Tomorrow's biorefineries in Europe

Connecting Feedstock availability and Market opportunities. Case study on a Madagascar and a European Vegetable Oil Biorefinery.

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From Vegetable Oils to High Value Monomers

Castor

Safflower
Crambe

Meal

Straw/Hull

Oil Extraction

Refined Oil

Trans-esterificat.
+ Thermal
Cleavage

Hydrolysis

Conversion to Nitrile

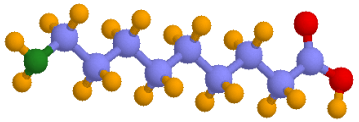
Cross Metathesis

Hydrogenation

Oxidative Cleavage

Conversion to Nitrile

HIGH
VALUE
Monomers
C9, C11,
C12, C13



Activated Carbon

N-rich Fertilizer

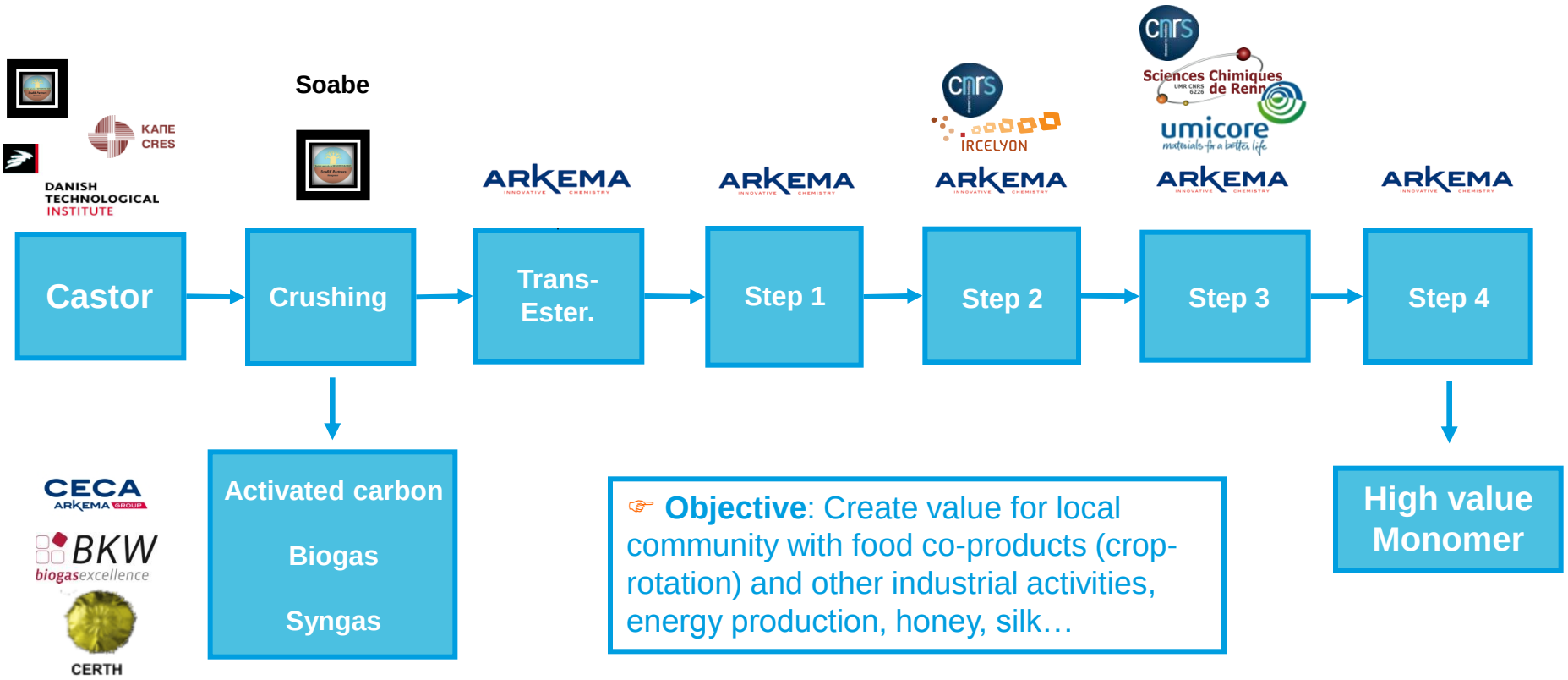
Gasification

Biogas

ENERGY

Compost /
fertilizer

Value Chain 1 : Castor – Case study



Oil crops : Rotation field tests

- **Madagascar**


Cowpea crop rotation test

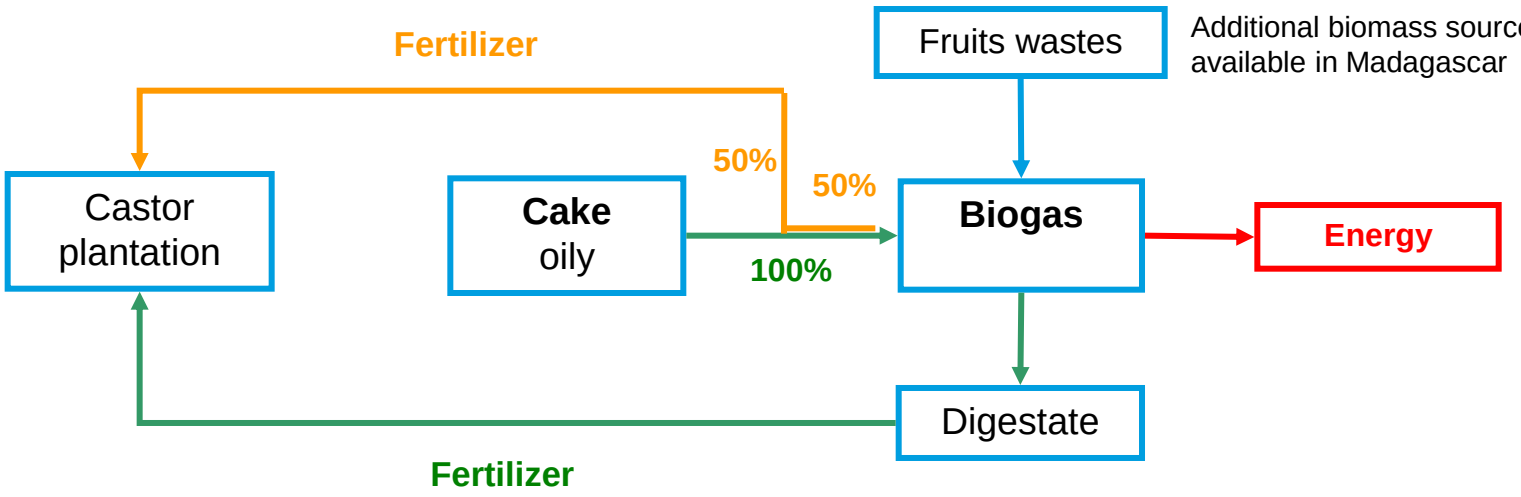

Corn crop rotation


Castor Production

- **Greece**


The oil crop rotation field (25.06.2012).

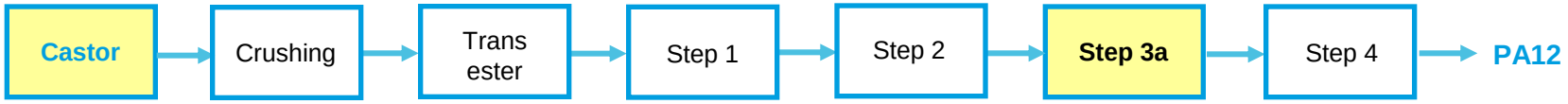
Biogas issue



- **2 options identified for cake valorization in fertilizer and biogas**
- **Interesting potential in Madagascar for local energy supply**
  - Cake (nitrogen source) to be used with other carbon sources such as fruit wastes
  - Feasibility of oily cake use to be confirmed

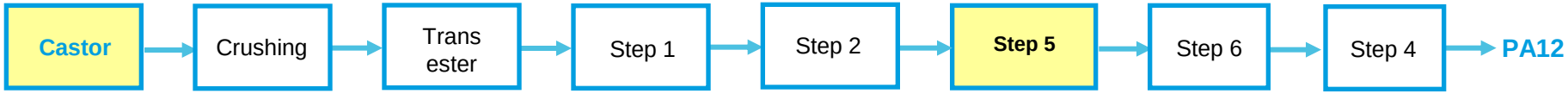
Castor → PA12 : Several Chemistries investigated

❖ **Chemistry A : Metathesis** – Base case



❖ **Chemistry B : Metathesis** – Best case → Less steps=Lower CAPEX

❖ **Chemistry C : Hydroformylation** → High TurnOver Numbers



❖ **Chemistry D : Oxidative cleavage** → No expensive catalyst

☞ **Benchmark of the different options : risks, IP, LCA, costs…**

Castor

Castor oil production and use

Castor oil exports map

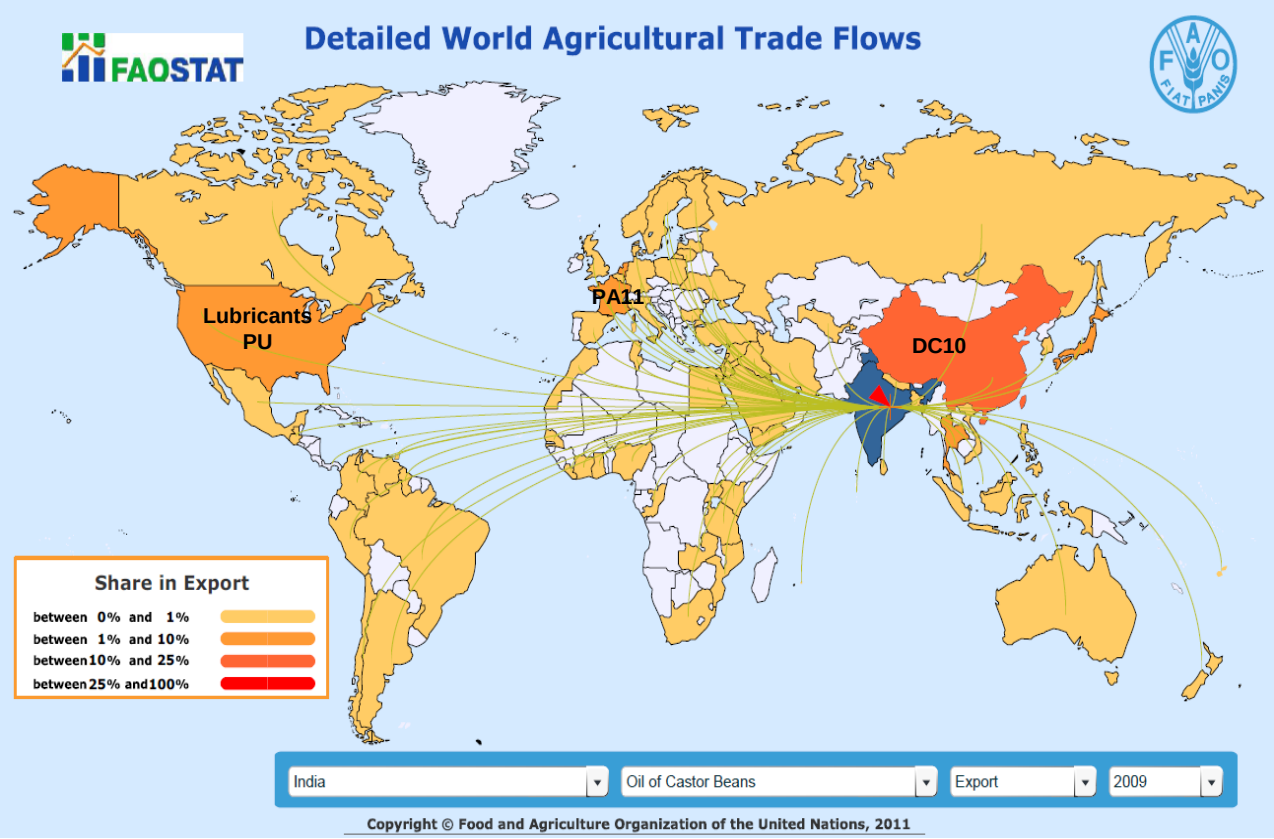
Castor oil production :

≈600.000T/y

≈80% India

+ China, Brazil

Price≈1200€/T



Uses :

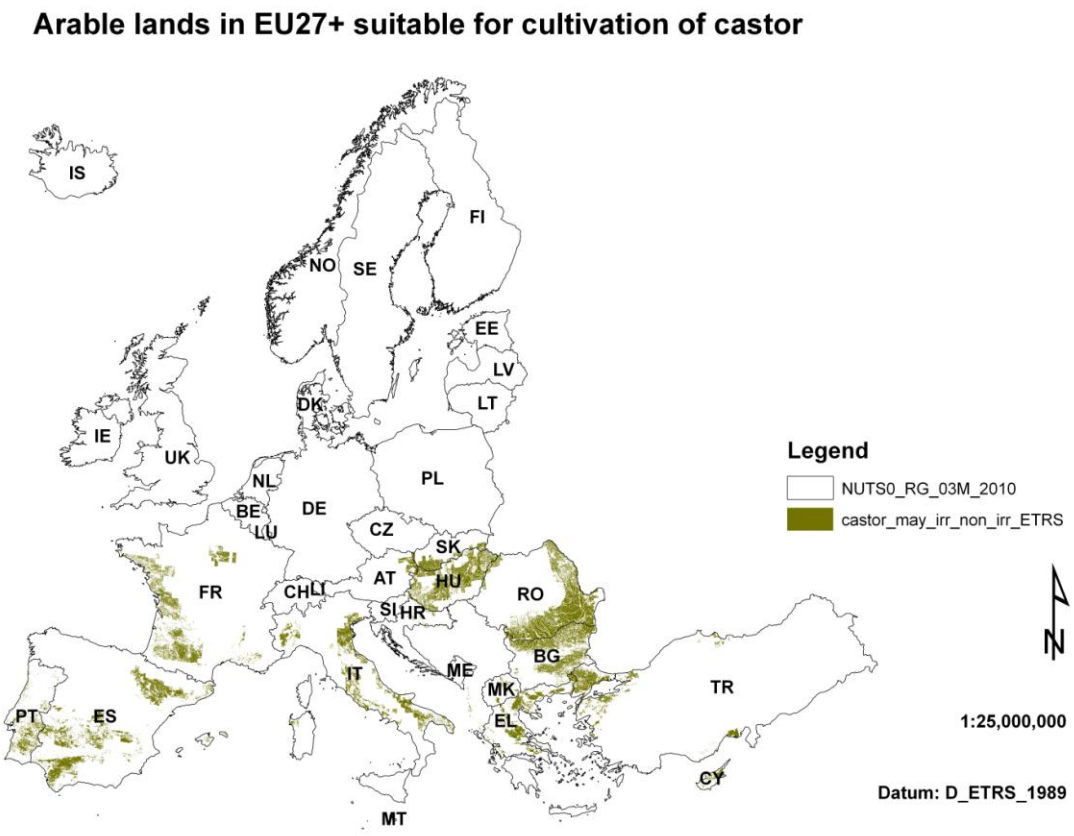
Lubricants

Polymers

(PU, PA, PE)

Cosmetics

Castor : Potential cultivation areas

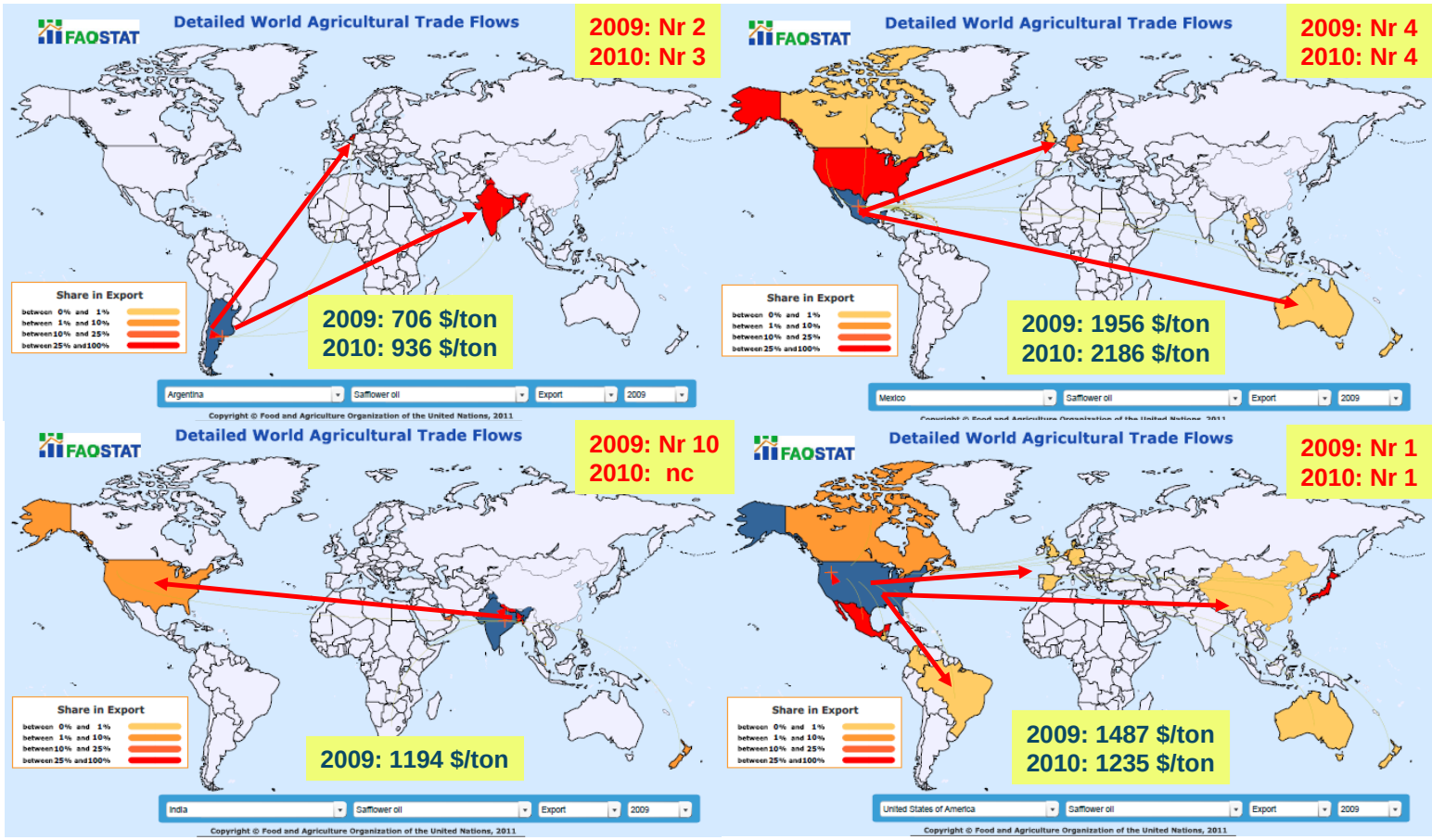


Map based on temperature during germination, precipitation during growing period, altitude, irrigated land, monthly average temperature, germination date

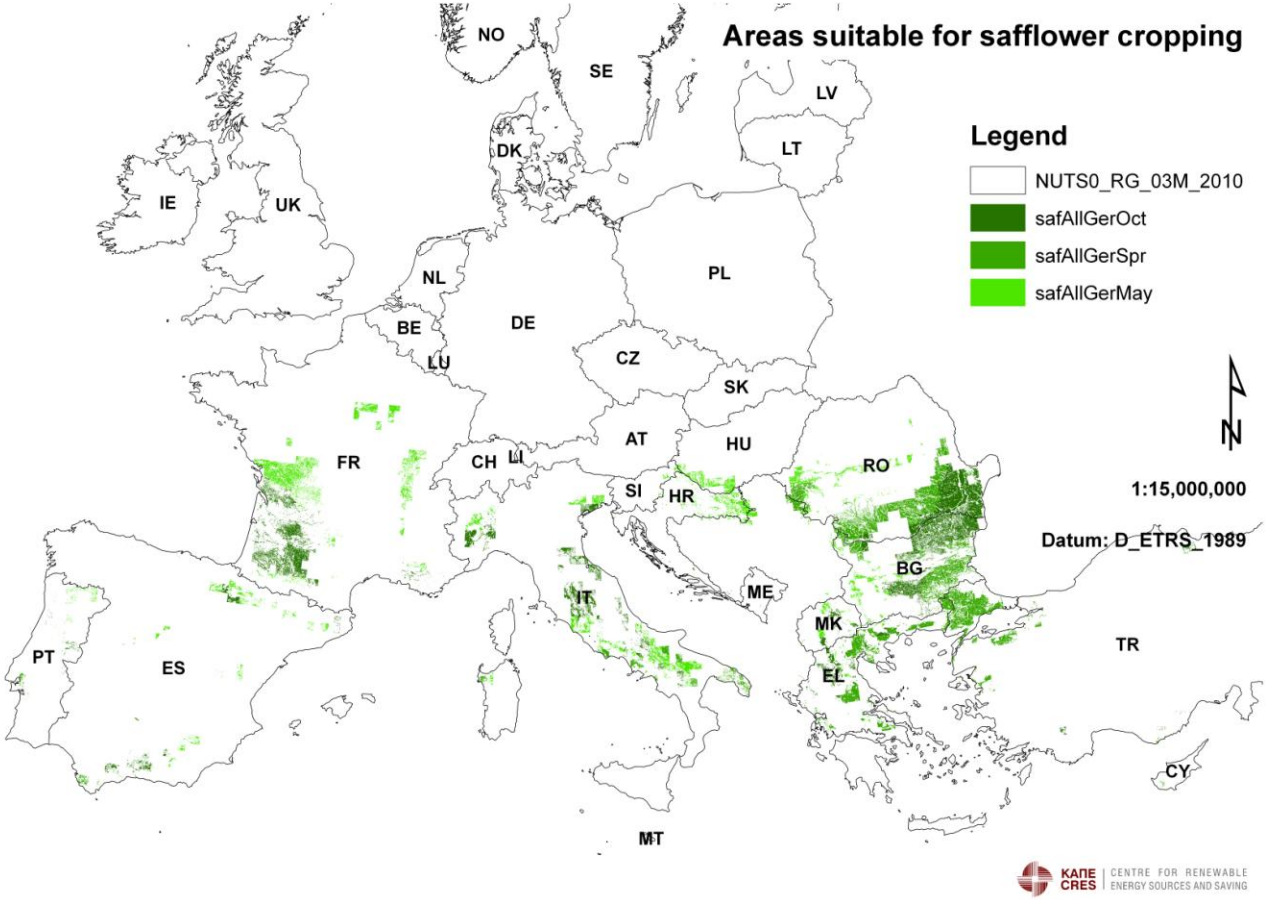
☞ Variety improvement program recommended

Safflower – VC2

Safflower oil trade



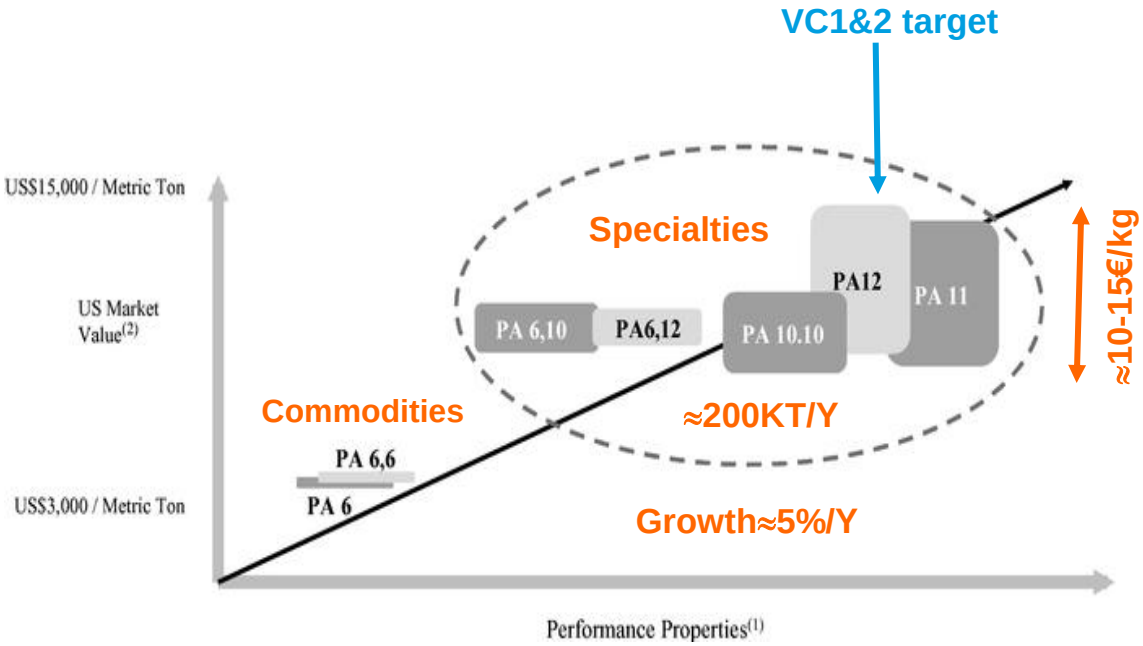
Safflower : Potential cultivation areas



Map based on temperature during germination, precipitation during growing period, altitude, irrigated land, monthly average temperature, germination date

Polyamides market

☞ Value / Performance



Source: Cathay Industrial Biotech Ltd., IPO F1 form, July 19th 2011

Main end-markets

Value Chain 1 – Castor to Polyamides

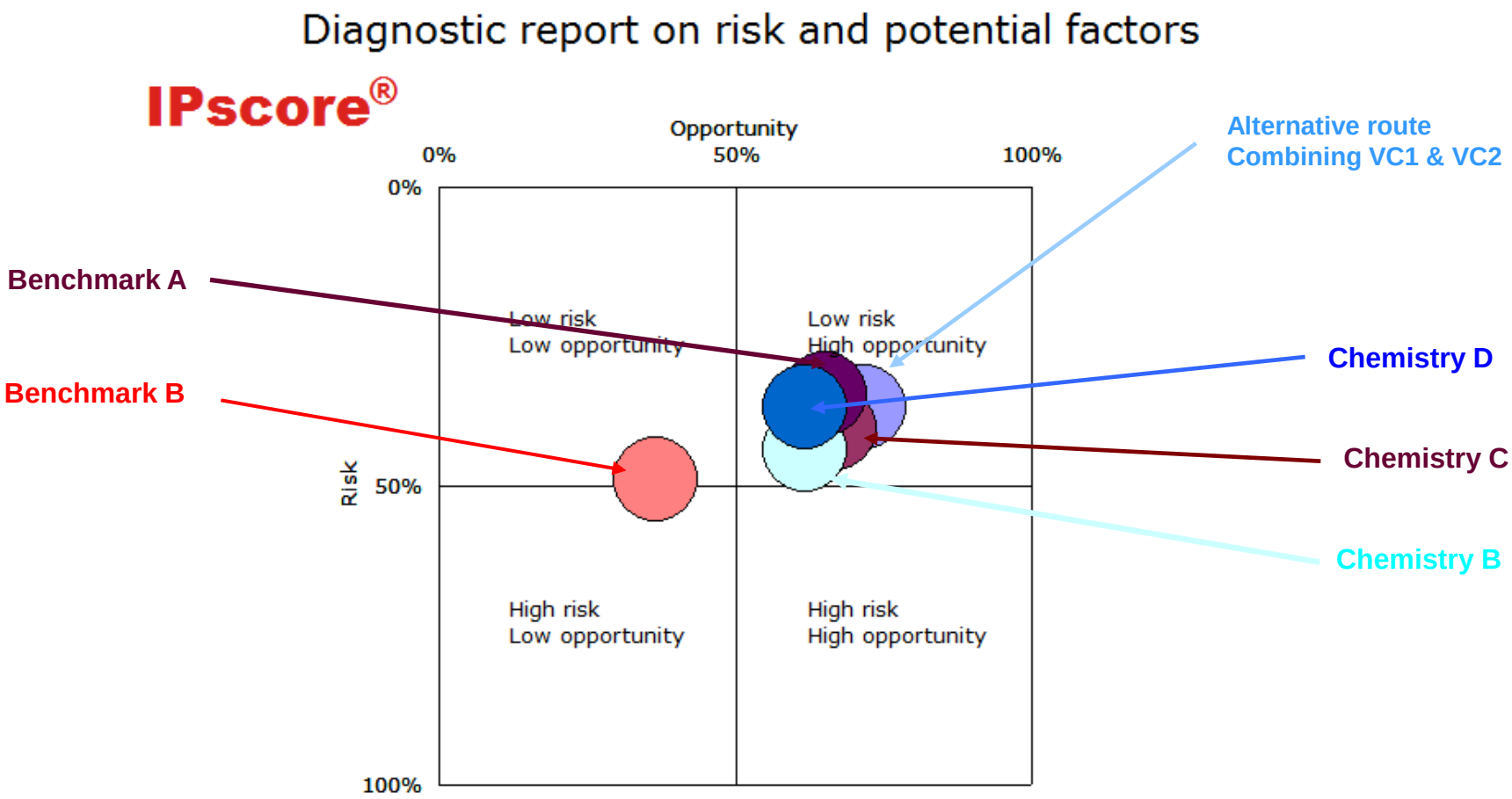
Technology Analysis

Risk - SWOT – IP Score – LCA – CAPEX - Jobs

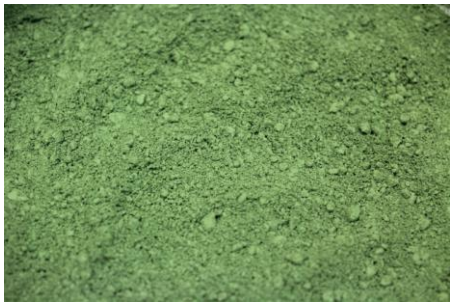
Value Chain 1 – Six Forces Analysis

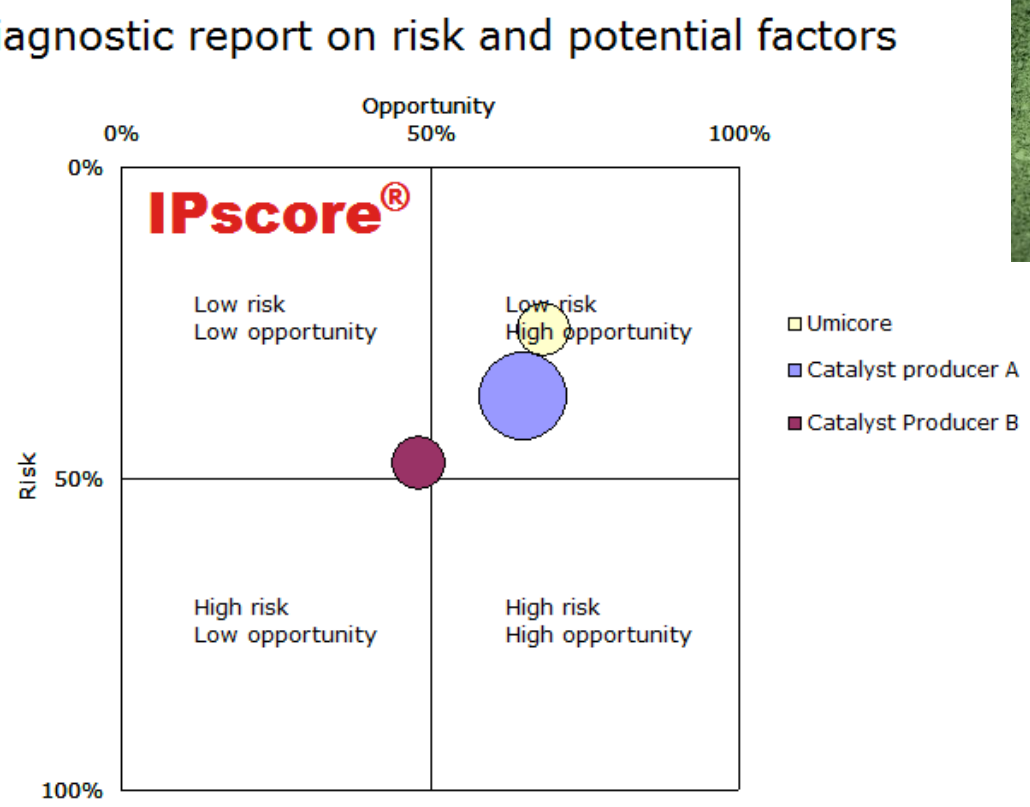
Category	Relative Power	Notes
Bargaining power of **Suppliers** (of Biomass)	**Medium**	Castor is mostly grown in India (80 % of world production). Current producers are now well organize and control the production volume and price. There is an opportunity to create some competition, in generating a new value chain.
Bargaining Power of **Customers** (of chemicals & fuels)	**Medium**	Long chain Polyamide market, is growing. The customers are mostly looking for technical properties, such as in application where polyamides can replace metals. They can chose between fossil based and bio-based materials, but will prefer highest technical properties, which is currently delivered by bio-based materials.
Threat of **New Competitors**	**Low**	Castor oil can be produced in Brazil, China and several other places, but needs expertise. Long chain polyamides are highly technical products, and current processes are capital intensive. Products have to be certified by the customer in a long process.
Threat of **Substitute Products** or services	**Medium**	Currently there are no possible substitute for castor oil, although there are some research on GMO crops, producing ricinoleic acid. Polyamide could be substituted by other products with higher properties, but this would take a very long time. There are more threats of substitution by other polyamides.
Competitive **Rivalry**	**High**	Polyamide production is a well established and capital intensive process. Existing technology is well established as large scale plants, but it is difficult to replicate the existing processes at small scale.
Stakeholders: Government / Public	**High**	Public is favoring renewable products. Government can positively favor renewable products (Bio-Preferred) and Biofuels, through subsidies, Non Governmental Organization should see positively the potential of economic development for African countries proposed by the Value Chain 1

IP score – Competition benchmark

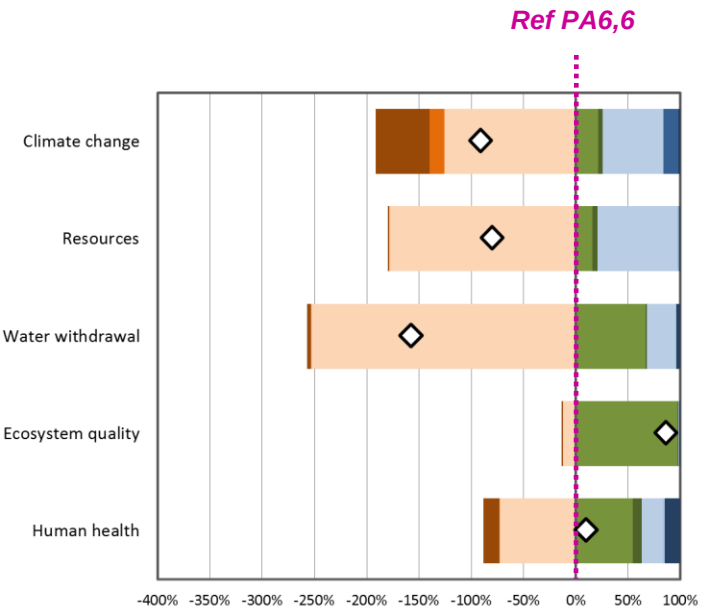


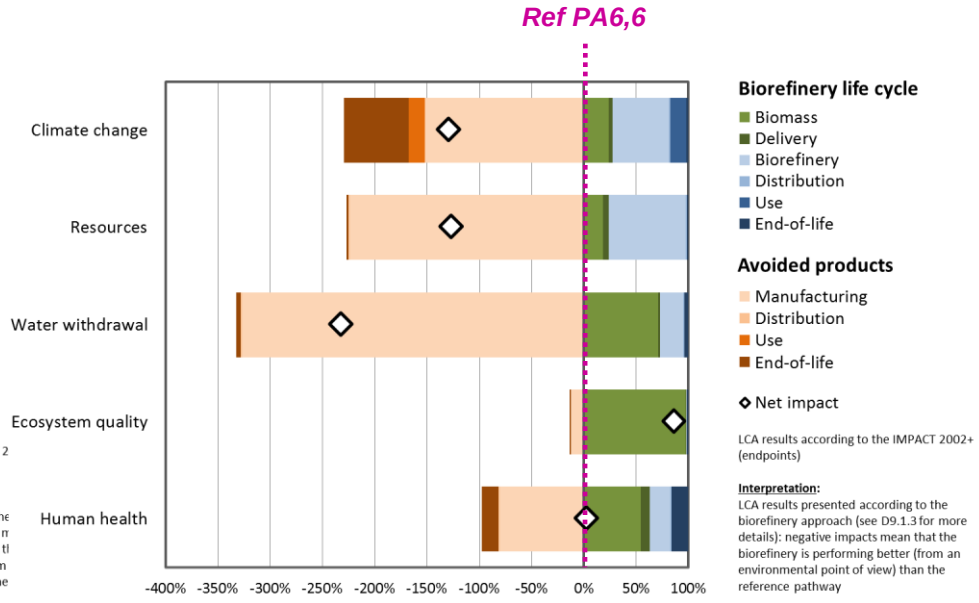
IP score – Metathesis catalysts





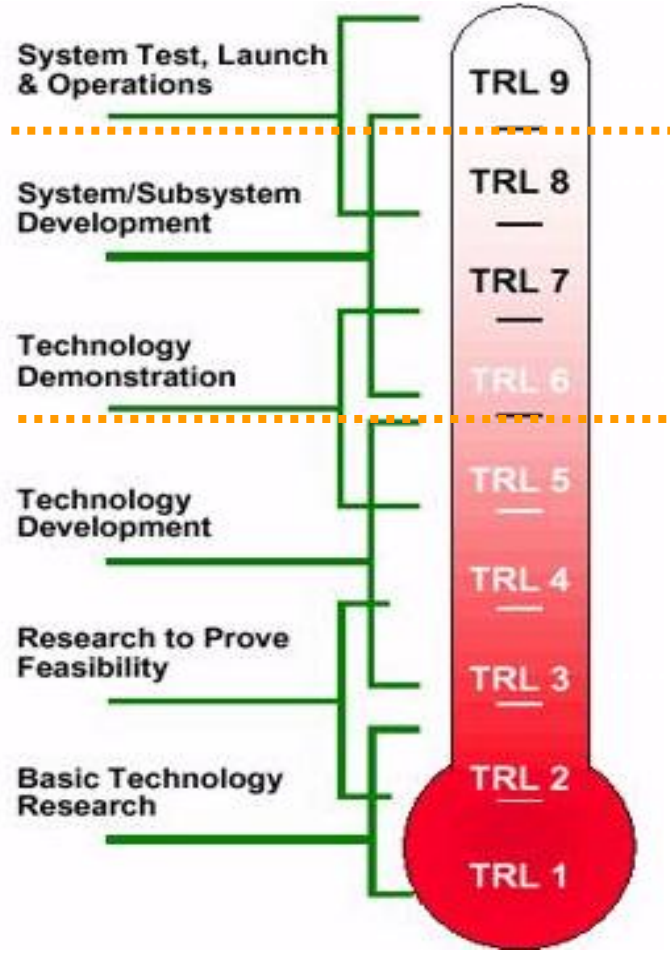
LCA : Castor→PA12





Chemistry A - base case ⇒ **Chemistry B – Best case**

TRL evaluation : Castor→PA12



Castor – Crushing – Transesterification – Step 1

Castor (Madagascar)

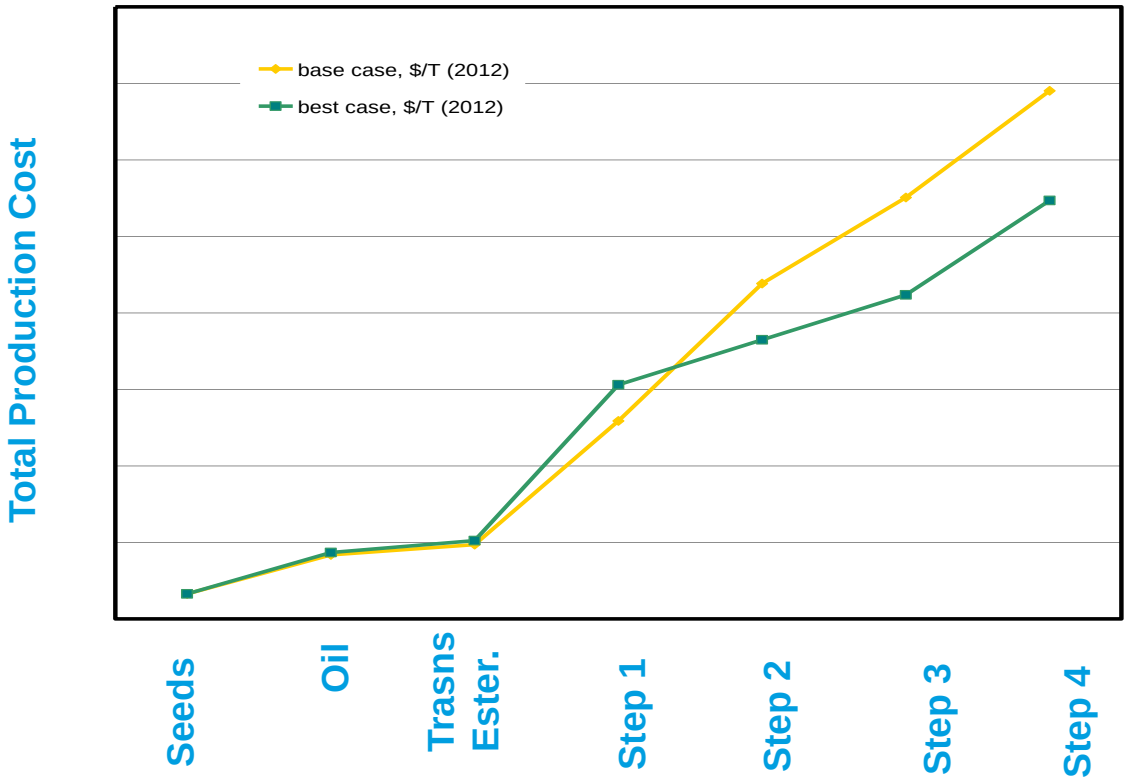
DEMO

Step 1 (improved) – Step 2 - Step 3a/3b – Step 4 - Step 9

Step 3c ·····▸ **Alternative scenario in progress**

Production costs : Castor→PA12

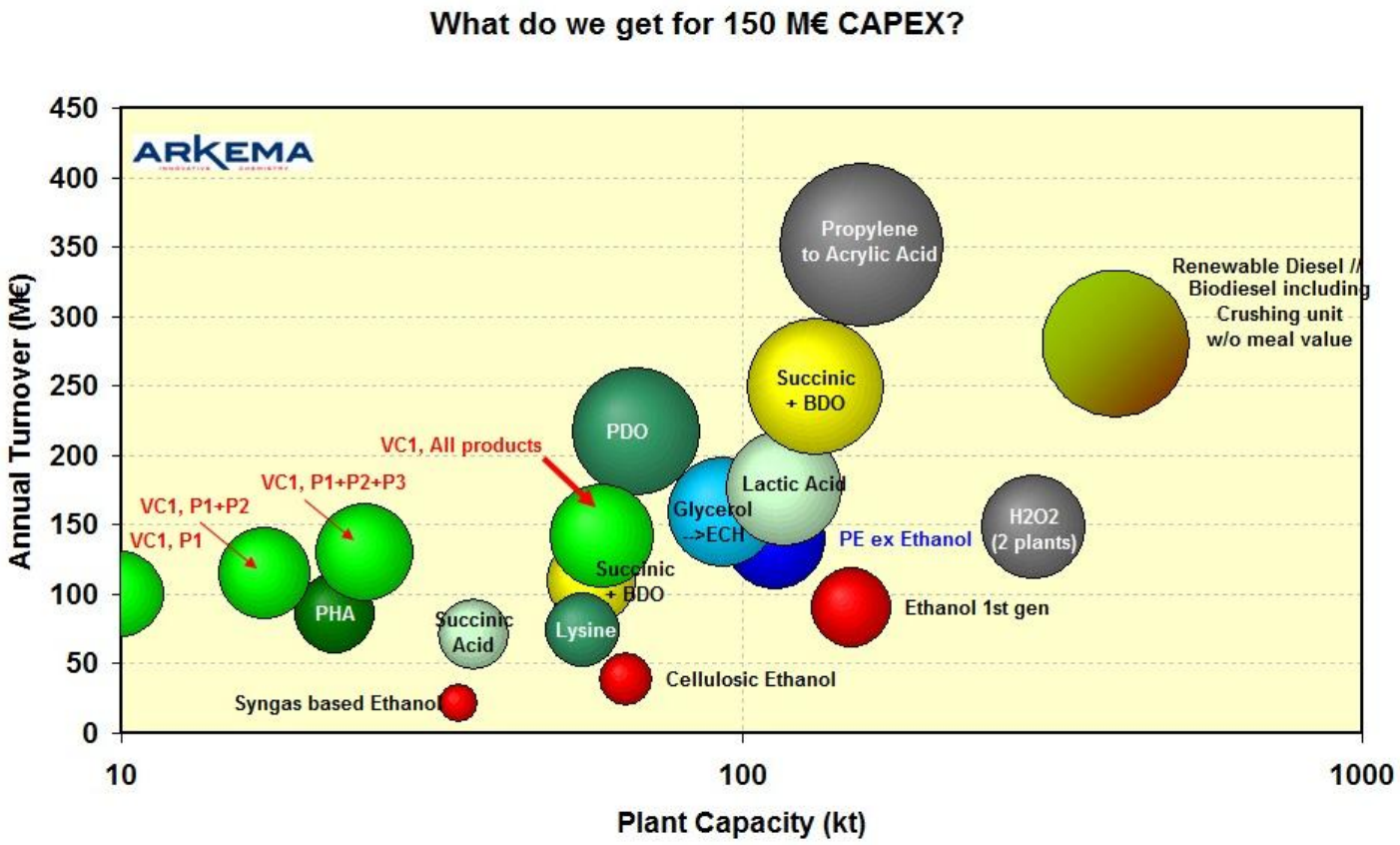
From base case (chemistry A) to best case (chemistry B)



21 %
cost reduction

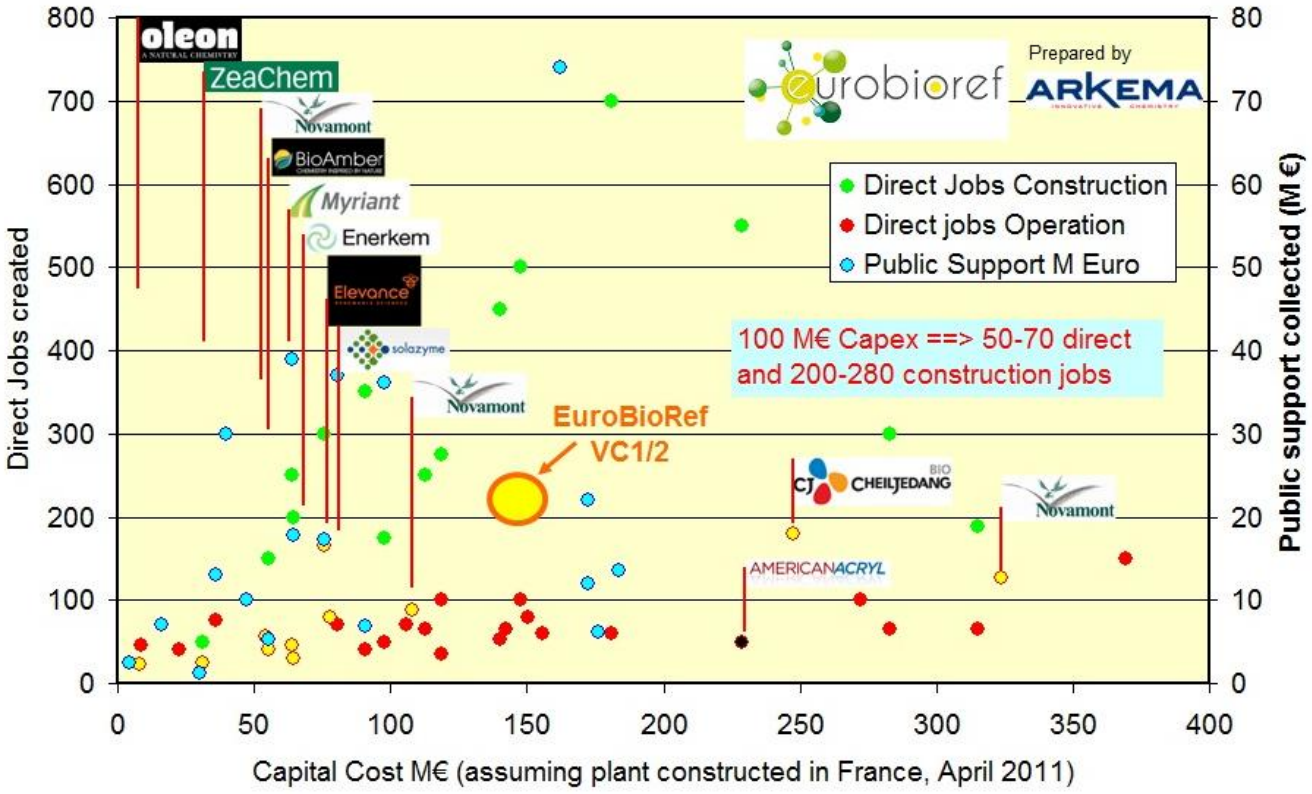
- **20% saving** achieved from **base case** to **best case**
- **Step 1** critical step for cost reduction

Capital Cost Impact



Plant assumed to be built in France, overnight in 2011, Data based on plants announced in literature
Extrapolation factors assumed to be 0.65 for Chemical plants and 0.85 for Fermentation processes

Jobs creation



Analysis of Biobased projects announced and completed
Public support is not related to number of jobs created.

Conclusion – VC1&2 summary

Market Need, Opportunity & Impact

Market **demand** and **growth** for renewable **high performance polyamides**

Main **end markets** : automotive, energy, consumer goods, lubricants, cosmetics…

Opportunity to **reduce CO_2 emissions** in transportation with metal substitution by lightweight polyamides
(100 kg weight saving → -0.35 L fuel/100km → -9 g CO2/km)

Technology

Castor → Seeds → Oil → Transesterification → → → Polymerization → **PA12**
Safflower/Crambe → Seeds → Oil → →→ Polymerization → **PAs**

Meal/Hull → fertilizer, activated carbon, energy (biogas)

Energy ←→ biogas (electricity, heat) , fatty esters (road fuel), jatropha oil (crushing)

Business Model & Commercial applications

Castor seeds & oil (Soabe), meal & fertilizers (Soabe, BKW), crambe & safflower oil, electricity/heat (BKW), activated carbon (CECA), catalyst (Umicore), PA (Arkema)

Seeds (Madagascar, Europe) → Oil (crushing unit, Europe) → PA (customers – Europe)

Interest Group : fuel company (road fuel)

Technology Development Level (TRL)

8 new technologies at **TRL=6** or more (pilot) at the end of the project

Castor (Madagascar), Crambe (Poland), Safflower (Greece) thermal cleavage, metathesis, oxidative cleavage, hydrogenation, fatty esters (biodiesel)

Castor based PA12 sample

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Thanks for your attention…