



www.eurobioRef.org

EuroBioRef: Designing next generation biorefineries

3rd Iberoamerican Congress on Biorefineries (CIAB)



Concepción, Chile, November 23-25 2015
Coordinator: Prof. Franck Dumeignil (UCCS)
Speaker: Prof. Franck Dumeignil (UCCS)



Call of the 7th Framework Programme : COLLABORATIVE PROGRAMME

Joint Programme FP7-2009-BIOREFINERY-CP

- **Nanosciences, Nanotechnologies, Materials and new Production Technologies**
- **Energy**
- **Food, Agriculture and Fisheries, and Biotechnology**
- **Environment (including Climate Change)**



Establishment of a Network of Projects



Franck Dumeignil




<http://eurobioref.org/>


37.4 M€
 **23 M€**

29 Partners
15 Nationalities


4 years




Mickaël O'Donohue




www.biocore-europe.org

20.3 M€
 **14 M€**


24 Partners
13 Nationalities



Ashok K Bhattacharya



www.suprabio.eu

19 M€
 **12,5 M€**

17 Partners
8 Nationalities

2 years



Johan Elvnert



www.star-colibri.eu

2.4 M€
 **2 M€**

12 Partners
6 Nationalities



An Integrated European BioRefineries Network

1st March 2010 – 28th February 2014



Duration: 4 years

A Large-Scale Project...

- 29 Partners



- 15 Nations



- 4 Years



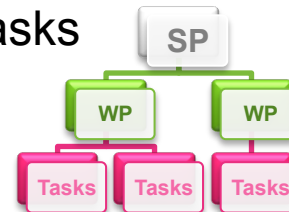
- ca. 3,400 Person Months



- 38 M€ of Global Budget, 23 M€ of EC grant



- 10 Sub-Projects, 35 Work Packages, 153 Tasks

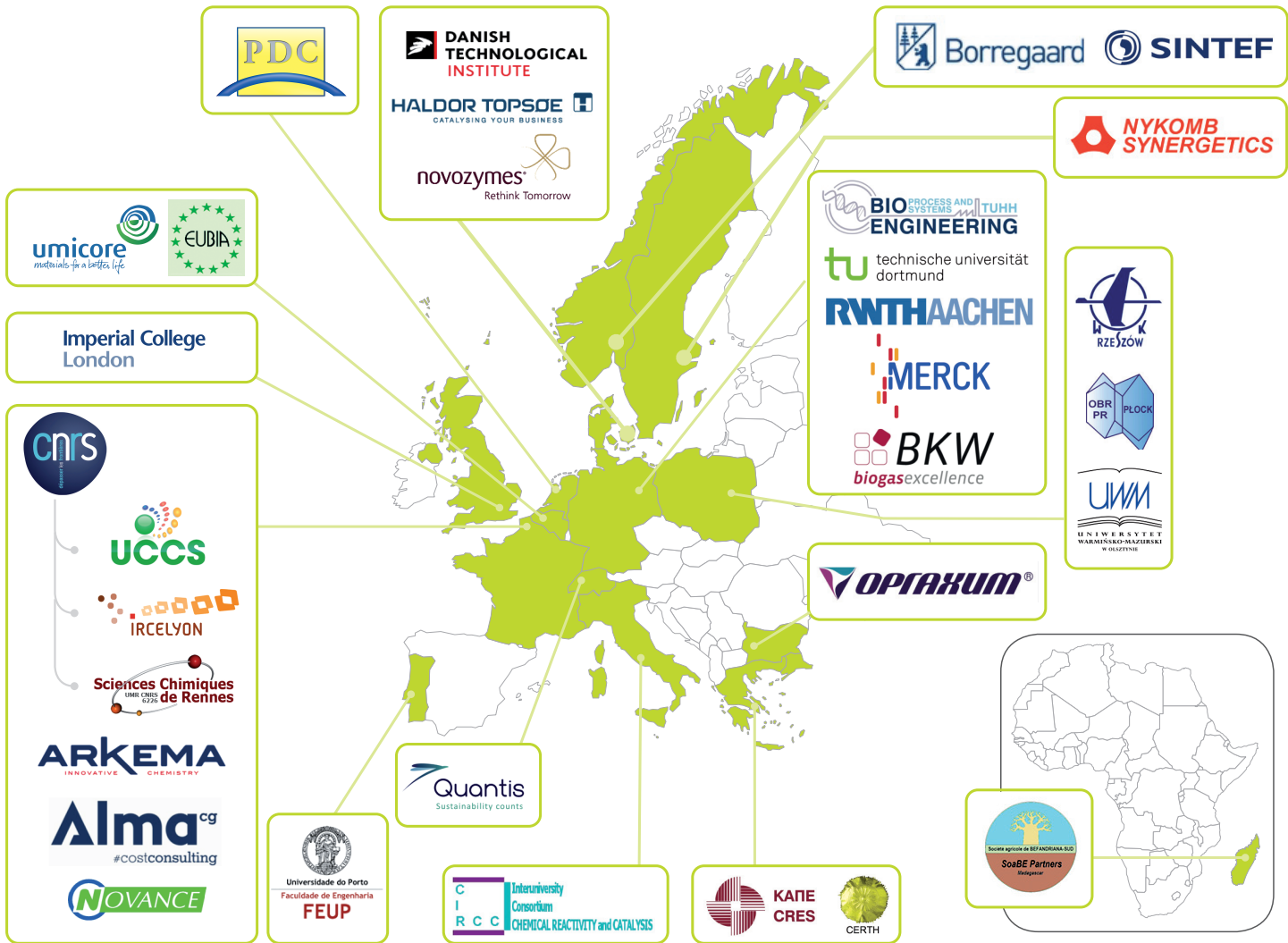


- 59 Milestones



- 214 EC Deliverables

...Involving a Wide Consortium



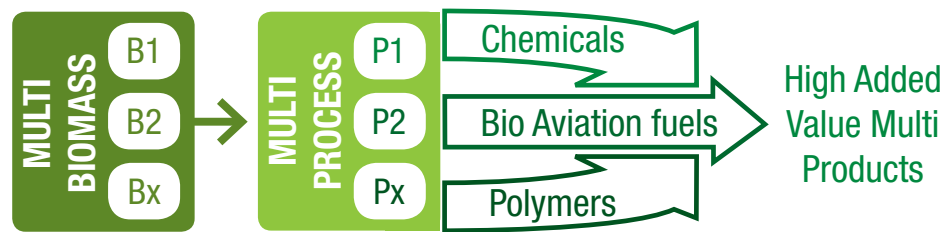
Next Generation Biorefinery: Principle

EUROpean Multilevel Integrated BIOREFinery Design for Sustainable Biomass Processing

Classical BIOREFinery



Integrated EuroBioRef Biorefinery Concept



EuroBioRef will bridge the gap between agriculture and chemical industry by integrating the whole biomass chain in a **Multi-feedstock (non-edible), **Multi-process** (chemical, biochemical, thermochemical), **Multi-products** (aviation fuels and chemicals) commercially viable and adaptable approach for a sustainable bio-economy in Europe.**

Next Generation Biorefinery: Objectives

Biodiversity

Produce and use a high diversity of sustainable biomasses adapted for European regions

High Energy Aviation Fuel

High specific energy bio-jetfuel (42 MJ/kg)

Produce Multiple Products (reaching TRL > 5)

(Chemicals, polymers, materials) in a flexible and optimised way...

Improve cost efficiency by 30%

through improved reaction conditions and separation effectiveness, improved plant and feedstock flexibility, reduction in production time and logistics

Reduce energy consumption by 30%

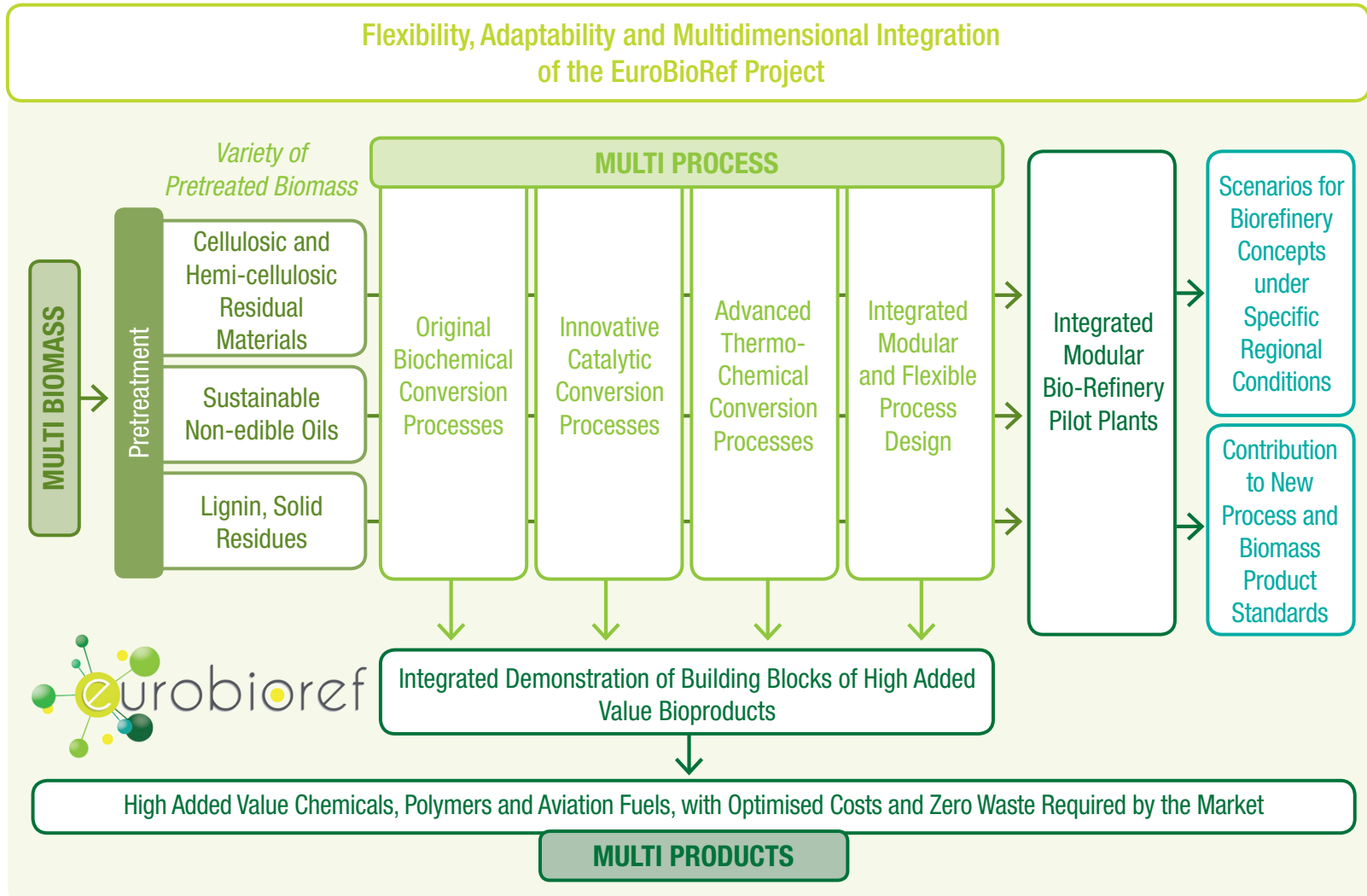
Product zero wastes

and rationalize the use of raw materials

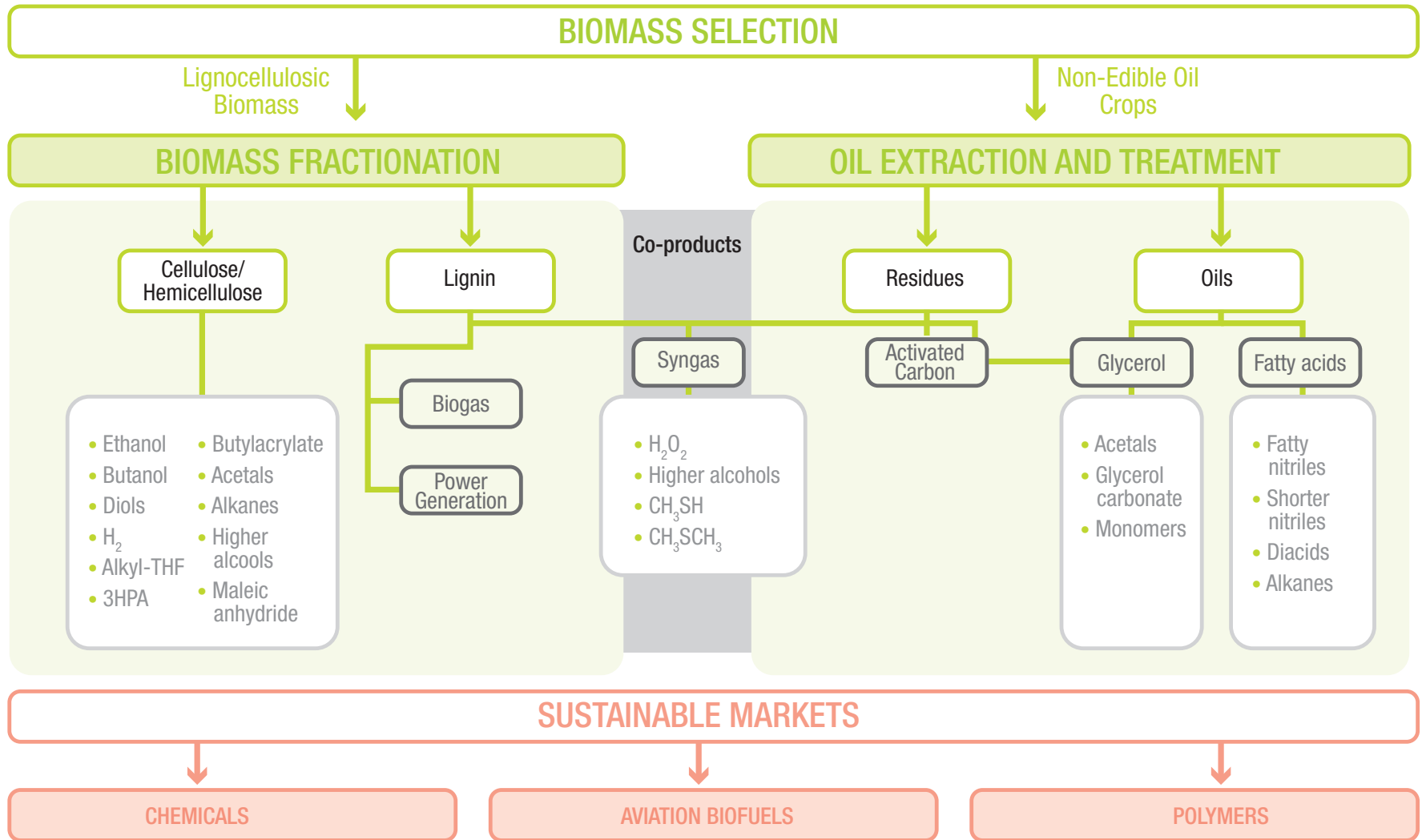
Reduce time to Market (month)



Next Generation Biorefinery: Concept



Target Products



Project structure

SP10: Exploitation, dissemination, communication, standardisation, training

Lab scale

SP2: Biomass feedstock

SP3: Biomass pre-treatment

SP4: Biochemistry, Separations

SP5: Chemistry

SP6: Thermochemistry

SP1: General strategy framework



Demo scale

SP7: Process design & Demos



SP8: Industrial up-scaling

SP9: Socio-economics, LCA

SP11: Management

Configuration of the project

Work by technical/scientific field

SP10: Exploitation, dissemination, communication, standardisation, training

SP2: Biomass feedstock

SP3: Biomass pre-treatment

SP4: Biochemistry, Separations

SP5: Chemistry

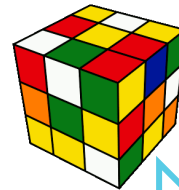
SP6: Thermochemistry

SP7: Process design & Demos

SP8: Industrial up-scaling

SP9: Socio-economics, LCA

SP11: Management



2 years



Integration (Value Chains)

See booklet



Some results of SP1

SP10: Exploitation, dissemination, communication, standardisation, training

Lab scale

SP2: Biomass feedstock

SP3: Biomass pre-treatment

SP4: Biochemistry, Separations

SP5: Chemistry

SP6: Thermochemistry

Demo scale

SP7: Process design & Demos

SP8: Industrial up-scaling

SP1: General strategy framework

SP9: Socio-economics, LCA

SP11: Management

A chemicals-driven biorefinery

EuroBioRef biorefineries are chemicals/materials-driven:

- Best part of the crops: High value chemicals and products
- Residues: Production of energy

This is a **rethinking of commonly admitted biorefineries concepts that are strongly biofuels-driven.**



6 Value Chains

6 value chains corresponding to 6 different scenarios of biorefineries integrating results and concepts developed in EuroBioRef have been designed and multidimensionally assessed, to realize *demonstrations of the developed technologies*, but also to *assess scenarios of industrial exploitation*.

Value Chain 1: Castor oil to polymers

Value Chain 2: Crambe/safflower oils to polymers

Value Chain 3: Alcohols to fuels (ATF)

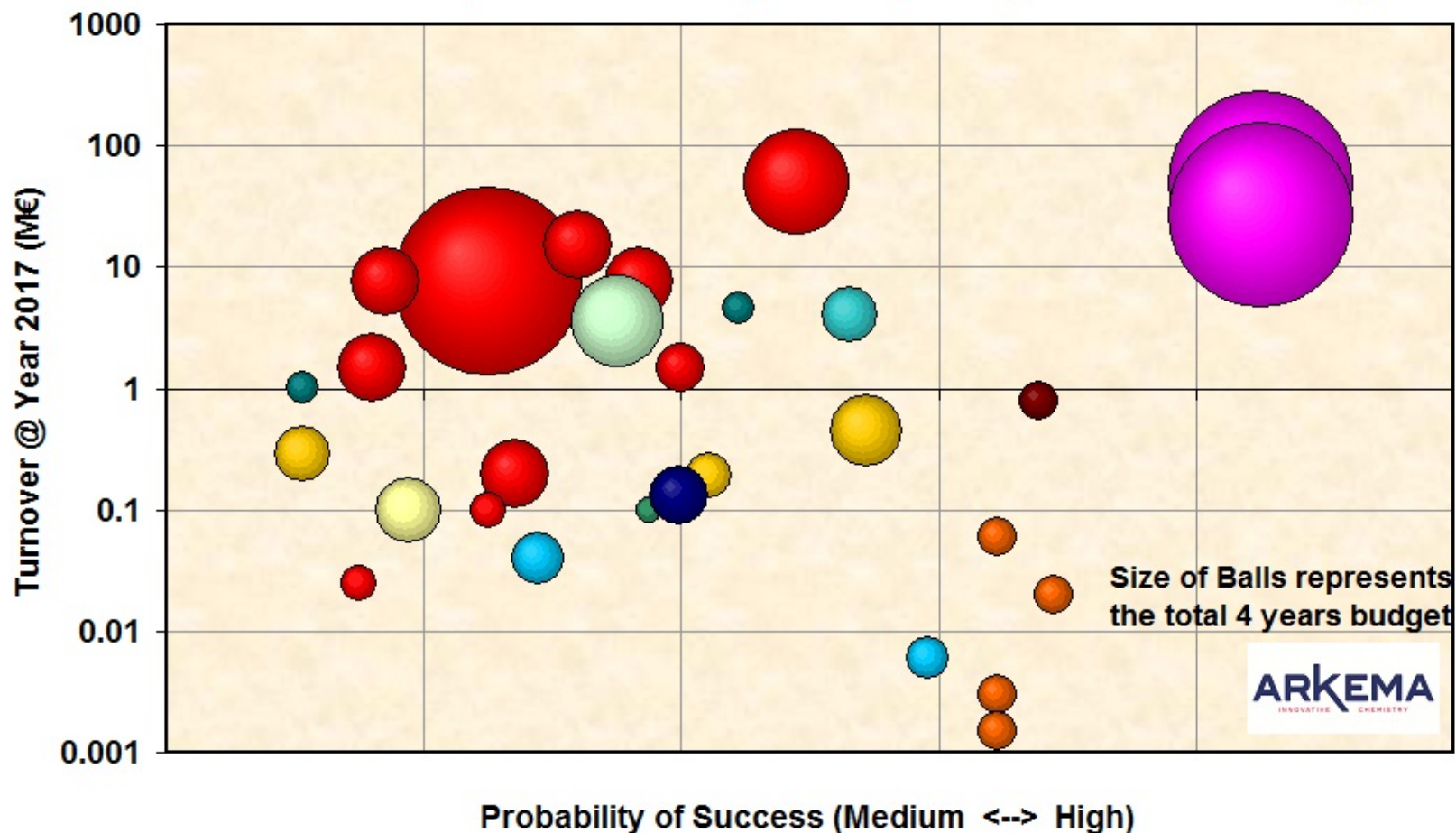
Value Chain 4: Lignocellulosics to acrylates

Value Chain 5: Syngas-based products

Value Chain 6: Integrated productions in existing assets

Expected turnover

Exploitation of the Results @ Year 2017
(each color correspond to a partner) - M48



Some results of SP2

SP10: Exploitation, dissemination, communication, standardisation, training

Lab scale

SP2: Biomass feedstock

SP3: Biomass pre-treatment

SP4: Biochemistry, Separations

SP5: Chemistry

SP6: Thermochemistry

Demo scale

SP7: Process design & Demos

SP8: Industrial up-scaling

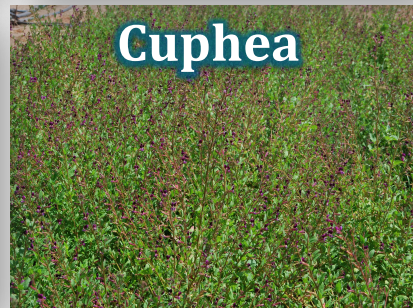
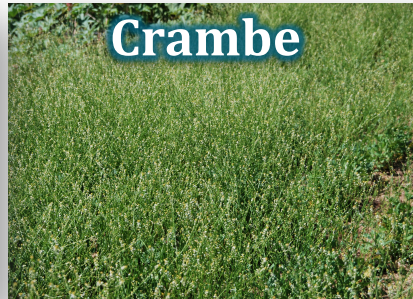
SP11: Management

SP1: General strategy framework

SP9: Socio-economics, LCA

Fields trials in Greece, Poland & Madagascar

Oleaginous plants



Lignocellulosics



Mapping of potential cultures location in Europe



Miscanthus



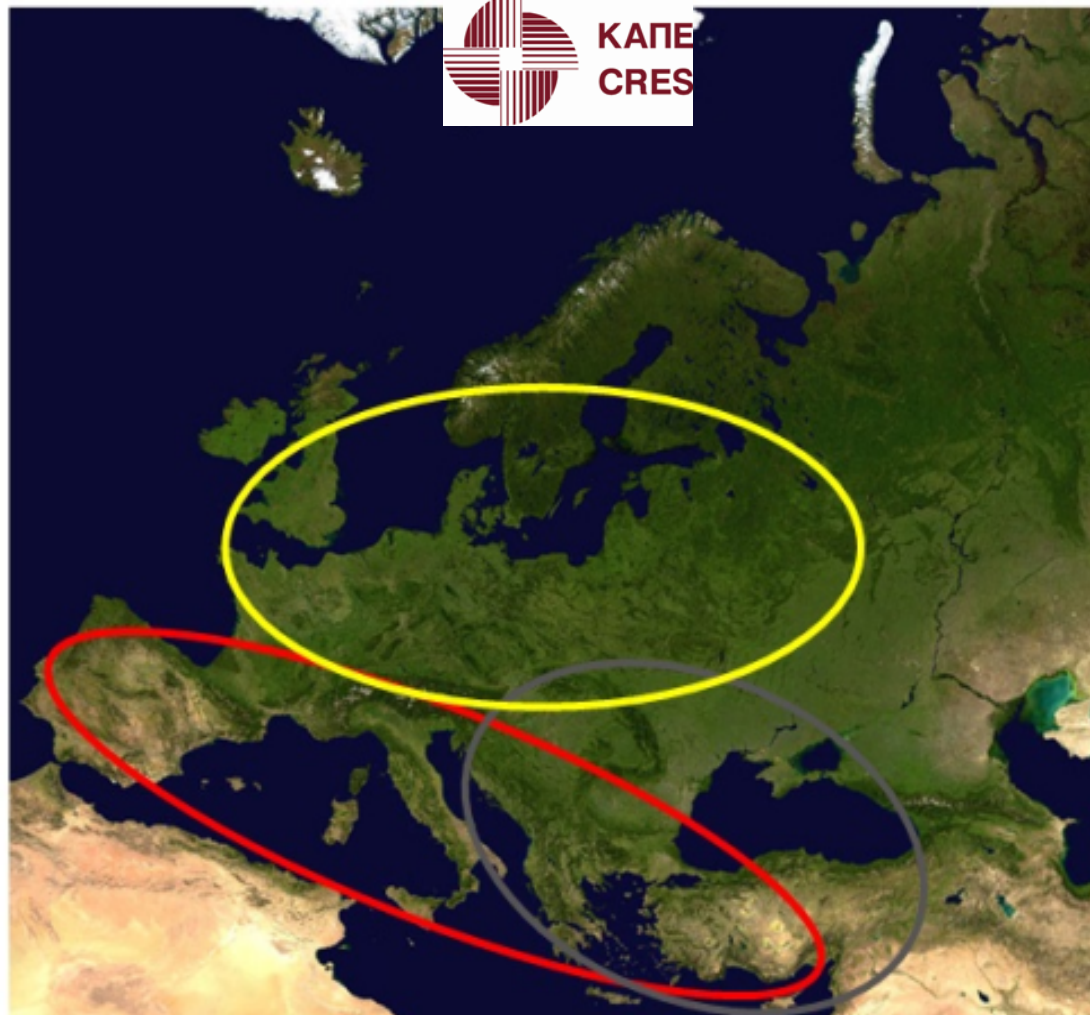
Giant reed



Switchgrass



Castor seeds



Crambe



Willow



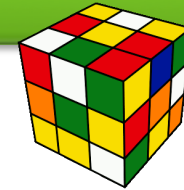
Safflower

Logistics

Development of a comprehensive tool for optimizing biomass logistics



15 (or more) handling elements in each supply chain
250 data sheets



Training



- Olsztyn, PL 12/2012
- Theoretical and practical
- Farmers, businessmen, policy makers, deciders, scientists, students



Real tests

Willow harvesting



Storage trials
(willow piles)



Pile of willow in front of the BALI™ demo plant



Some results of SP3

SP10: Exploitation, dissemination, communication, standardisation, training

Lab scale

SP2: Biomass feedstock

SP3: Biomass pre-treatment

SP4: Biochemistry, Separations

SP5: Chemistry

SP6: Thermochemistry

Demo scale

SP7: Process design & Demos

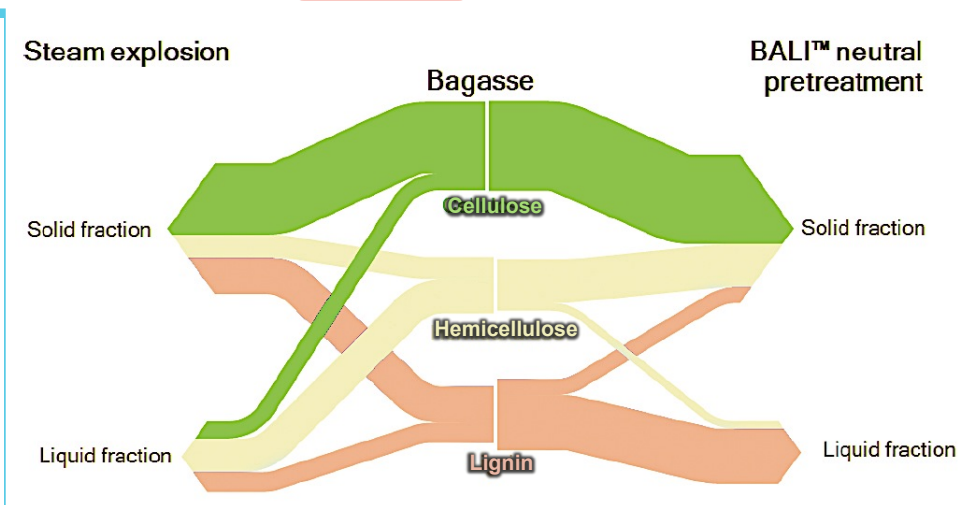
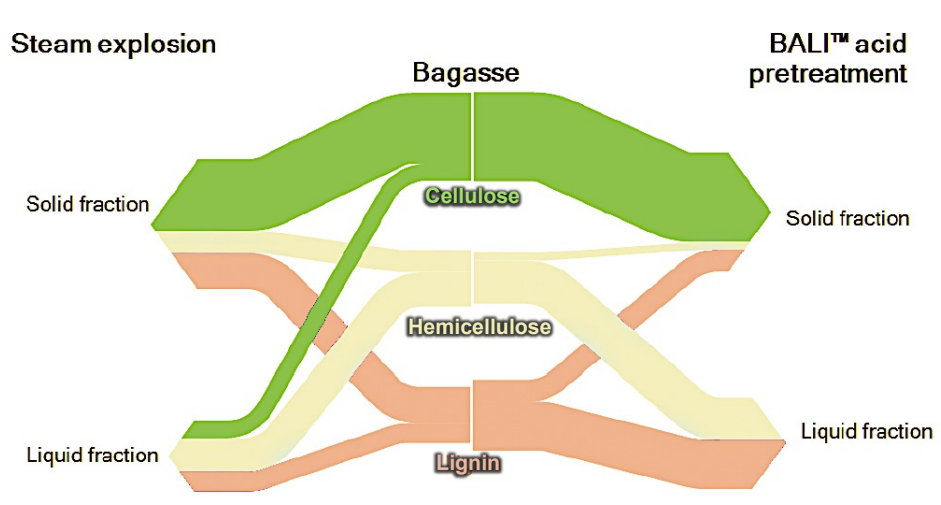
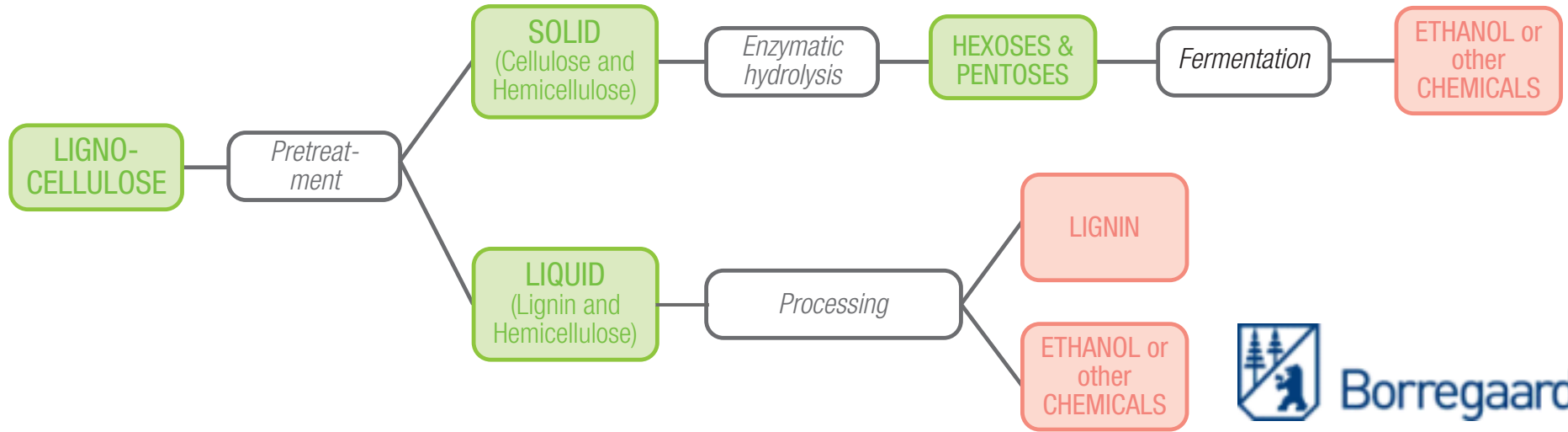
SP8: Industrial up-scaling

SP11: Management

SP1: General strategy framework

SP9: Socio-economics, LCA

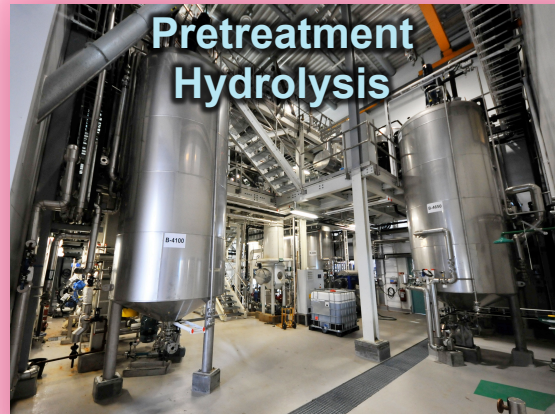
Lignocellulosics fractionation: BALI™ process (1)



Lignocellulosics fractionation: BALI™ process (2)



Pile of willow in front of the BALI™ demo plant



Pretreatment Hydrolysis



Borregaard



BALI™ demo plant

1 to 1.5 kt per day



Pretreated willow, willow pulp and lignin

High glucose yield:

- Bagasse (benchmark)
- Miscanthus
- Giant Reed
- Switchgrass
- Willow

High quality lignin:

- Bagasse (benchmark)
- Willow
- Spruce

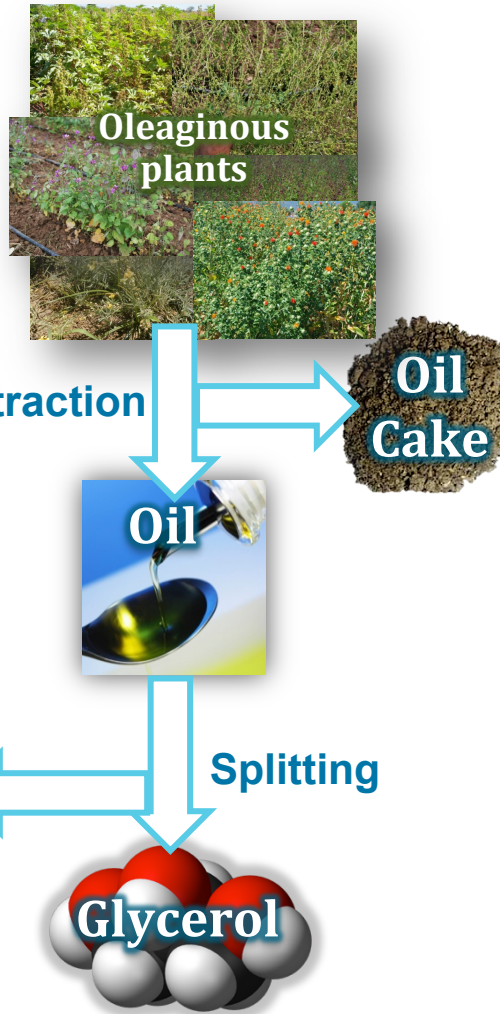
Target to be the full scale by 2017

Oil extraction/refining

Enzymatic hydrolysis

New process for castor oil:

- Hydrolysis rate > 95%
- No by-product
- Distillation yield increased by 5%
- 70% reduction of water
- Full recycling of hydrolysis water
- Substantial reduction of energy consumption



Crushing of jatropha and castor:

Fatty acids profiles very close to the commercial ones

Refining of lunaria, castor and crambe oils:

Distribution in fatty acids in the expected range for the corresponding commercial oils

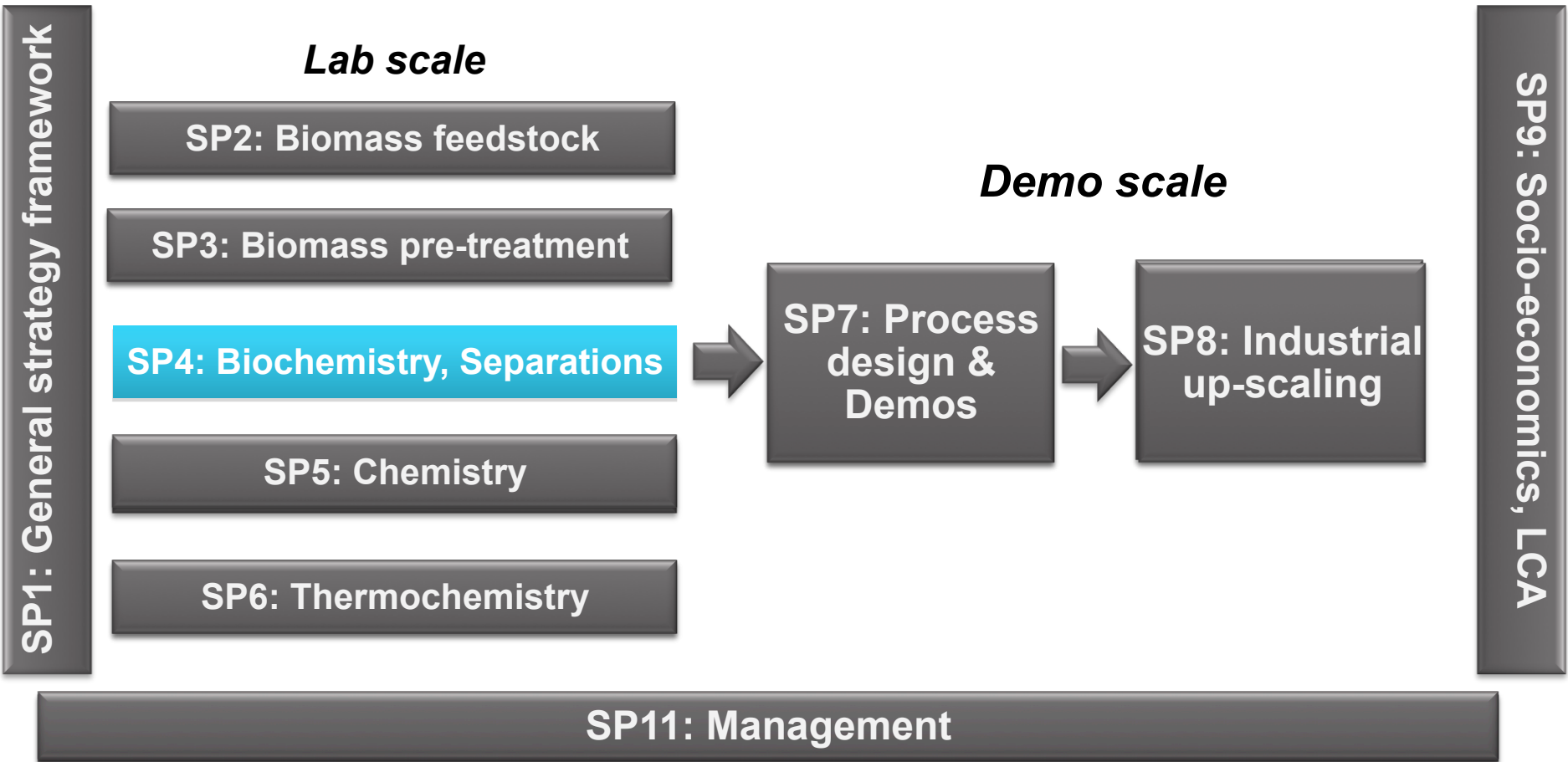
Saponification of lunaria and crambe oils:

Distillation to isolate **erucic acid**



Some results of SP4

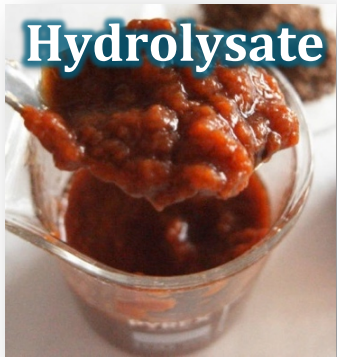
SP10: Exploitation, dissemination, communication, standardisation, training



n-Butanol, 1,3-propanediol and biogas production

Lignocellulosics

Oleaginous plants



BKW
biogasexcellence

TUHH
Technische Universität Hamburg-Harburg



Biogas
400 L/kg oTS
(castor cake)

Patent filed



1,3-propanediol

60 g/L (under unsterile conditions!)



3-hydroxypropionic acid
Unsatisfactory performances

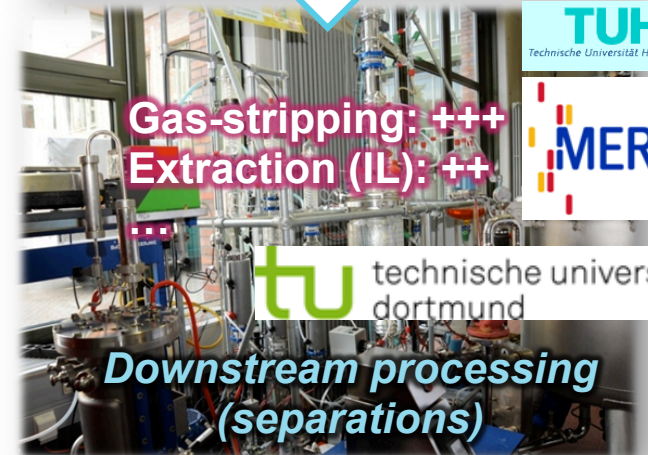
Clostridium pasteurianum
DSMZ 525

21 g/L n-butanol in fermentation broth

Miniplant



Fermentation

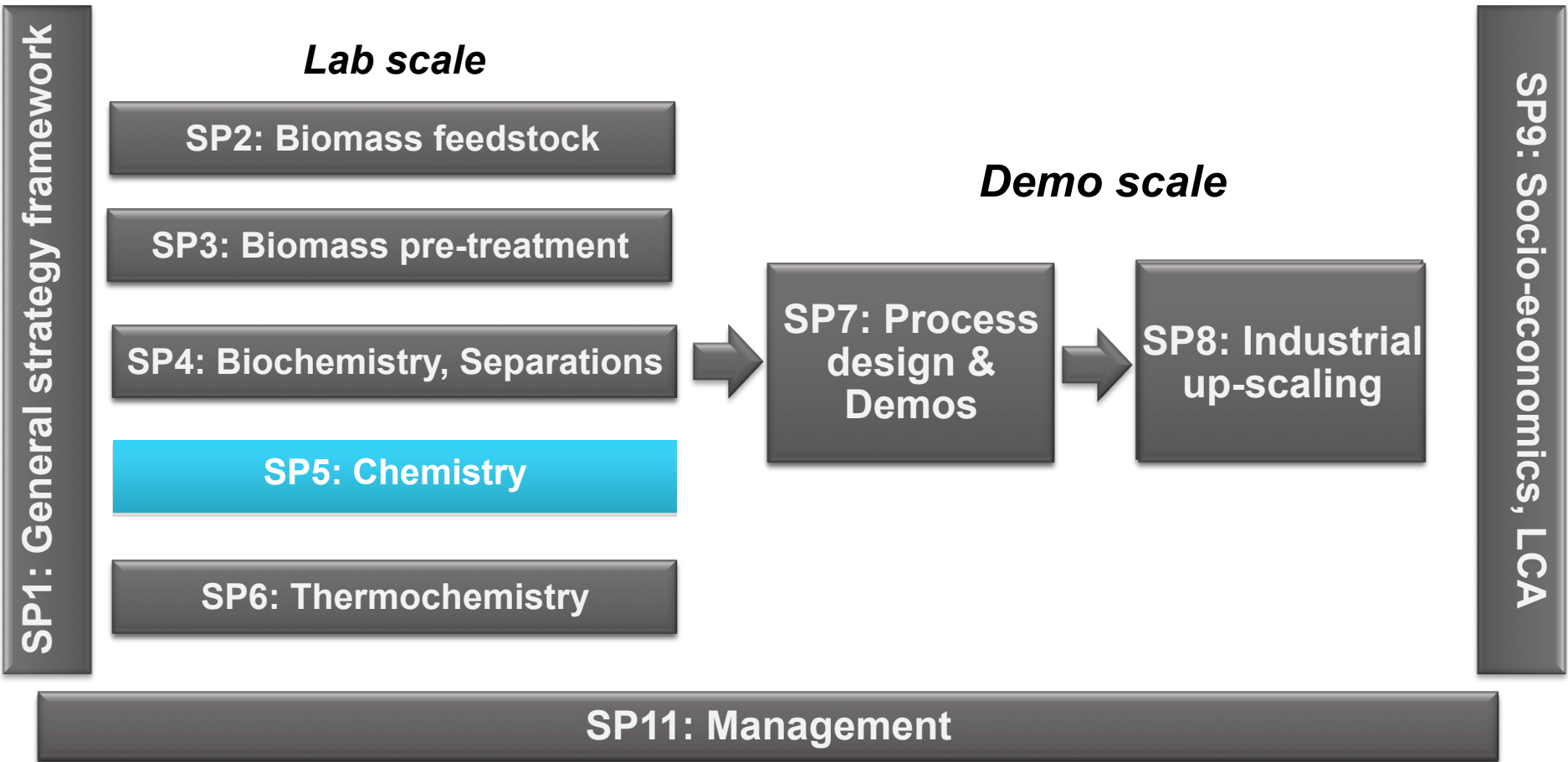


Gas-stripping: +++
Extraction (IL): ++

Downstream processing (separations)

Some results of SP5

SP10: Exploitation, dissemination, communication, standardisation, training



Catalytic transformations



Biomass selection



castor, crambe, safflower, willow, giant reed, miscanthus

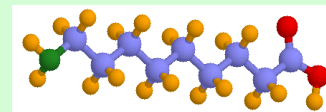
Metathesis
High TON with functionalized substrates (nitriles, esters)

Dehydration
New catalyst for 3HPA with 100% yield

Oxidative Cleavage
New nitrile substrates achieved

Guerbet
New parallel equipment designed

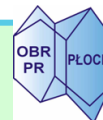
High value monomers



Acrylics, Polyamides

Aviation & Road Fuel

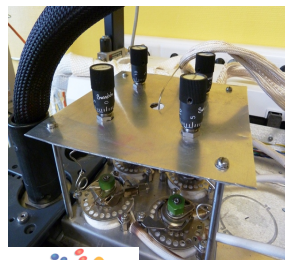
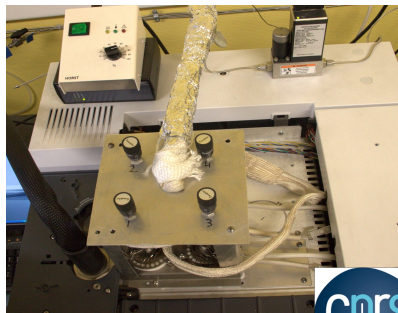
Dedicated value chain with new technology



(VC3)



Guerbet parallel equipment (4 reactors)



(52) DEMANDE INTERNATIONALE FILING EN VERTU DU TRAITE DE COOPERATION EN MATIERE DE BREVETS (PCT)

(51) Classement international de la demande: **H01M 2/04** (2006.01); **H01M 2/20** (2006.01); **H01M 2/24** (2006.01)

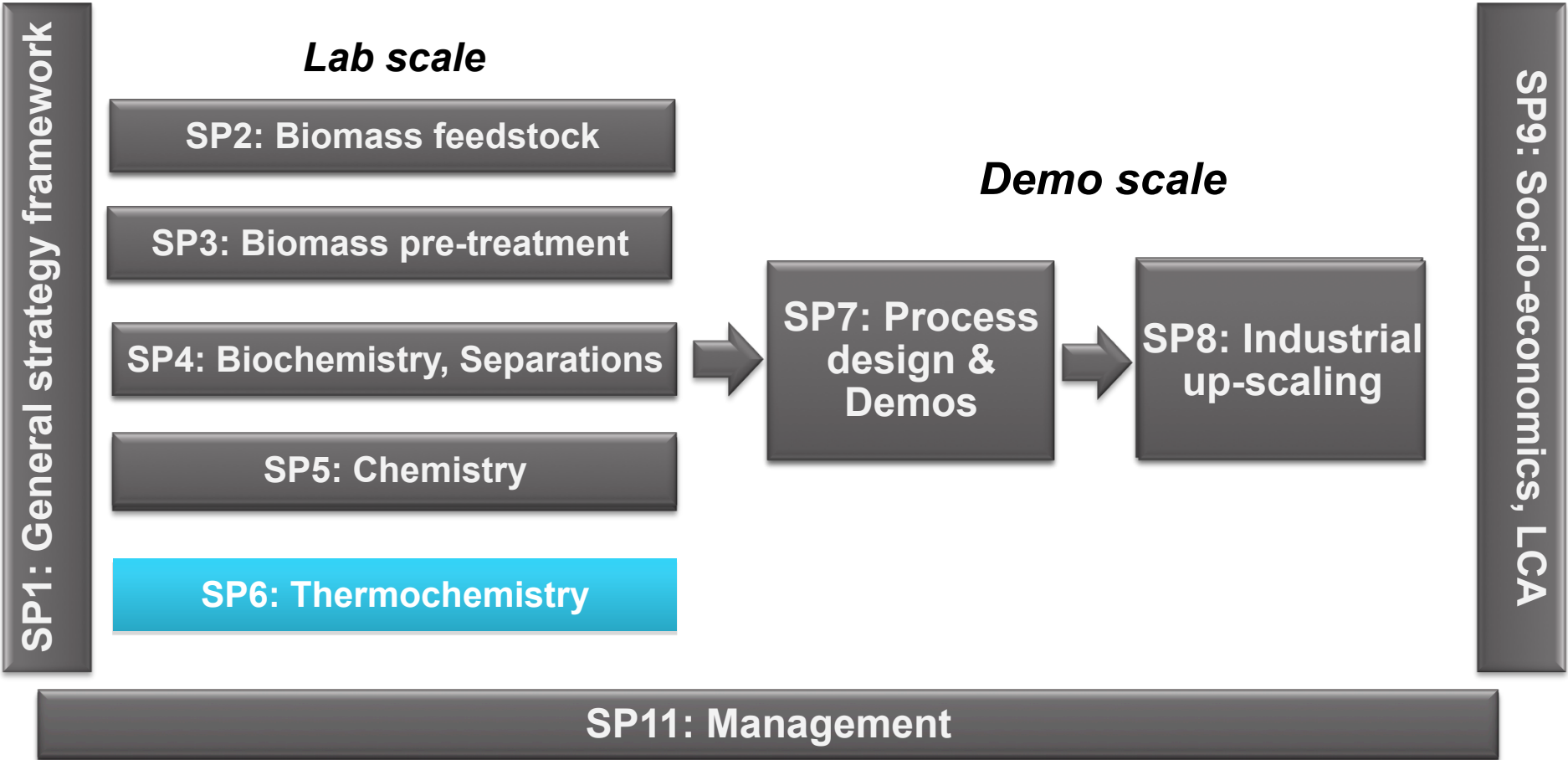
(54) Titre de la demande internationale: **Dispositif de production d'énergie**

(57) Résumé: **Le présent dispositif concerne un système de production d'énergie qui comprend un ensemble de cellules électrochimiques et un dispositif de distribution de réactifs.**

- 30 patent applications filed
- 9 demos selected and achieved in SP8
- Key technologies involved in 4 value chains

Some results of SP6

SP10: Exploitation, dissemination, communication, standardisation, training



Thermochemical treatment of biorefinery residues

Gasification

10+ biomasses assessed

Syngas
 $\text{CO} + \text{H}_2$

Power

**$\text{CH}_3\text{SH}, \text{H}_2\text{O}_2$
& HIGHER
ALCOHOLS**

Example of application: gas cleaning

Activated carbons production

30+ biomasses assessed

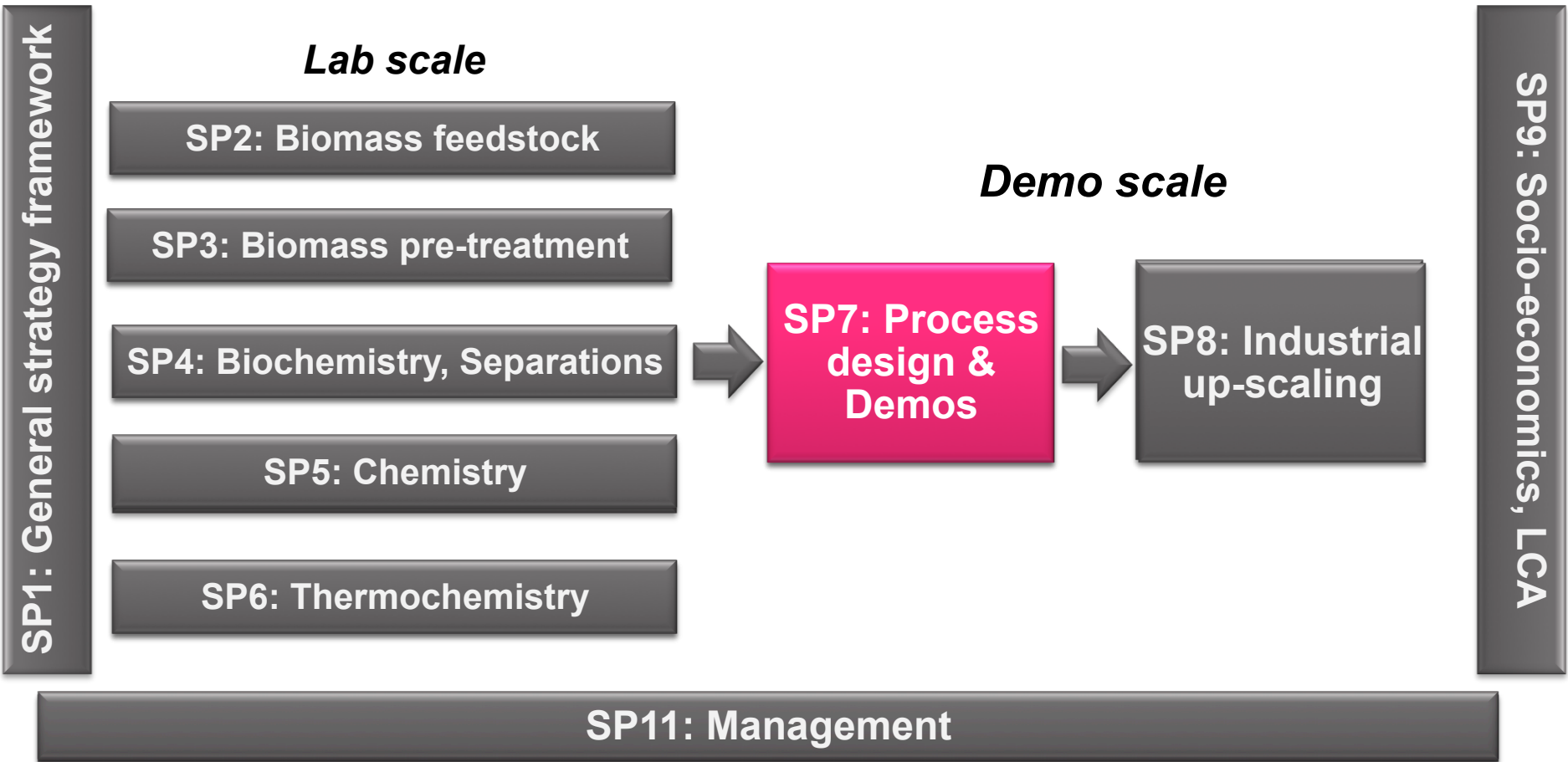
53 physically activated samples

110 chemically activated samples

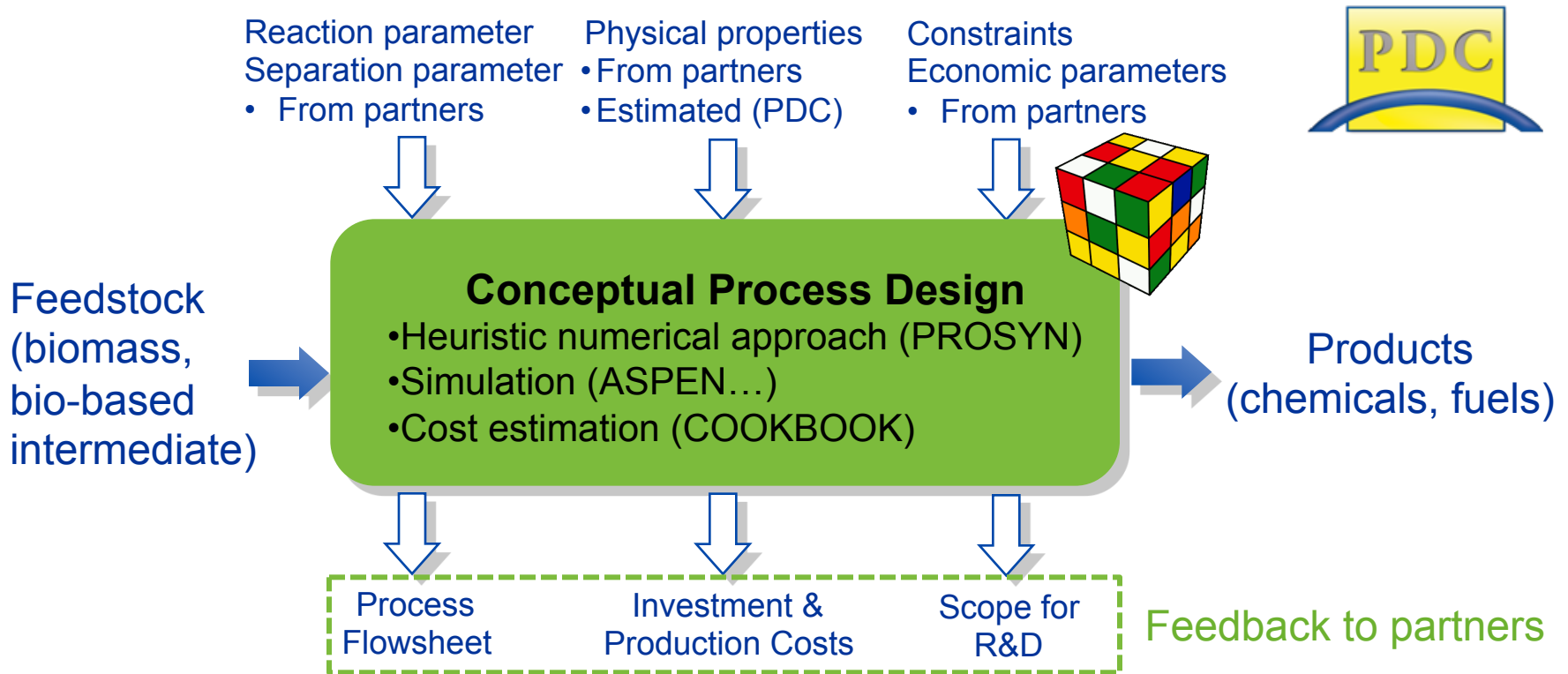
Up to $1900 \text{ m}^2 \cdot \text{g}^{-1}$

Some results of SP7

SP10: Exploitation, dissemination, communication, standardisation, training



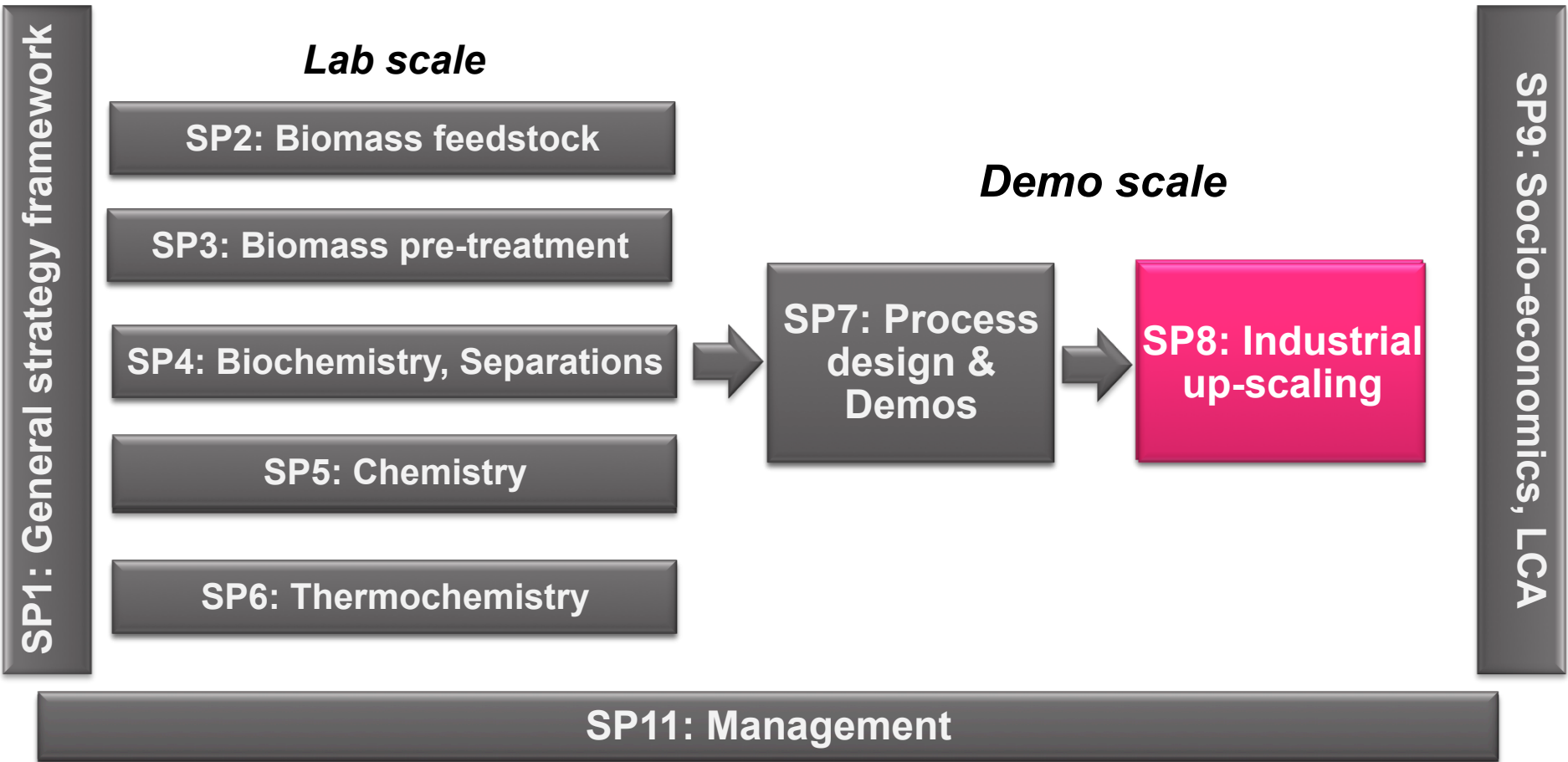
Conceptual process design and integration (+ demos)



- Individual processes in SP4-SP6 are designed (total 13)
- 6 value chains (each consisting of a series of processes) were evaluated

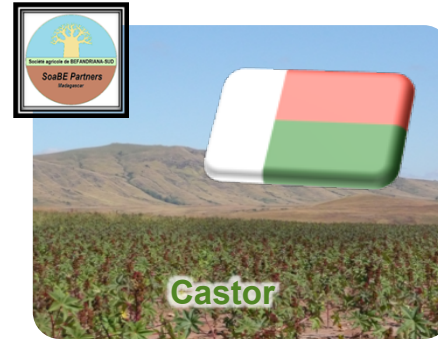
Some results of SP8

SP10: Exploitation, dissemination, communication, standardisation, training



Large test fields & primary refining

New large scale cultures established



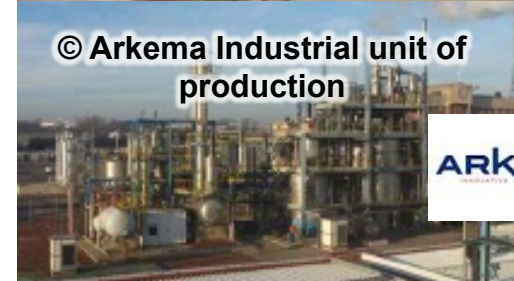
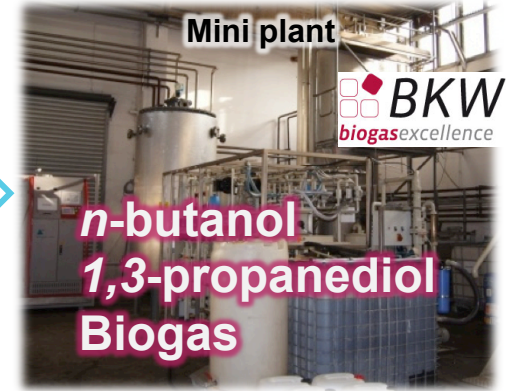
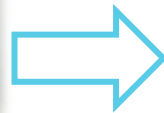
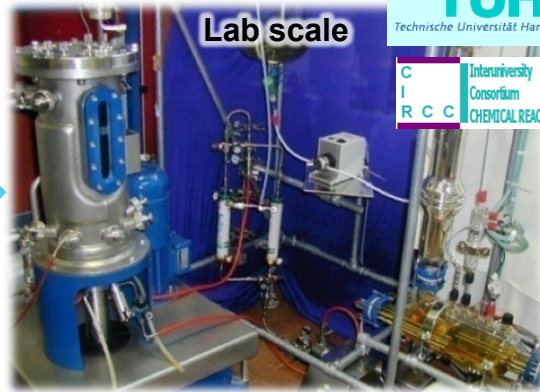
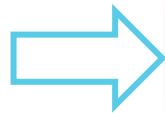
Fractionation demo unit building and operation



Oil seeds processing

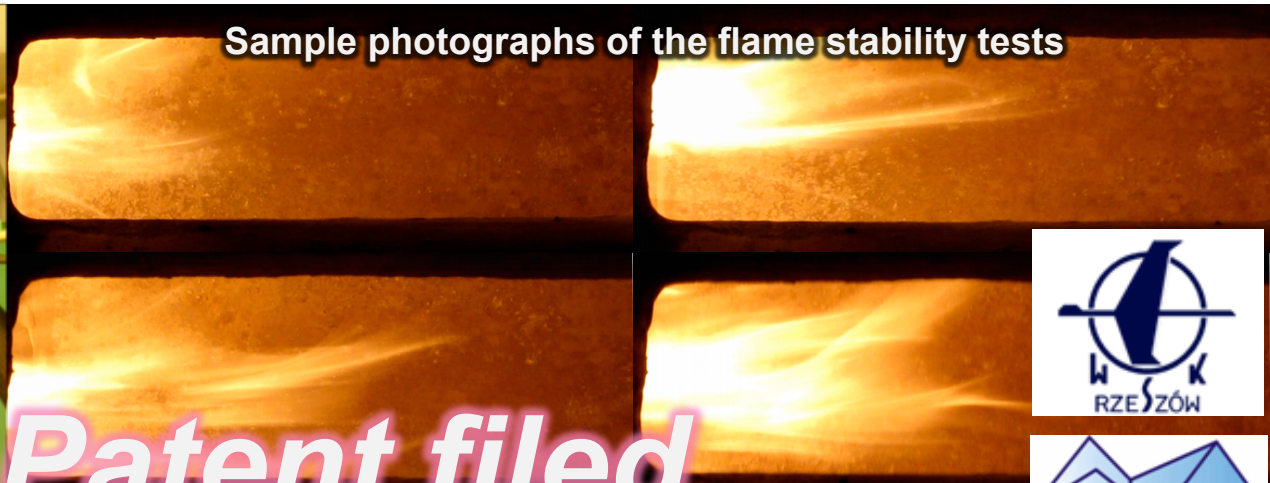


BIOTECHS & Chemistry

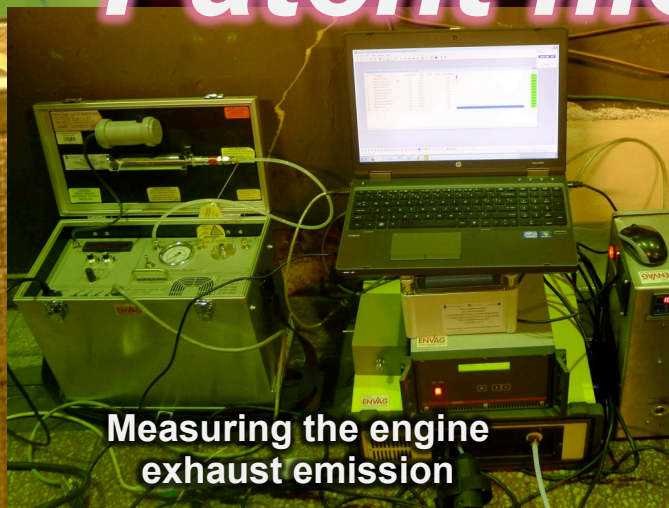


And a lot more products and derived products...

Aviation fuels (**15 m³** designed and successfully tested!)

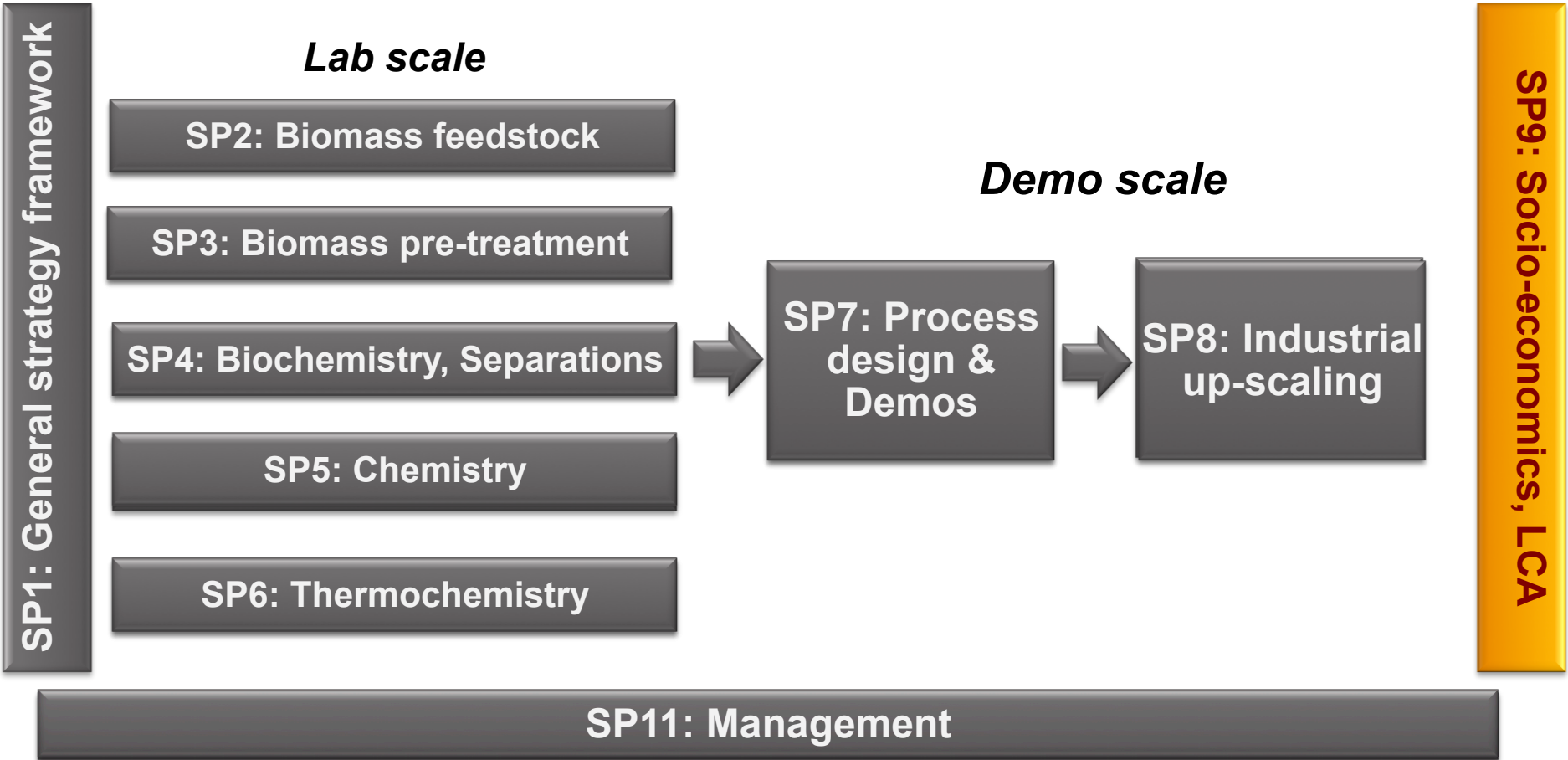


Patent filed



Some results of SP9

SP10: Exploitation, dissemination, communication, standardisation, training



Assessment of legal framework for EU biorefineries



Biomass & Renewable Energy

- Renewable Energy Directive, RED (2008)

- RED Sustainability requirements
- CEN draft sustainability standards for biomass

- Biomass Action Plan
- EIBI, SET-Plan, FP7,
- Lead Market Initiative

Feedstocks

- Common Agricultural Policy
- Waste Framework Directive (2008)

- Forest Stewardship Council
- FLEGT

- Forest Action Plan

Conversion processes

- EU Industrial Emissions Directive (2010)
- The REACH Directive (2006)

- Emission Trading System

End-products & markets

- Fuel Quality Directive (2009)

- CEN product standards
- ISO product standards
- Eco-labelling

- Green Public Procurement Policy

LCA methodology: Harmonised indicators

Download LCA methodology for biorefineries: <http://www.eurobioref.org/index.php/dissemination>

Endpoints



Resources



Climate change



Human health



Ecosystem quality



Water withdrawal



Midpoints

- Non-renewable energy use
- Mineral extraction

- Global warming

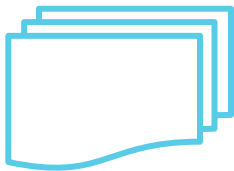
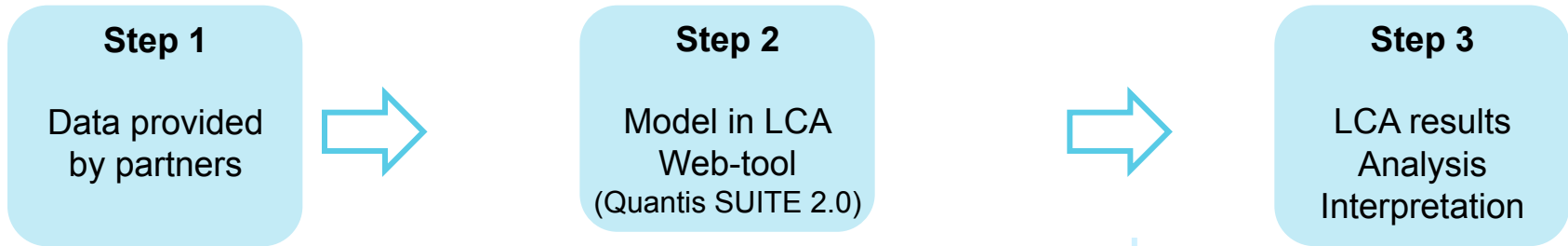
- Human toxicity (carcinogens and non-carcinogens)
- Ionizing radiation
- Respiratory effects
- Ozone depletion
- Photochemical oxidation

- Aquatic acidification
- Aquatic ecotoxicity
- Aquatic eutrophication
- Land occupation
- Terrestrial acidification/nitrification
- Terrestrial ecotoxicity
- Water turbid

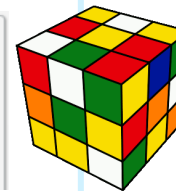
- Water withdrawal

Set of harmonised midpoint indicators (ReCiPe)

LCA approach in EuroBioRef: Approach



01.04. Fertilizers		
01.04.01. Fertilizers as N		
Urea	50	kg
urea, as N, at regional storehouse [kg] - RER (456)		
NPK (11-22-16), as N	13.75	kg
monoammonium phosphate, as N, at regional storehouse [kg] - RER (48)		



Assessment

Biomass

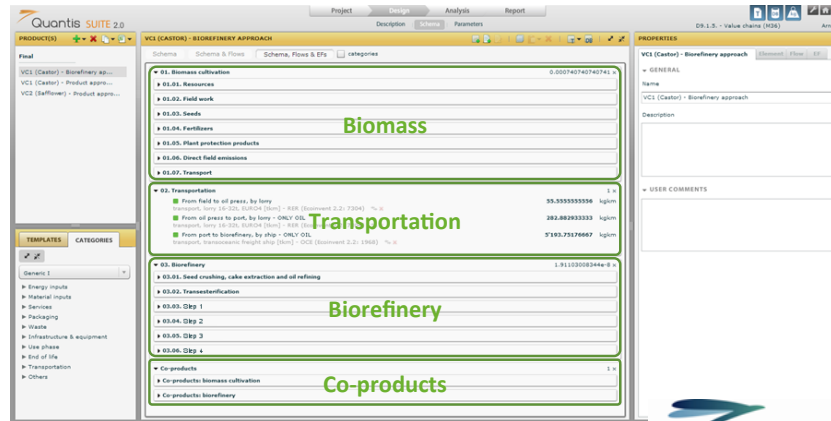
- Oil crop field trials
- Crop rotation field trials

Logistics

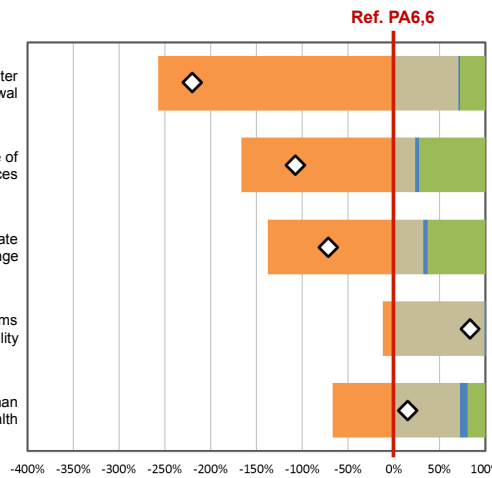
- Supply chain modelling

Processing

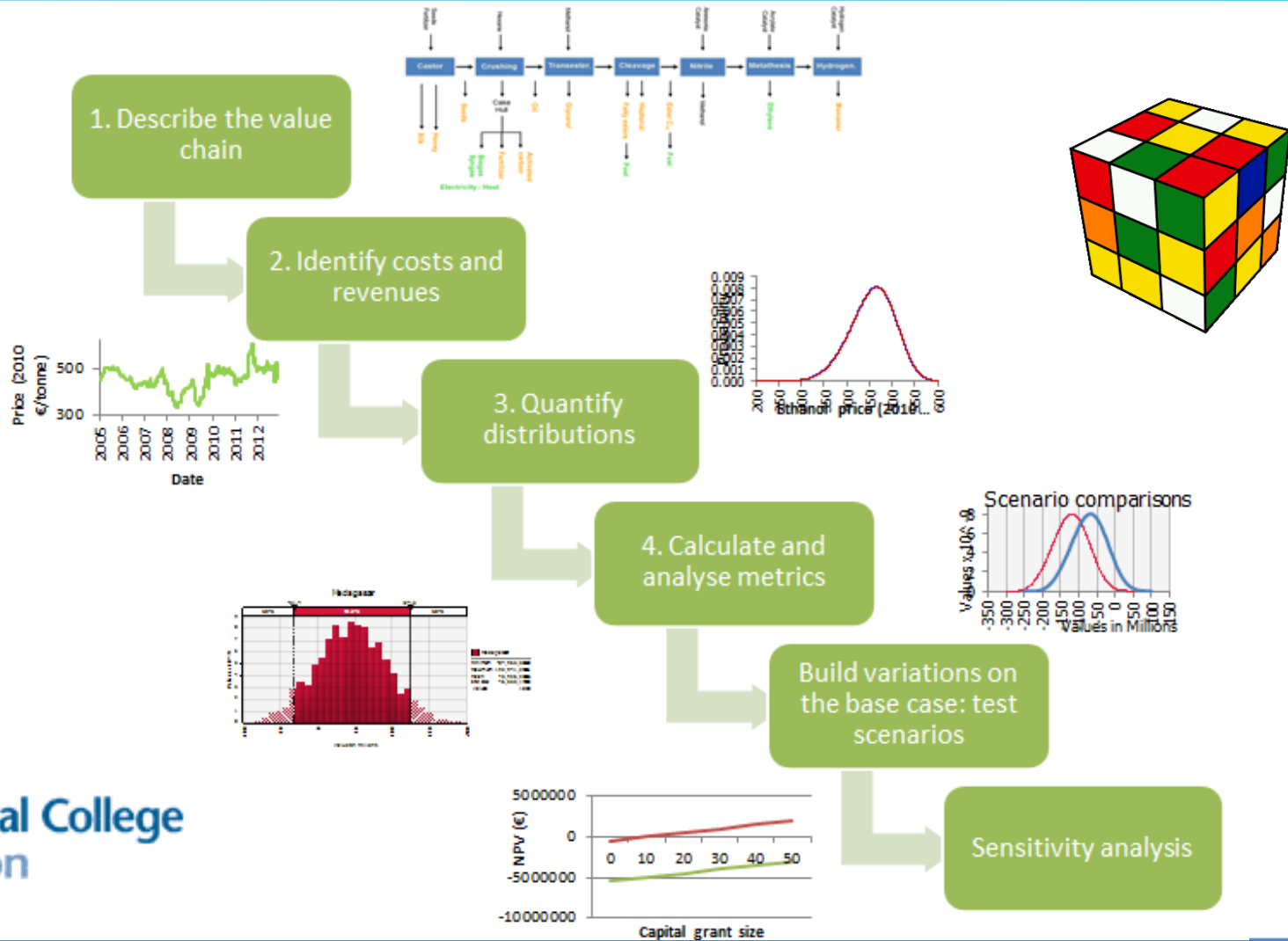
- Chemistry
- Process design
- Process integration
- Mass/energy balance



- Water withdrawal
- Use of resources
- Climate change
- Ecosystems quality
- Human health

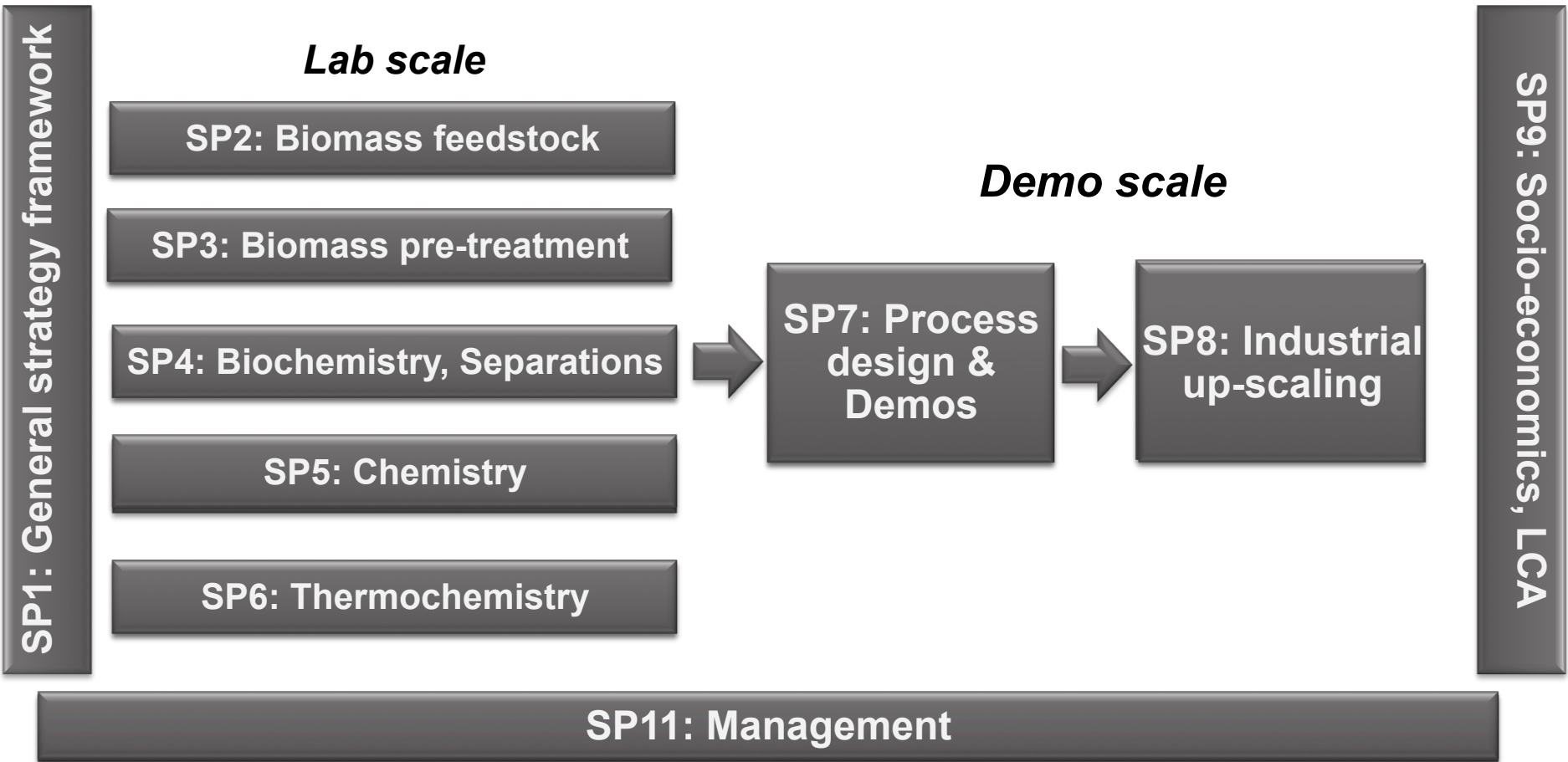


Cost modeling to assess future economic performance

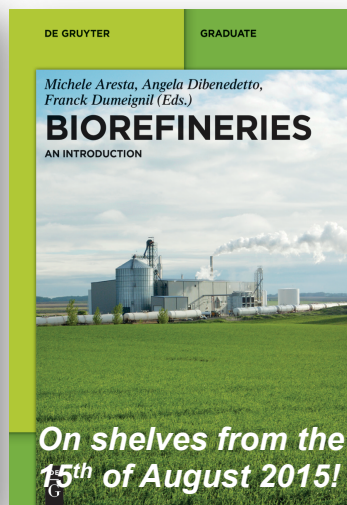
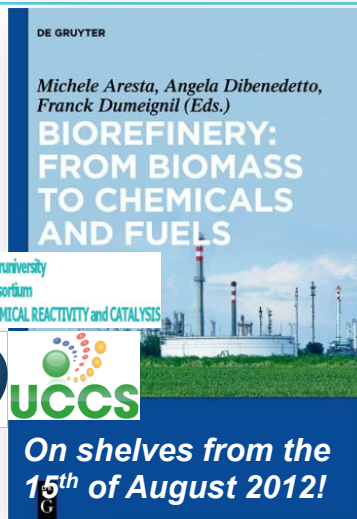


Some results of SP10

SP10: Exploitation, dissemination, communication, standardisation, training



Remarkable documents & videos



English version downloadable here:

http://eurobioref.org/documents/EuroBioRef_English.VOB



Booklet available at: <http://www.eurobioref.org>

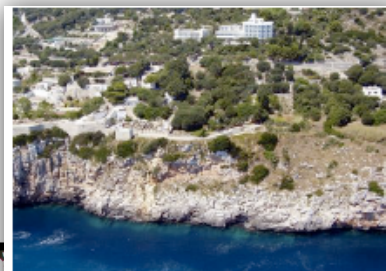


Video of results downloadable here:

<http://www.eurobioref.org/index.php/eurobioref-results>

Education & training

Summer School
“The concept of Biorefinery comes into operation”



September 18th-24th, 2011



Setting of a European master on biorefineries

European Master on Biorefineries



+ 10+ master courses...



Lecce, Italy
Participants: 80

+ Many other training actions...



Key dissemination figures

- **300+ communications in international congresses**
- **33 patents**
- **65+ scientific papers**

Conclusion

EuroBioRef's Achievements vs Objectives



Biodiversity

Produce and use a high diversity of sustainable biomasses adapted for European regions

High Energy Aviation Fuel

High specific energy bio-jetfuel (42 MJ/kg)

Produce Multiple Products (reaching TRL > 5)

(Chemicals, polymers, materials) in a flexible and optimised way...

Improve cost efficiency by 30%

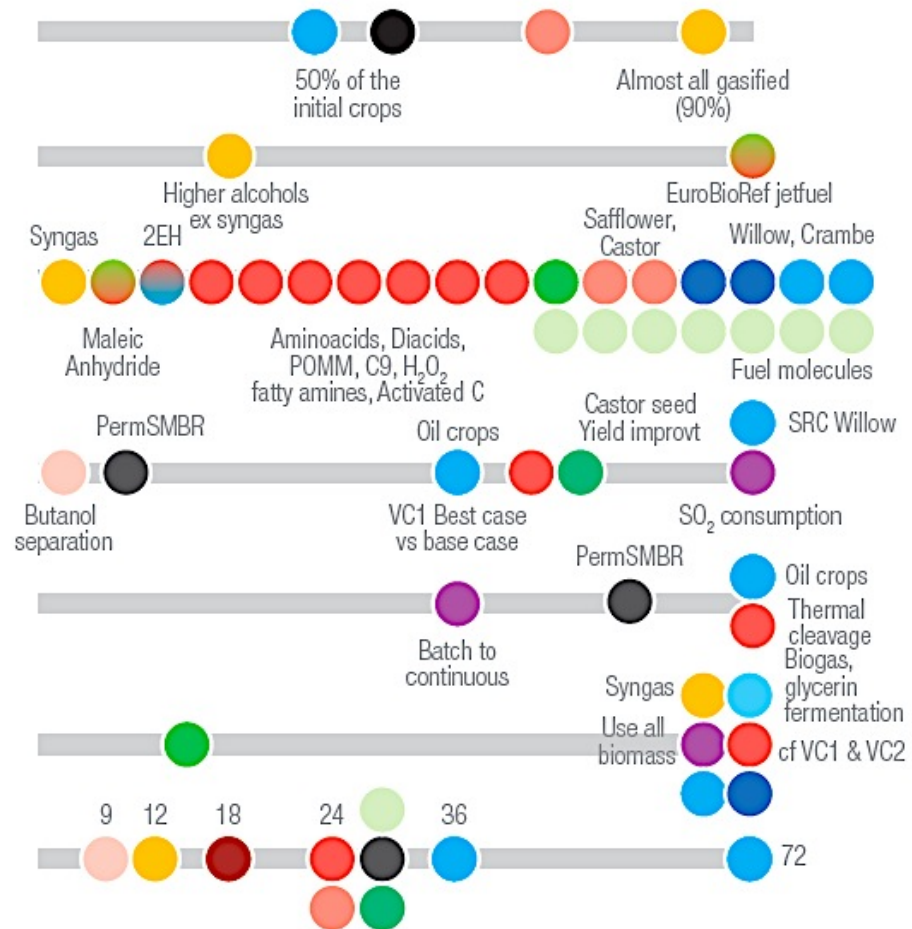
through improved reaction conditions and separation effectiveness, improved plant and feedstock flexibility, reduction in production time and logistics

Reduce energy consumption by 30%

Product zero wastes

and rationalize the use of raw materials

Reduce time to Market (month)

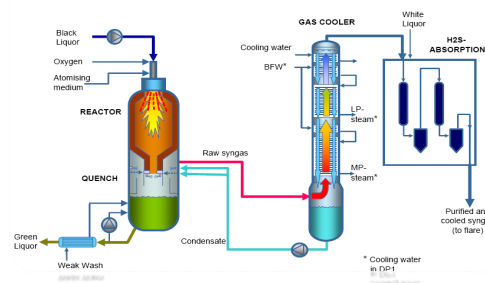


Common goal

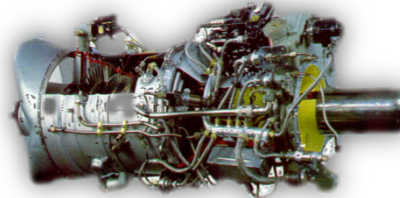
EUROpean Multilevel Integrated BIOREFinery Design for Sustainable Biomass Processing



DP-1: High Temp, O₂ blown Plant, Piteå, Sweden



Common Goal: Producing Aviation Fuels Blends as well as Chemicals



Acknowledgement

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 241718

