safety regulation

- On-going **discussions about the classification of the CRISPR/Cas9 tool as GM-process** subject to regulation or as exempted mutagenesis technique listed in Annex I.B of the EU directive 2001/18/EC.
- CRISPR/Cas9 was created in 2012. A decision regarding the legal status of CRISPR was expected in early 2016, but **in 2017 this decision is still pending**. Even after a decision, the case might proceed to the European Court of Justice which could take years.
- The **analysis of the actual regulatory status suggests that the process foreseen for the COSMOS project is subject to the regulation** because the CRISPR/Cas9 system requires the introduction of foreign DNA in order to function. Although these transgenes can be removed later through crossing, it is then offspring of a transgene which under the current EU regulation is considered GMO and therefore subject to the regulation.
- As long as the **EU regulation focuses on processes instead of end-products**, it remains questionable if the CRISPR/Cas system will be added to the list of non-GM mutagenesis techniques.
- Until a final decision is taken, **legal barriers to the piloting and commercialising of the crambe and camelina versions created by the COSMOS project should be expected.**

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Activitiy 1

- Subgroups (4-5 persons)
- Select a secretary to write and present for second activity
- Use a post-it to indicate in the theoretical supply chain where is your main interest.
- Include your name and organisation

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Activitiy 2

- Subgroups (4-5 persons)
- Select a secretary to write and present
- Discussion of statement/question and write down 5 main statements according to the section of the SWOT (15 mins)

- Secretary presents five main statements

  (3 minutes!)
- Change group and start again!!!!

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SWOT

1. SWOT of reducing the dependence of imported oils for the oleochemical/industrial sector in the EU
2. SWOT of growing more crops that can provide these oils such as camelina and crambe
3. SWOT of incentives/policies for the (vegetable) oil industry in the EU
4. SWOT of using alternative crops with genetic modification as in CRISPR
5. SWOT of using extracted proteins and fats from insects for other products such as the feed industry for animals or human food

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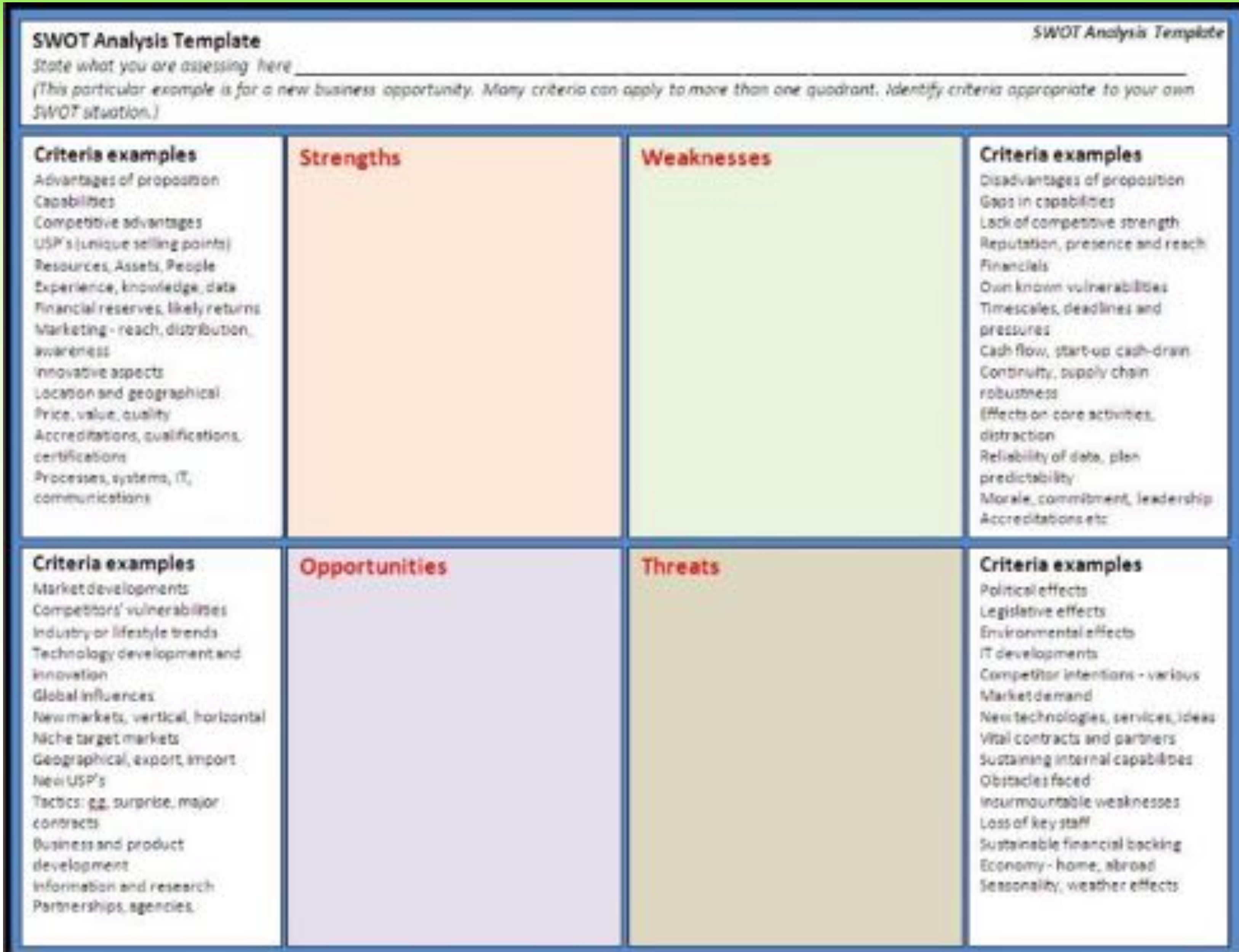

SWOT Analysis Template

SWOT Analysis Template

State what you are assessing here ______________________________

(This particular example is for a new business opportunity. Many criteria can apply to more than one quadrant. Identify criteria appropriate to your own SWOT situation.)

Criteria examples	Strengths	Weaknesses	Criteria examples
Advantages of proposition Capabilities Competitive advantages USP's (unique selling points) Resources, Assets, People Experience, knowledge, data Financial reserves, likely returns Marketing - reach, distribution, awareness Innovative aspects Location and geographical Price, value, quality Accreditations, qualifications, certifications Processes, systems, IT, communications			Disadvantages of proposition Gaps in capabilities Lack of competitive strength Reputation, presence and reach Financials Own known vulnerabilities Timescales, deadlines and pressures Cash flow, start-up cash-drain Continuity, supply chain robustness Effects on core activities, distraction Reliability of data, plan predictability Morale, commitment, leadership Accreditations etc
Criteria examples	**Opportunities**	**Threats**	**Criteria examples**
Market developments Competitors' vulnerabilities Industry or lifestyle trends Technology development and innovation Global influences New markets, vertical, horizontal Niche target markets Geographical, export, import New USP's Tactics: e.g. surprise, major contracts Business and product development Information and research Partnerships, agencies			Political effects Legislative effects Environmental effects IT developments Competitor intentions - various Market demand New technologies, services, ideas Vital contracts and partners Sustaining internal capabilities Obstacles faced Insurmountable weaknesses Loss of key staff Sustainable financial backing Economy - home, abroad Seasonality, weather effects

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(Templatelab, 2017)

Thank you for your attention!

Any questions ?

r.diaz-chavez@imperial.ac.uk

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Economic implications of the COSMOS project

Stakeholder Workshop, Brussels
Stephan Piotrowski, nova-Institute
October 9, 2017

Funded by the Horizon 2020
Framework Programme of
the European Union

COSMOS
ADDING VALUE TO CAMELINA AND CRAMBE OIL

Introduction

- The main objective of COSMOS is to replace part of the demand of the European oleochemical industry for imported coconut and palm kernel oils and fatty acids and for castor oil as sources for medium-chain fatty acids (MCFA, C10–C14) and medium-chain polymer building blocks by the domestic oil crops camelina and crambe.
- The economic sense behind this objective depends on whether the following statements can be supported by evidence:
  - 1. Camelina and crambe can be attractive new crops for European farmers.
  - 2. There is demand by the European oleochemical industry for a replacement of the tropical oils.
  - 3. The project focusses on the right product portfolio with good market potential and the potential to profit from the use of European feedstocks.

Statement 1:

Camelina and crambe can be attractive new crops for European farmers

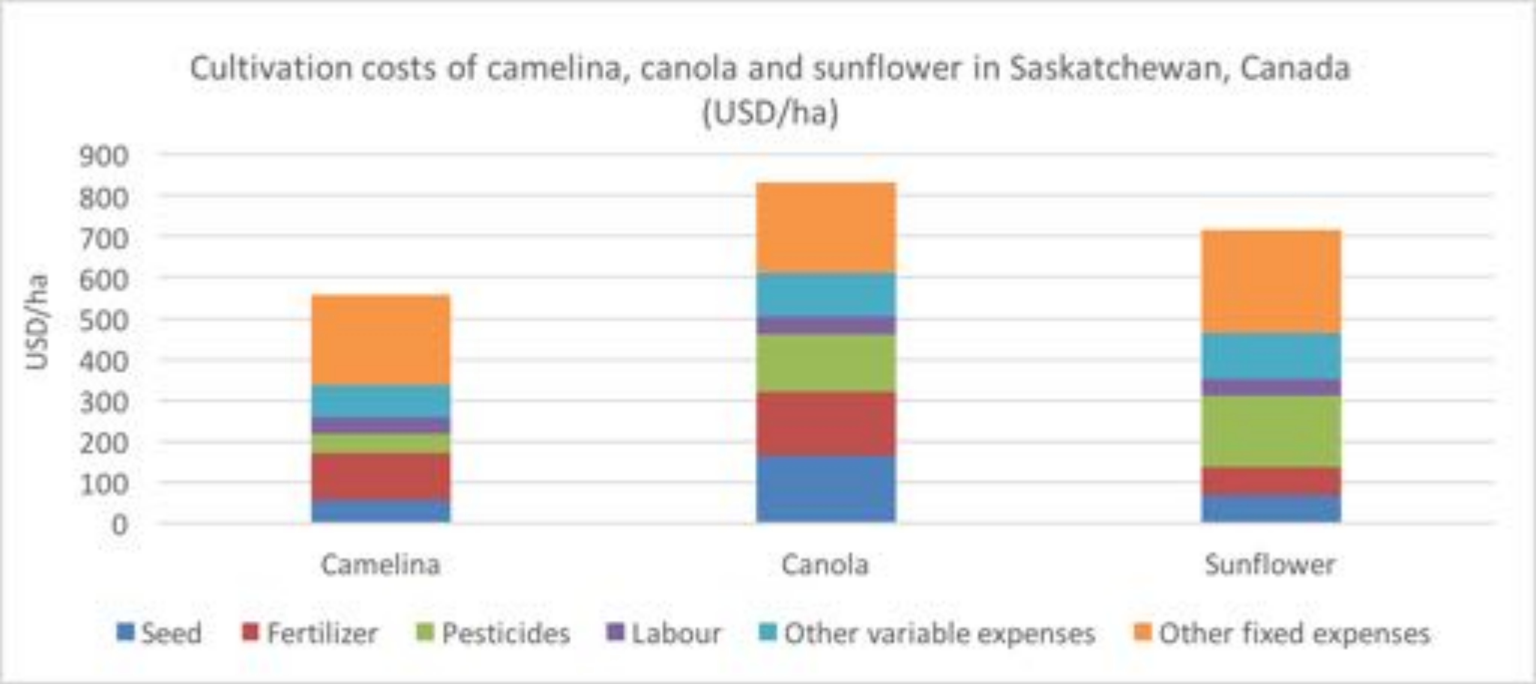
Economics of camelina and crambe cultivation

- Crambe
  - More resistant to diseases and insects than rapeseed
  - Short growing cycle (90-120 days)
  - Beneficial effect on the crop cycle
  - In Europe, up to 10 ha of field trials in Poland
  - Total cultivation area around 5,000 ha

- Camelina:
  - Adaptable to many different environmental conditions
  - Short growing cycle (85-100 days)
  - Relatively low inputs required
  - Ideal crop for use on less productive lands
  - Seed yields and oil content are highly variable based on environment
  - In Europe, commercial scale fields in Spain on about 2,000 ha.
  - About 2,000 ha of commercial cultivation area in Canada

Economics of camelina and crambe cultivation

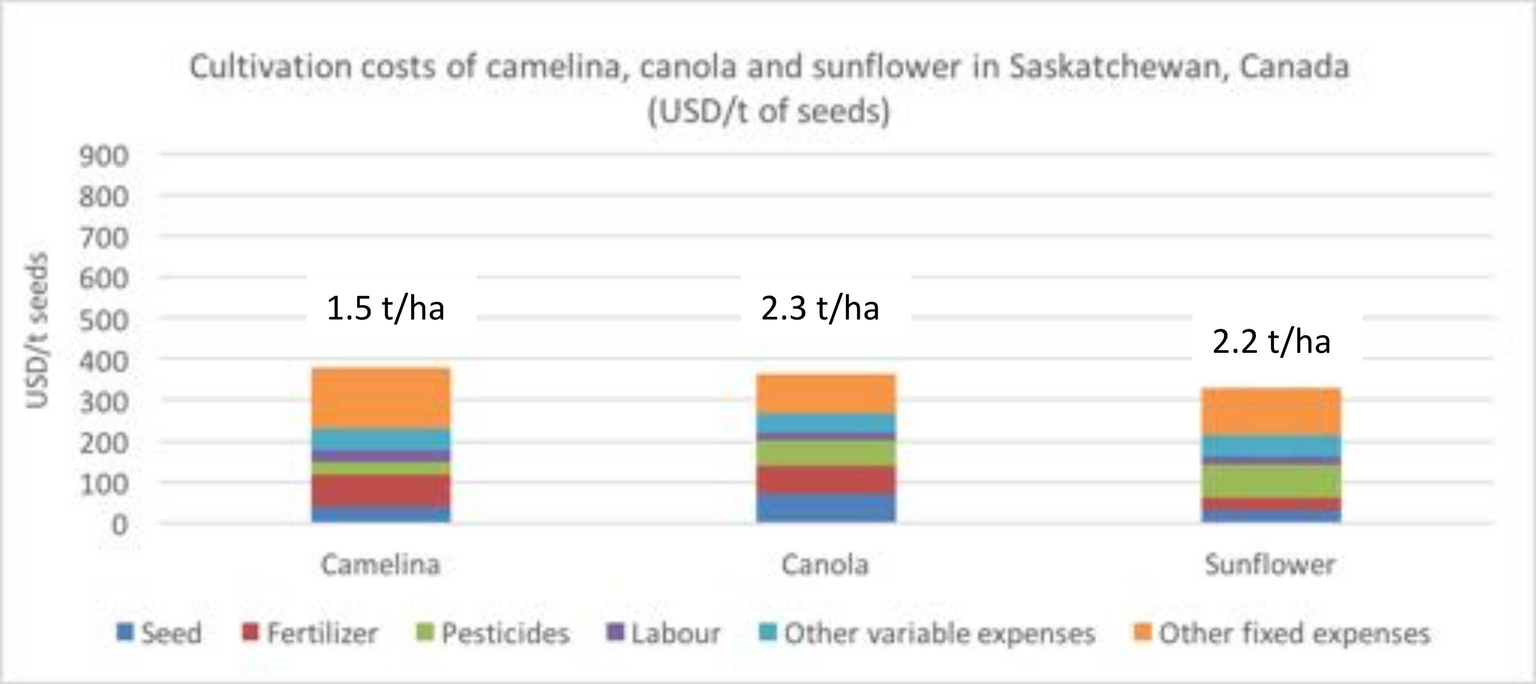
- Comparison of costs of different oil crops in Canada:



Source: Government of Saskatchewan 2016

Economics of camelina and crambe cultivation

- Comparison of costs of different oil crops in Canada:



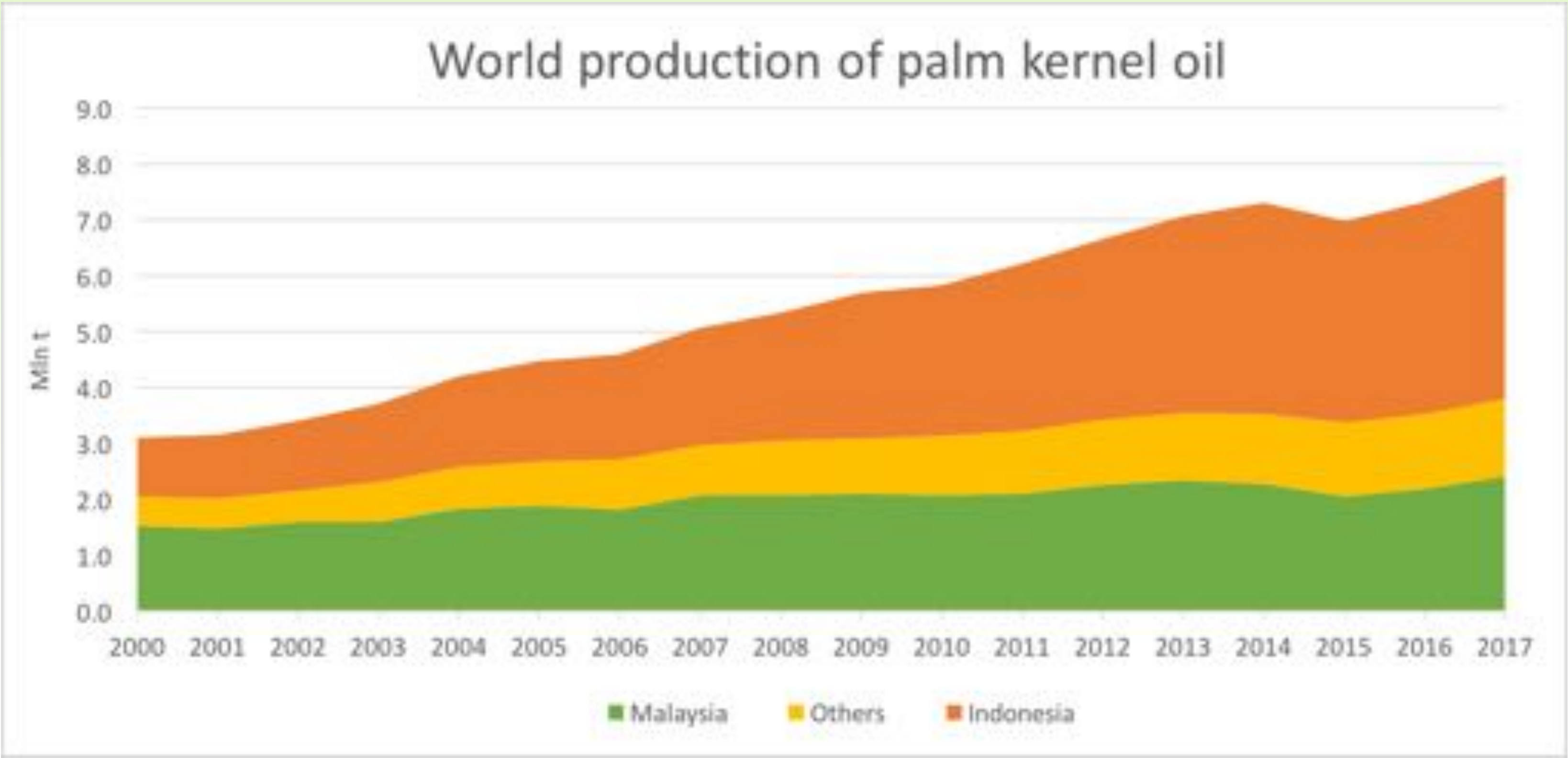
Source: Government of Saskatchewan 2016

Statement 2:

There is demand by the European oleochemical industry to replace imported coconut and palm kernel oils and fatty acids and castor oil as sources for medium-chain fatty acids (MCFA, C10–C14) and medium-chain polymer building blocks.

Demand to reduce the dependency on tropical oils

- Global production of PKO, CO and castor oil is limited to very few countries.



Source: FAOSTAT

Demand to reduce the dependency on tropical oils

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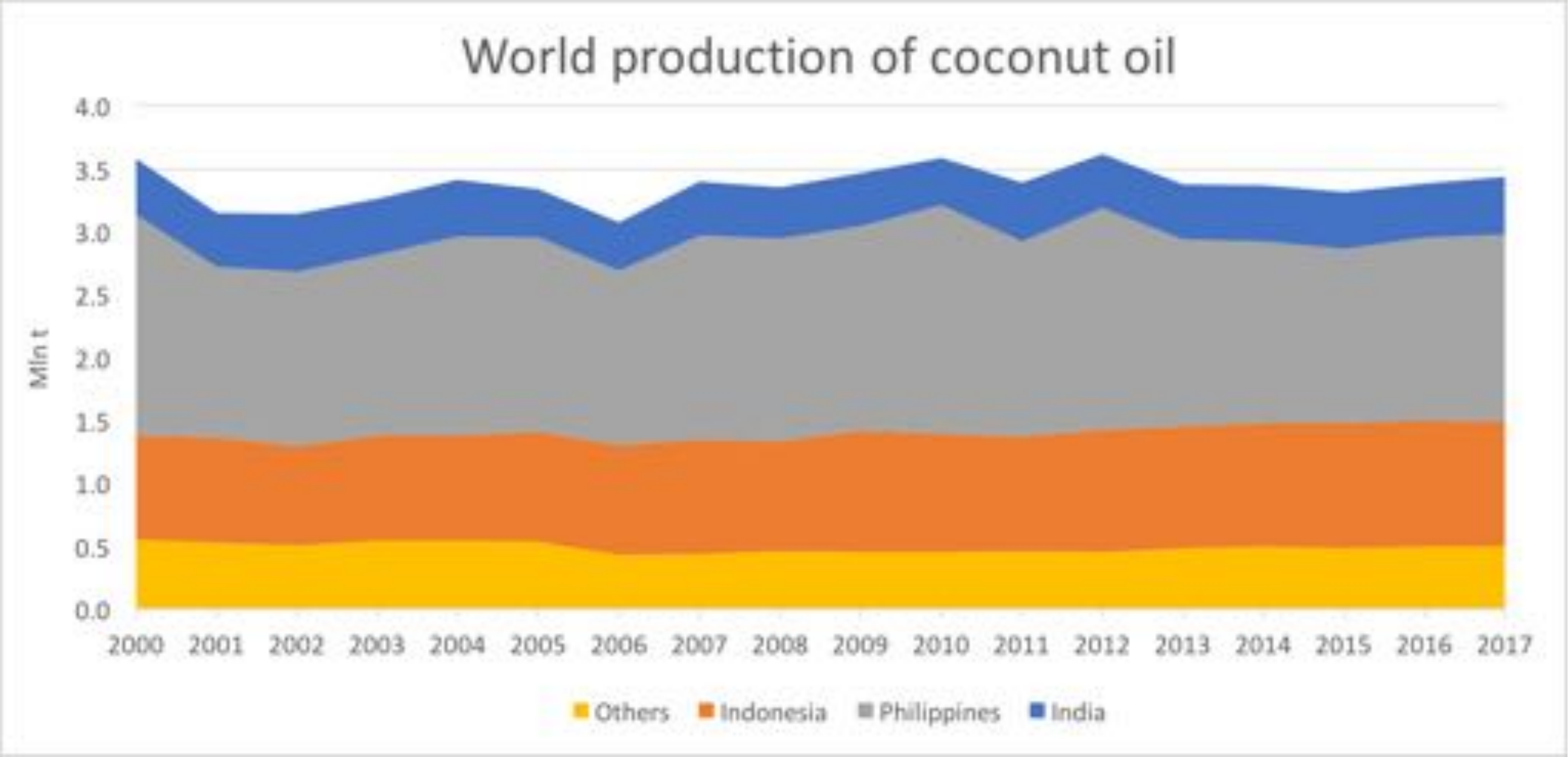

Source: FAOSTAT

Demand to reduce the dependency on tropical oils

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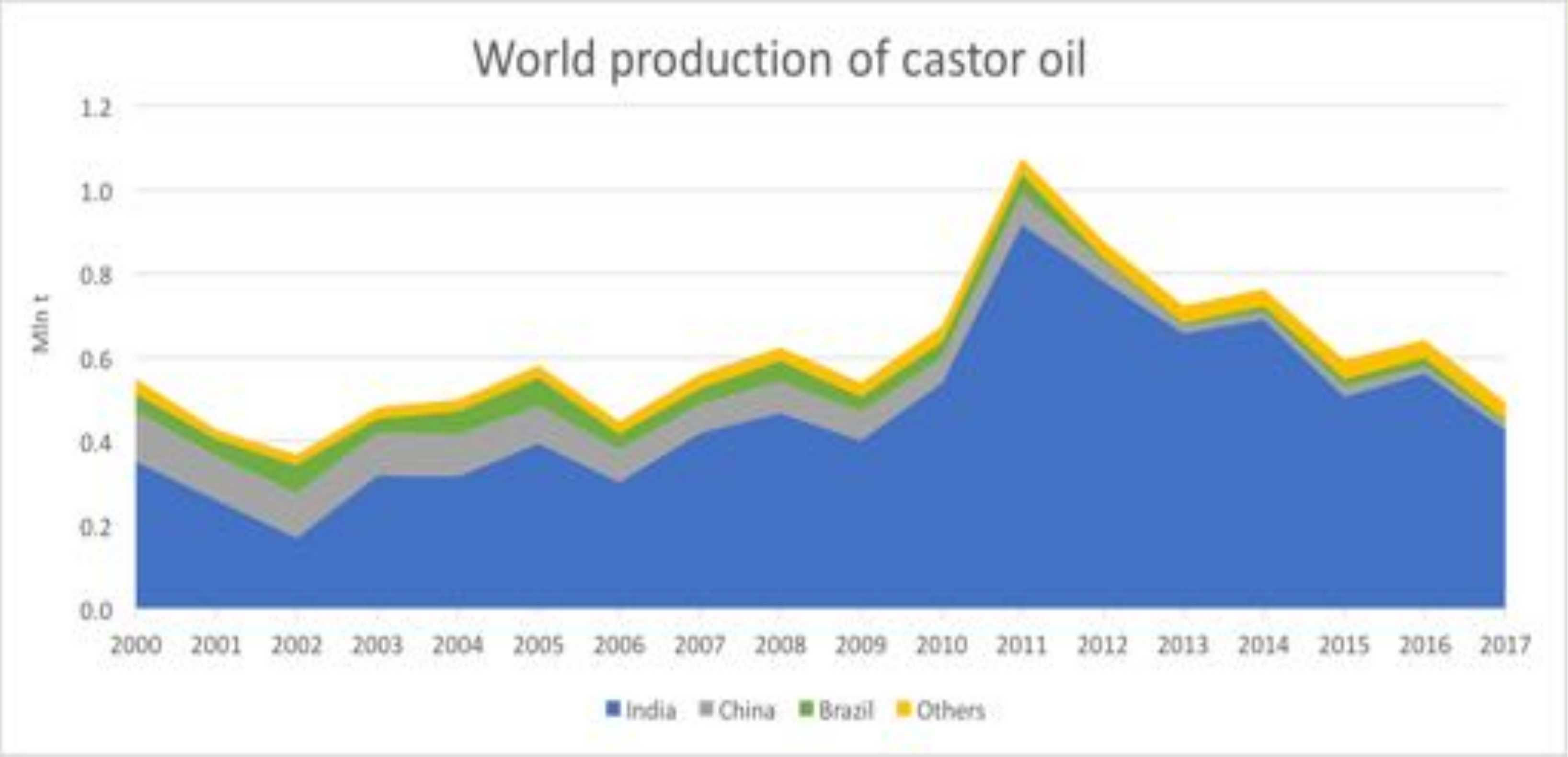
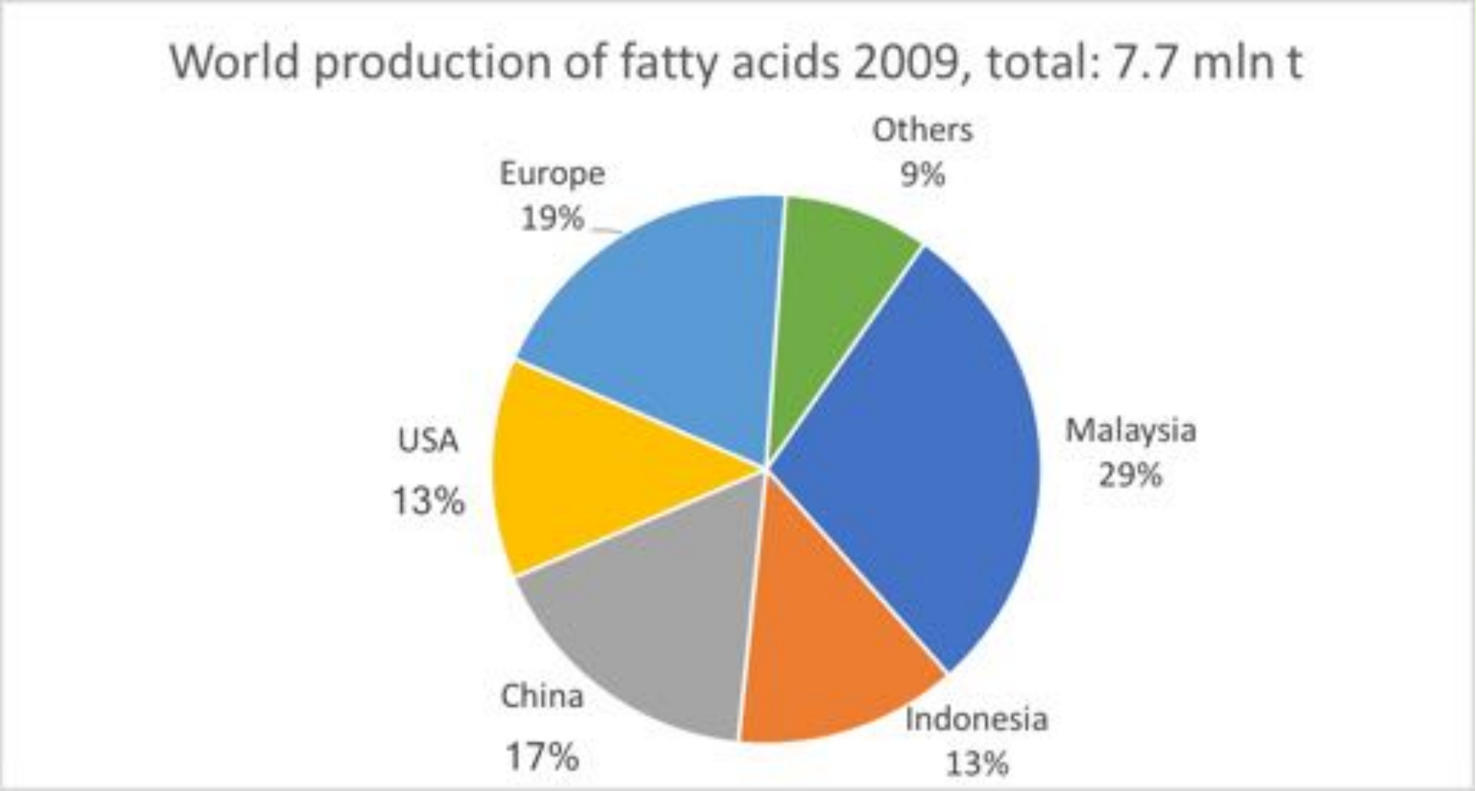


Source: FAOSTAT, OilWorld (assumption: 40% oil from castor seeds)

Demand to reduce the dependency on tropical oils

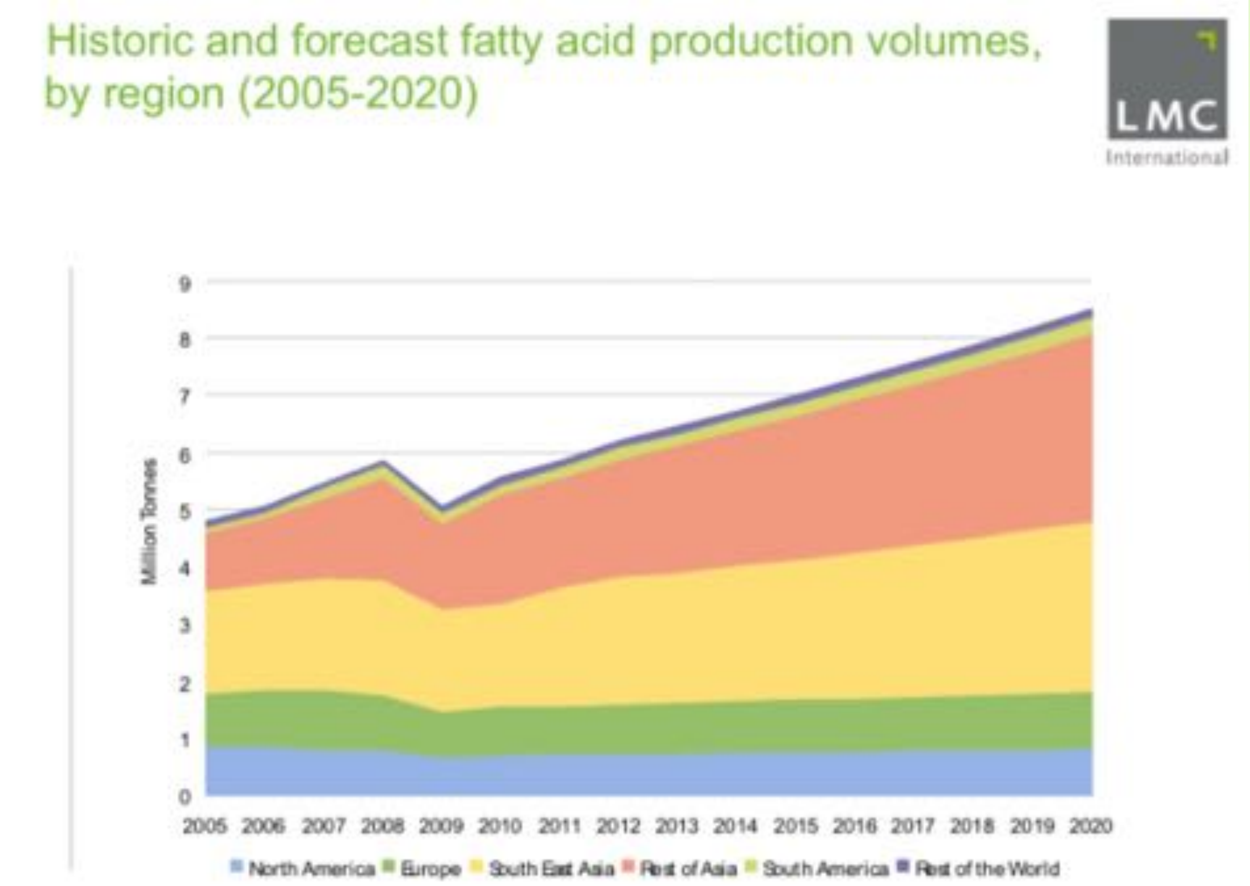
- Also the production of fatty acids is concentrated in a few countries.



Source: De Guzman 2010

Demand to reduce the dependency on tropical oils

- Also the production of fatty acids is concentrated in a few countries.



Source: LMC International 2011

Demand to reduce the dependency on tropical oils

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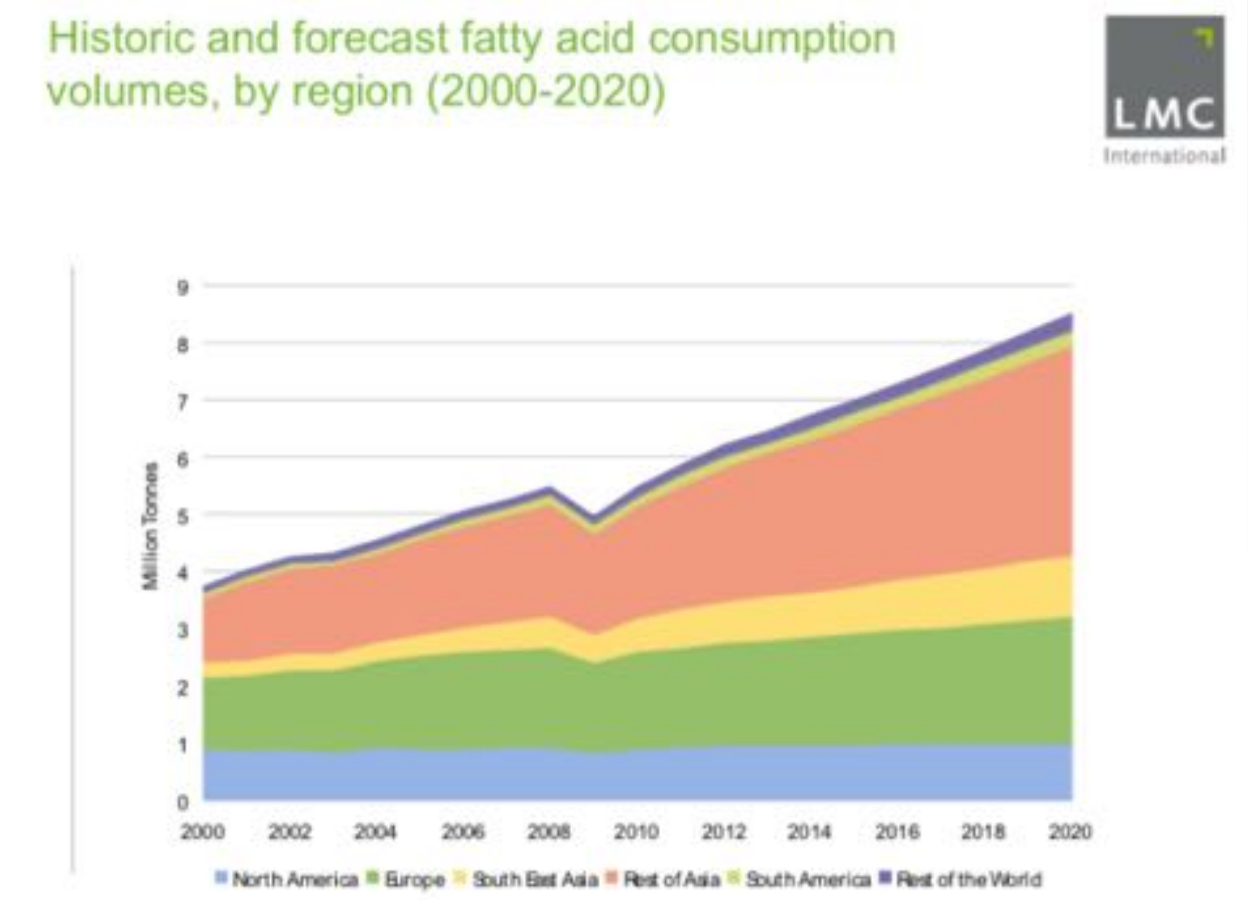
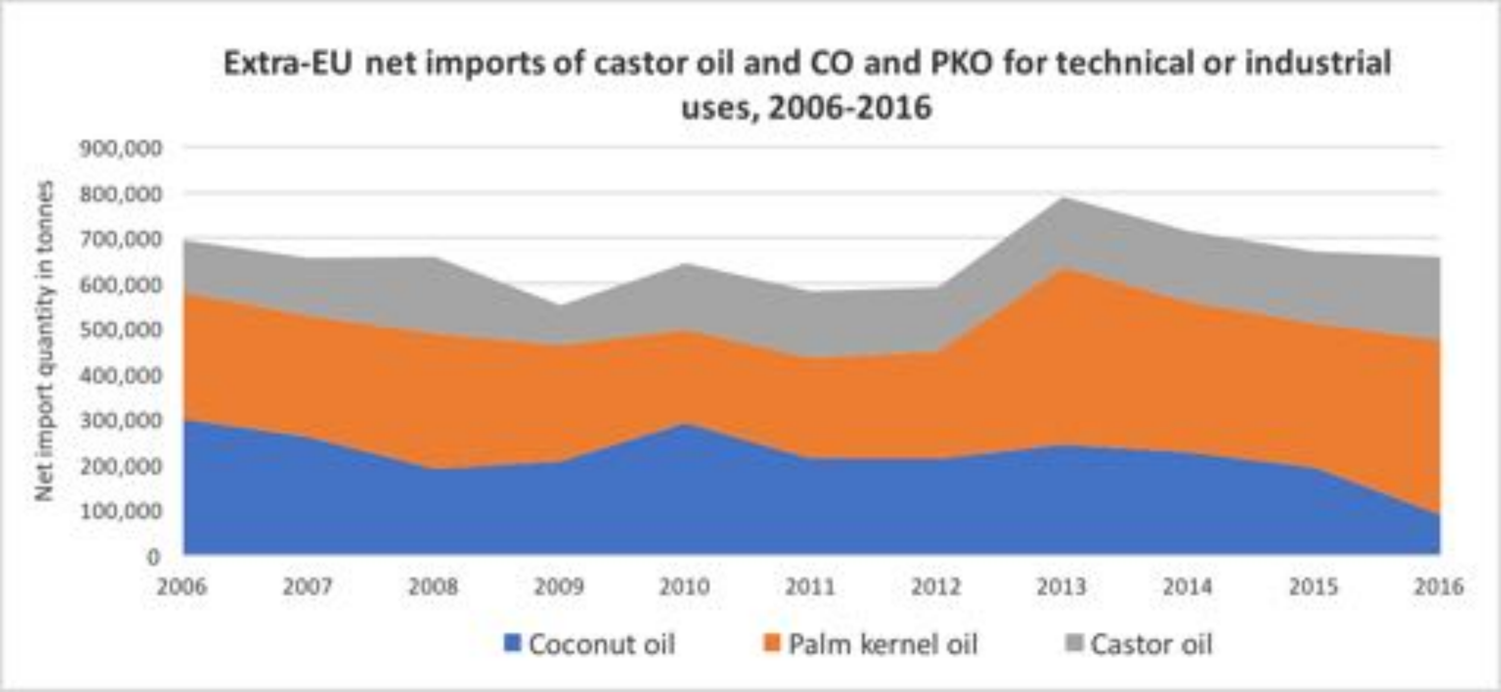


Source: LMC International 2011

Demand to reduce the dependency on tropical oils

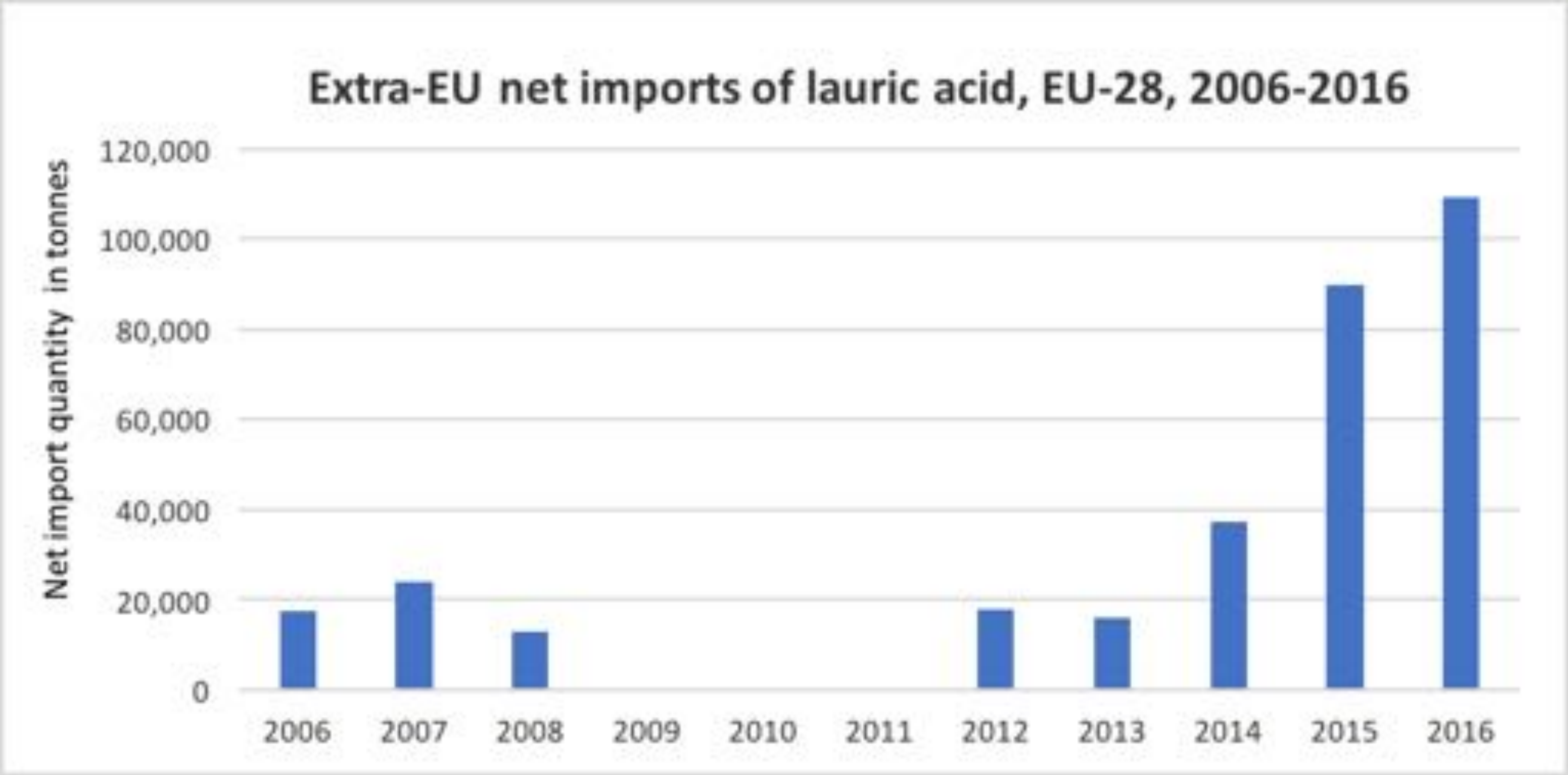
- The EU imports 4-6% of the global production of CO and PKO for technical or industrial uses, but about 24% of the global production of castor oil.



Source: Eurostat

Demand to reduce the dependency on tropical oils

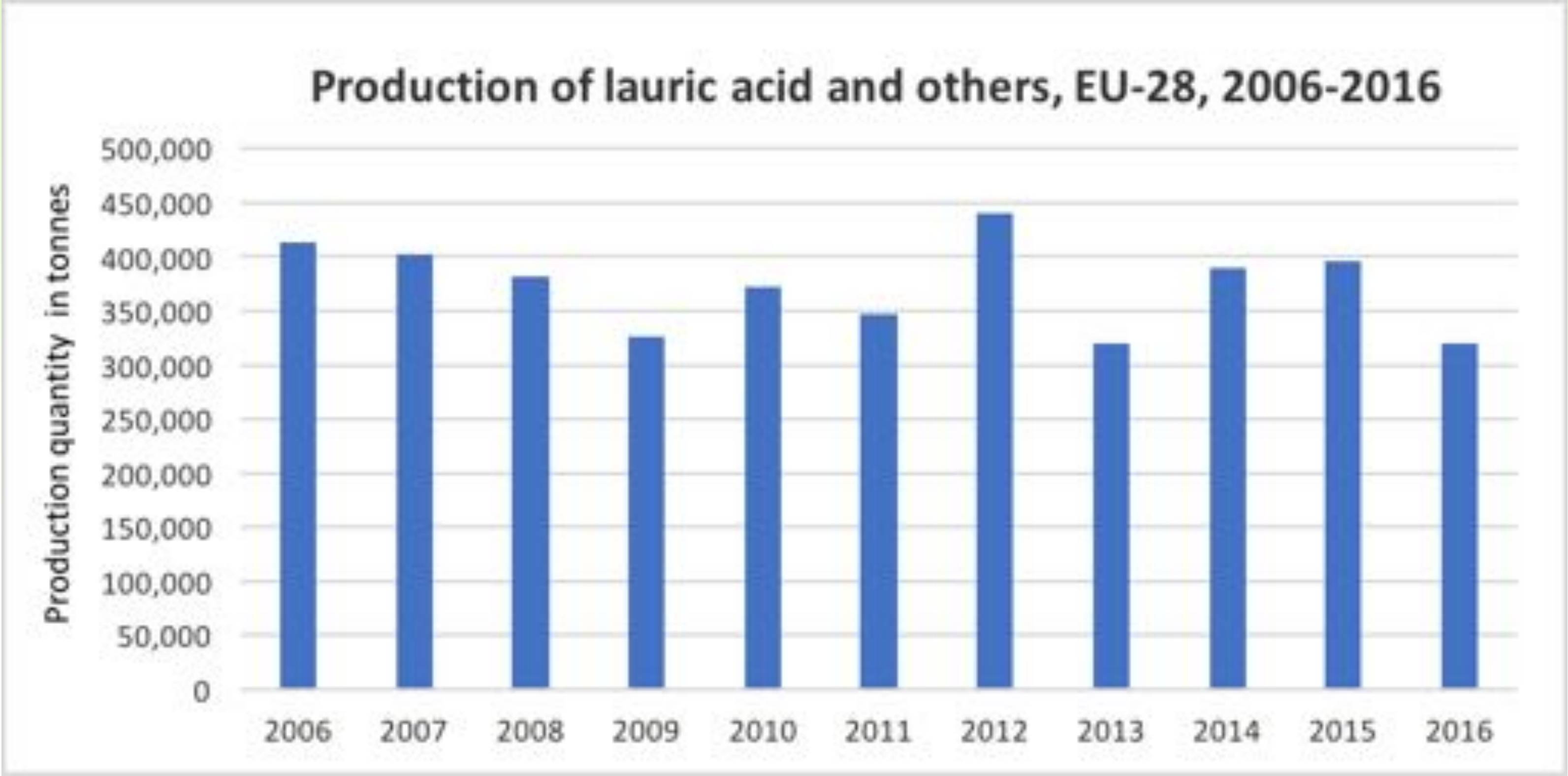
- In addition, the EU imports high amount of lauric acid in recent years.



Source: Eurostat

Demand to reduce the dependency on tropical oils

- The production of lauric acid and others in the EU amounts to about 350,000-450,000 t.



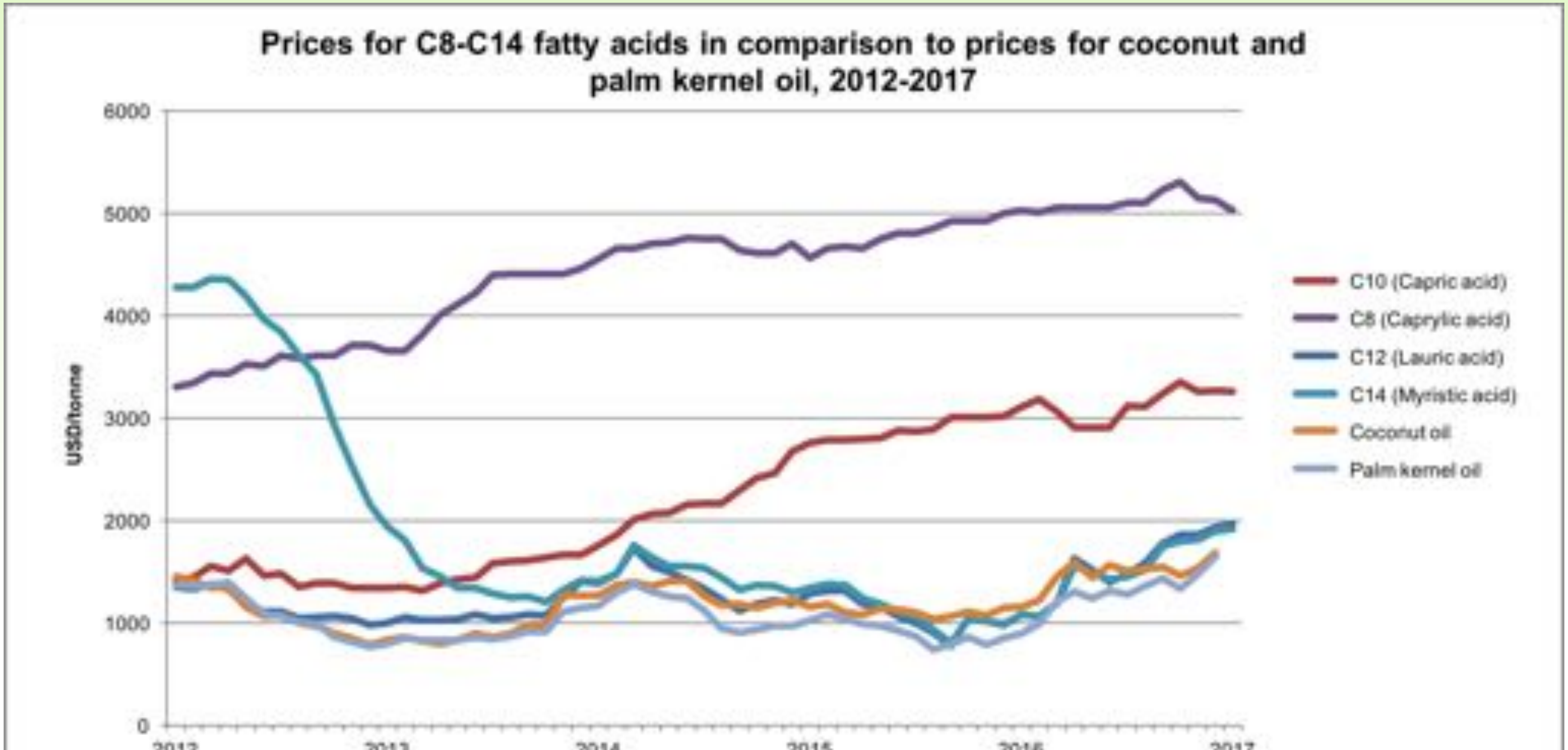
Source: Eurostat

Demand to reduce the dependency on tropical oils

- The total consumption of lauric acids therefore amounts to about 400,000 t in the EU.
- A recent market report concluded that the sum of global lauric acid, caprylic acid, caproic acid and capric acid production is around 550,000 t (Kendrick 2016). Additionally, the global market of myristic acid has been estimated to amount to 150,000 t (ETC 2013).
- Based on these figures, the EU therefore appears to take up more than half of the global production of fatty acids from lauric oils.

Demand to reduce the dependency on tropical oils

- Prices for the group of C8-C14 fatty acids are extremely volatile, due to supply side volatility and changes in demand of the uptaking industries.



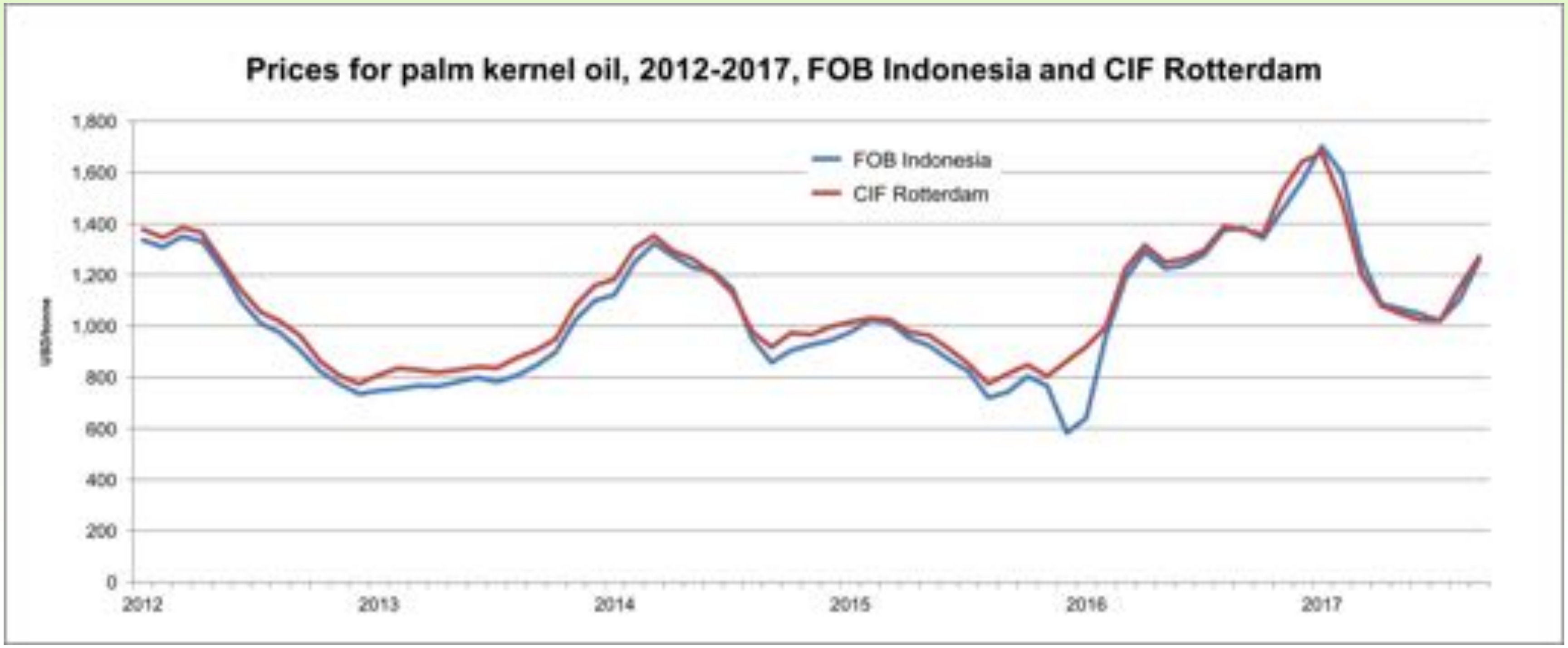
Source: ICIS 2017

Demand to reduce the dependency on tropical oils

- Supply security?
- Political stability?
- Reduction in lead time? –> less need for production planning, faster reaction to market changes, higher flexibility…
- Higher sustainability of European agriculture (at least in the perception of customers/image)?
- Political will to increase EU self-sufficiency?

Demand to reduce the dependency on tropical oils

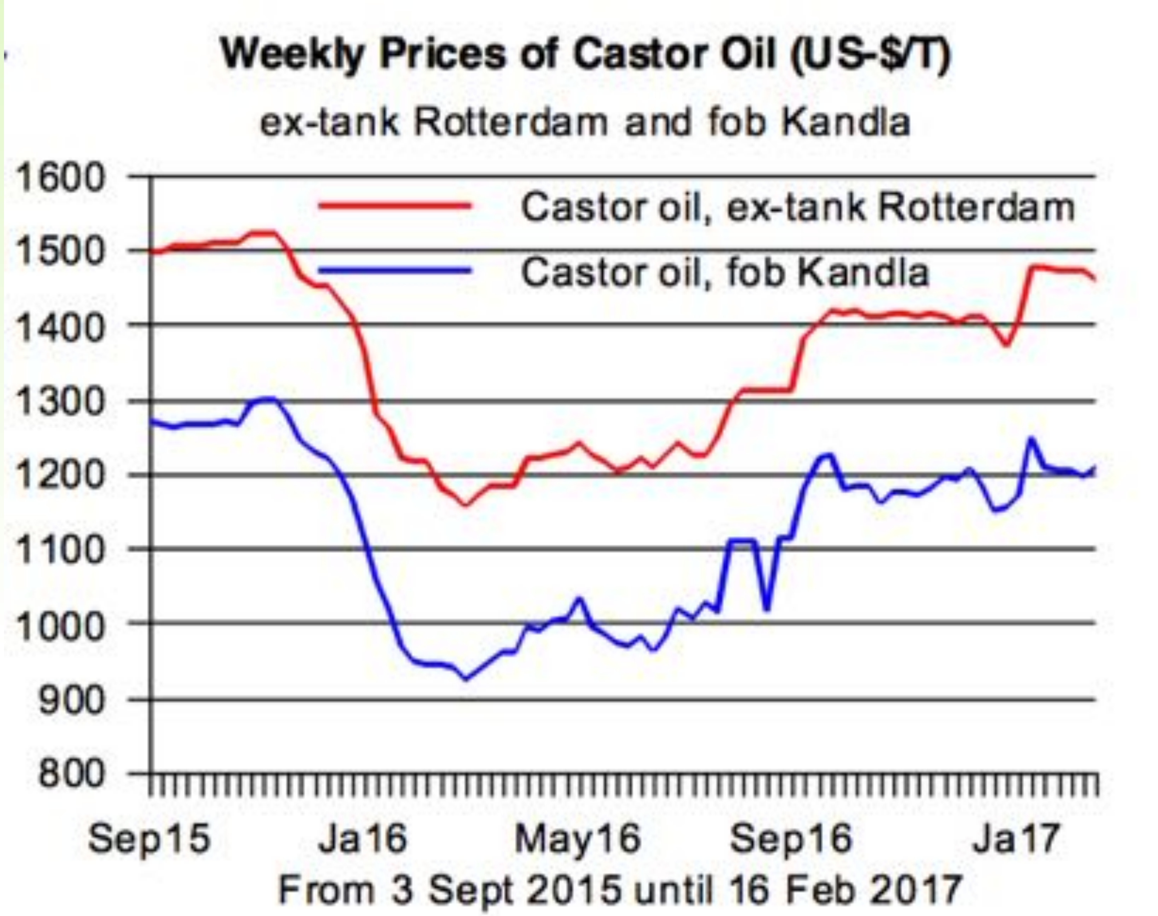
- Saving of transportation and logistics costs?



Source: http://www.palmoilanalytics.com

Demand to reduce the dependency on tropical oils

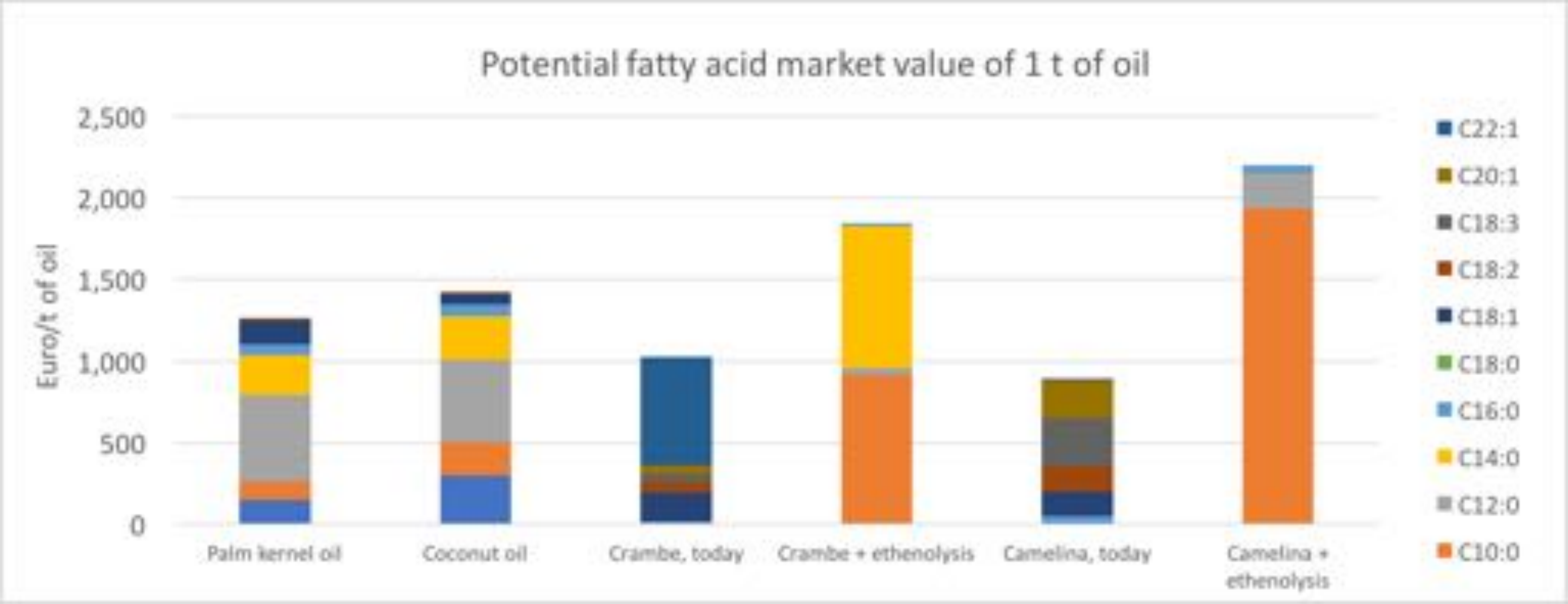
- Saving of transportation and logistics costs?



Source: Mielke, T. 2017

Demand to reduce the dependency on tropical oils

- Only based on fatty acid prices in recent years, camelina and crambe oil have a lower market value than palm kernel and coconut oil.
- Through chain cleavage chemistry, the fatty acid profiles of camelina could be turned around much in favour of capric (C10:0), lauric (C12:0) and myristic acid (C14:0).
- This could result in fatty acid market value from these oils above that of palm kernel and coconut oil.



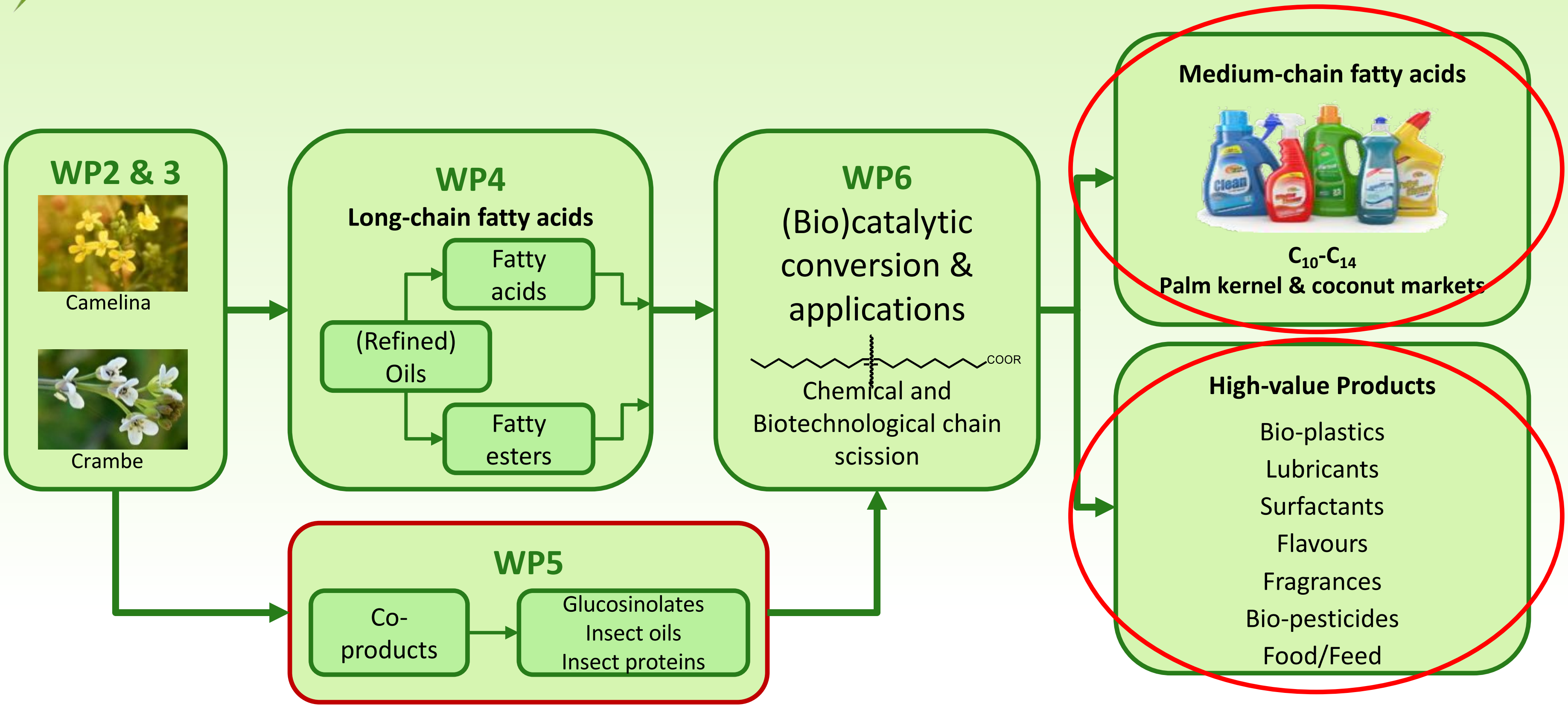
Demand to reduce the dependency on tropical oils

- What prices would the oleochemical industry be willing to pay for camelina and crambe oil?

		Fatty acid value of the oil (Euro/t oil)	Market price (Euro/t oil)
Coconut oil		1,500	900
Palm kernel oil		1,250	1,000
Camelina oil	Today	1,000	?
	Improved	2,000	?
Crambe oil	Today	1,000	?
	Improved	2,000	?

Statement 3:

The project focusses on the right product portfolio with good market potential and the potential to profit from the use of European feedstocks.


WP2 & 3
Camelina
Crambe
WP4
Long-chain fatty acids
Fatty acids
(Refined) Oils
Fatty esters
WP6
(Bio)catalytic conversion & applications
COOR
Chemical and Biotechnological chain scission
WP5
Co-products
Glucosinolates
Insect oils
Insect proteins
Medium-chain fatty acids
Clean
C_{10}-C_{14}
Palm kernel & coconut markets
High-value Products
Bio-plastics
Lubricants
Surfactants
Flavours
Fragrances
Bio-pesticides
Food/Feed

Thank you

stephan.piotrowski@nova-institut.de

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COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL