4FCrops Workshop
Madrid, 24 March 2009

BIOCARD Project

'*Global Process to Improve Cynara cardunculus Exploitation for Energy Applications*'

Project Background

- Specific Targeted Research Project (STREP)
- EC - FP6 under the objective SUSTDEV-2004-1.2.5
- Contract nº 019829
- 13 partners of 7 countries
- Starting date: 01/09/2005
- End project date: 30/11/2008
- General Budget:
  - Total budget → 3.944.829 €
  - Total funded → 2.499.997 €

Project Consortium

Participant Role *	Participant Number	Participant name	Participant short name	Country
CO	1	Tecnatom, s.a.	TECNATOM	E
CR	2	Universidad Politécnica de Madrid	UPM	E
CR	3	Instituto Sperimentale per la Meccanizzazione Agrícola	CRA-ISMA	IT
CR	4	ICP-CSIC	ICP-CSIC	E
CR	5	Fundación GAIKER	GAIKER	E
CR	6	QUEEN´S UNIVERSITY BELFAST	QUB	UK
CR	7	UNIVERSITA DI BOLOGNA (DICMA)	UNIBO	IT
CR	9	Fundación CIRCE – Centro de Investigación de Recursos y Consumos Energéticos	CIRCE	E
CR	10	Technical University of Denmark	DTU	DK
CR	11	VTT	VTT	FI
CR	12	ENDESA Generación S.A.	ENDESA	E
CR	13	MAN B&W	MAN B&W	GE

Objectives (I)

- The overall objective is to demonstrate the economical and technical viability of a global process to improve *Cynara cardunculus* exploitation for energy applications
- Research areas:
  - Crop management
  - Mechanization of the harvest
  - Conversion technologies for thermal applications
  - Conversion technologies for liquid biofuels

PROJECT STRUCTURE

WP1. Energy crop management and harvesting (UPM, CRA-ISMA, CIRCE, TECNATOM)

WP2. Biomass valorization for energy conversion (CIRCE, VTT, DTU, ENDESA)

WP3. Cynara seeds valorization for energy conversion (GAIKER, UPM, ICP-CSIC, UNIBO, QUB, MAN)

WP4. Overall technical and economical evaluation. Feasibility study (TECNATOM, UPM, CIRCE, GAIKER)

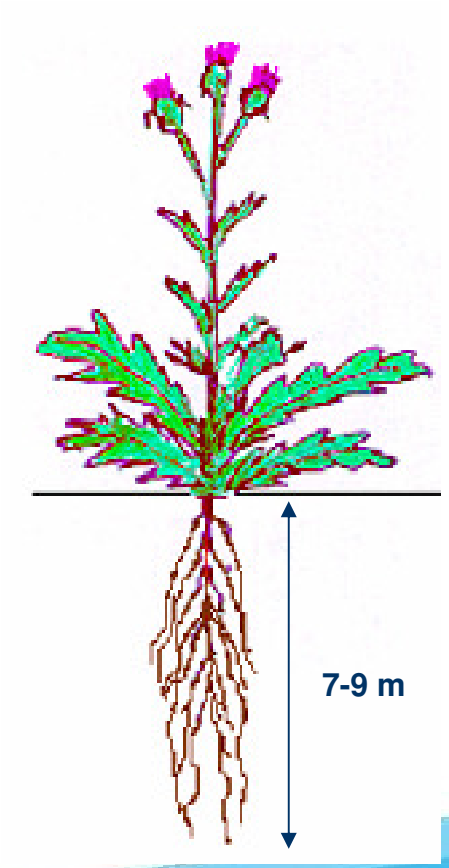
WP5. Dissemination and exploitation (All)

WP1- ENERGY CROP

Cynara cardunculus L.

- Asteraceae (Compositae)
- Mediterranean origin
- Perennial herb
- Annual growth cycle
- Very deep root system
- Floral stem 2-3 m high
- Gross heads (capitula)
- Lilac-violet florets
- Oil fruits (achenes, like sunflower)
- Common names:
  - CARDOON (vegetable)
  - CYNARA (energy crop)

ECOPHYSIOLOGICAL CHARACTERISTICS OF CYNARA CROP



- **Photosynthesis capacity during wintertime**

  At 5ºC the average CO_2 assimilation rate observed was of the order of 6 $\mu mol.m^{-2}.s^{-1}$ (about 30 % of full capacity at 25 ºC)

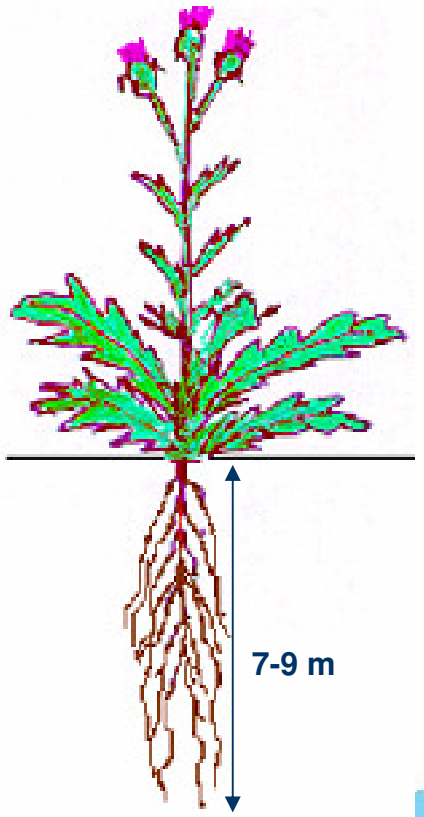
- **10-month period of active biomass growth**

  The root system accumulates carbohydrates like inulin from autumn to late spring; in summer they are translocated to the floral stem

- **High efficiency in fertilizers uptake**

  The deep root system prevents loss of fertilizers by lixiviation and cleans euthrophicated soils.

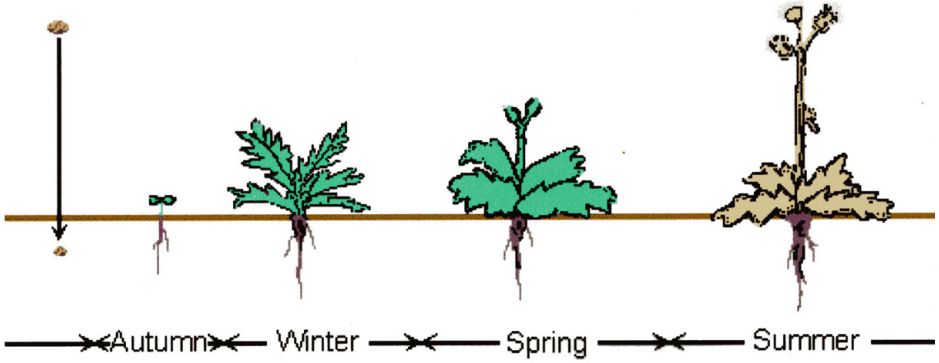
ECOPHYSIOLOGICAL CHARACTERISTICS OF CYNARA CROP



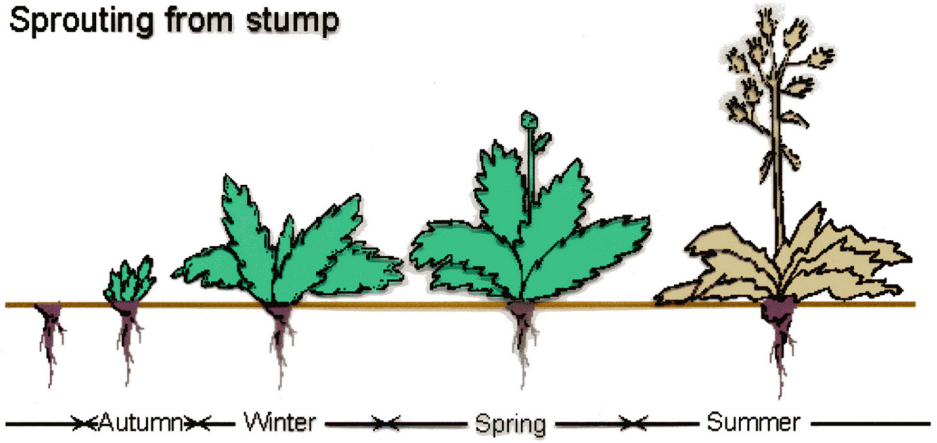
Adaptative mechanisms for dry conditions:

- **Very deep root system**
  that allows the use of water fallen in autumn, winter and spring.
- **In summer the aerial part dries**
  but the buds in the base of the stem remain alive and sprout in early autumn
- **Moderate salinity resistant**
  by osmotic adjustment by inorganic ions (Na^+ and K^+)

Sprouting from seed



Sprouting from stump



Establishment of the crop

(1st growth cycle)

Standard productive cycle

(2nd & following growth cycles)

PLANTLETS (autumn)

ROSETTE (winter)

ELONGATION (spring)

BLOSSOM (±June)

DRYING (August)

SPROUTING (September)

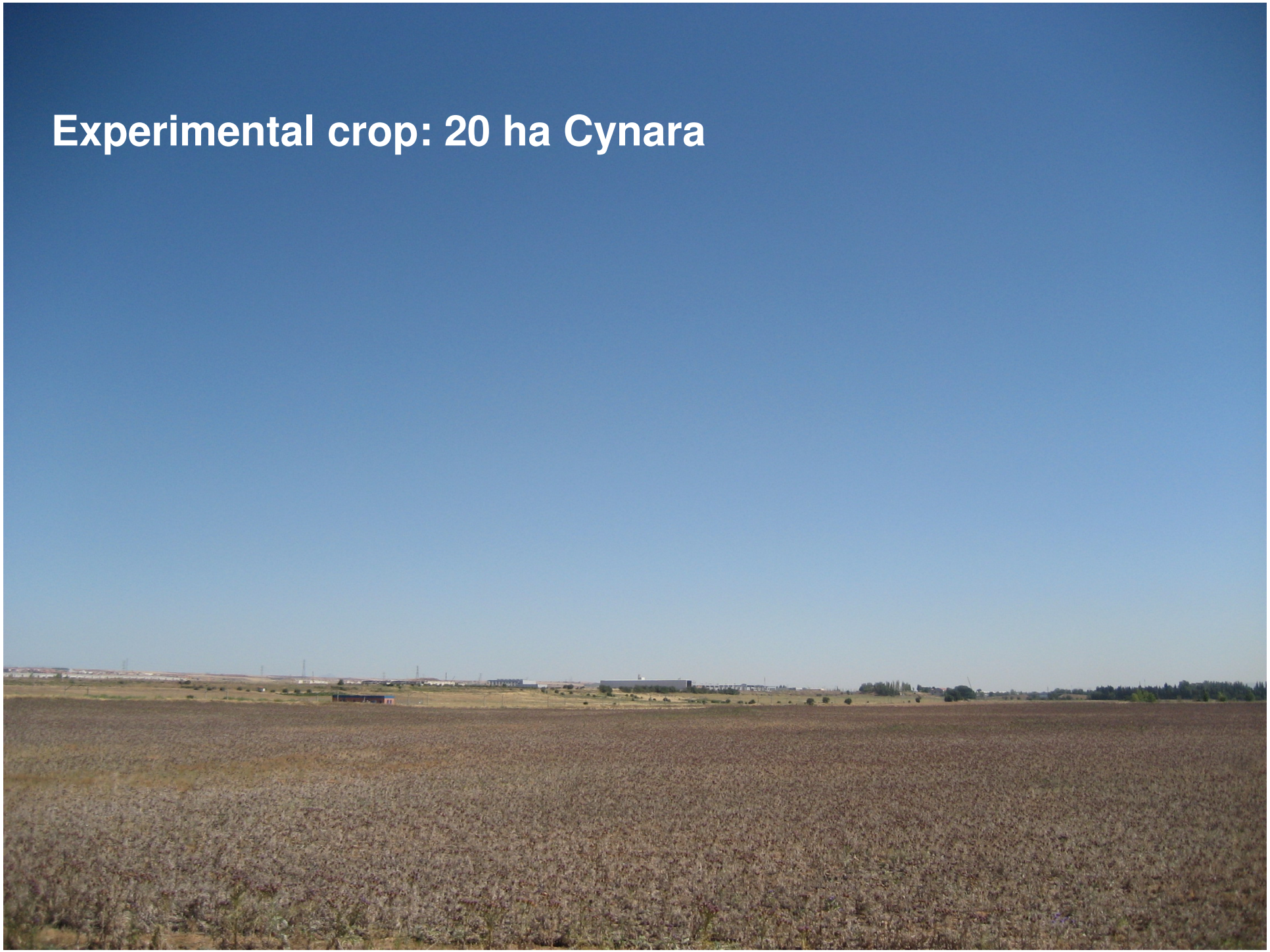
WP1 Objectives

1. Cynara biomass productivity
2. Cynara oil production
3. Development of a static system of biomass fractionation from bales to seeds and lignocellulosic biomass
4. Development of specific machinery to harvest and separate directly in the field the seeds and the biomass
5. Analysis of low-cost pre-treatments for Cynara biomass
6. Cynara biomass logistics

WP1 Objectives (I)

1.Cynara biomass productivity

Experimental crop: 20 ha Cynara



CYNARA MANAGEMENT AS A PERENNIAL CROP

- **FIRST YEAR (Implantation)**
  - Basal dressing
  - Subsoiling, ploughing and harrowing
  - Sowing
  - Herbicide treatment
  - Pest control
- **FOLLOWING YEARS**
  - Restoring fertilization
  - Pest control
  - Harvesting and transport

Cynara biomass productivity : Crop conditions

- The cultivation design in rows 80 cm apart gives more productivity (dry matter per ha) than the design in paired rows (two rows out of four).
- The distance between sowing points in the row must be on the order of 25-30 cm but the final density reached in the plantation is normally on the order of 15.000 to 20.000 plants/ha.

Cynara biomass productivity : Results

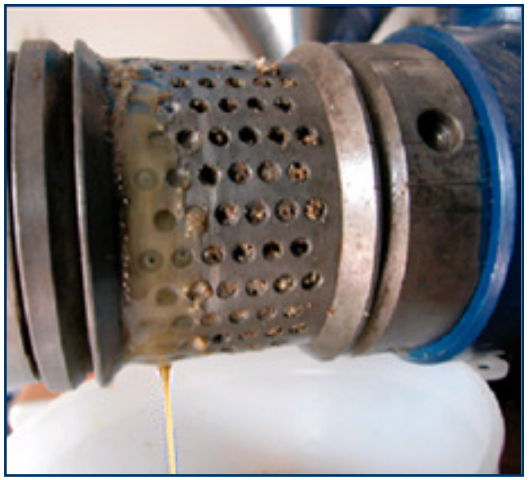
- Yield depends on the rainfall regime and the soil depth
- In favourable conditions (~500 mm/year, deep soil, loam texture), 14 t dry matter ha^{-1} $year^{-1}$ could be attained.
- If 200-300 mm rainfall is fallen during spring time, acceptable biomass production could be attained even in low deep soils.
- Low soil depth, could be a limiting factor for cynara biomass production when the spring rainfall was low.
- Cynara can overcome drought periods if the crop is well established. Production is then low but it can recover if the rainfall rises in the following year.
- Biomass partitioning: 37 % basal leaves, 11 % cauline leaves, 21 % stem (stalk+branches) and 31% heads, on average.

WP1.Objectives (II)

2. Cynara oil production

Cynara oil production : Results

- The cynara fruits are normally so-called “seeds”
- Heads weighing ≥ 22 g contain nearly 28% seeds (w/w).
- About 8.7% of the crop produce are oil seeds.
- Standard production: 1.2 t seeds/ha
- On average, the seeds contain 25% oil
- Fatty acid profile similar to common sunflower oil




Biodiesel de Cynara ca

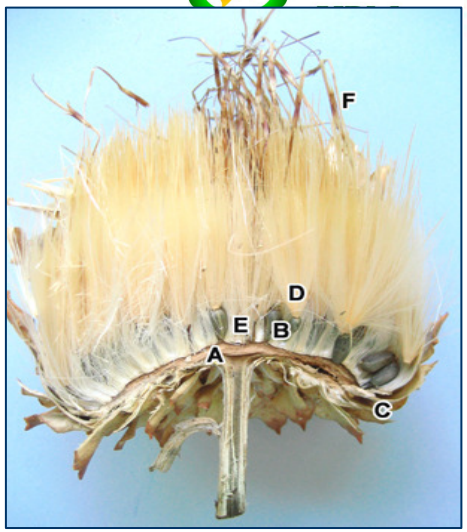

DURAN
1000 ml
800
600
400

WP1.Objectives (III)

3. Development of a static system of biomass fractionation from bales to seeds and lignocellulosic biomass

4. Development of specific machinery to harvest and separate directly in the field the the capitula an biomass or seeds and the biomass

Whole biomass

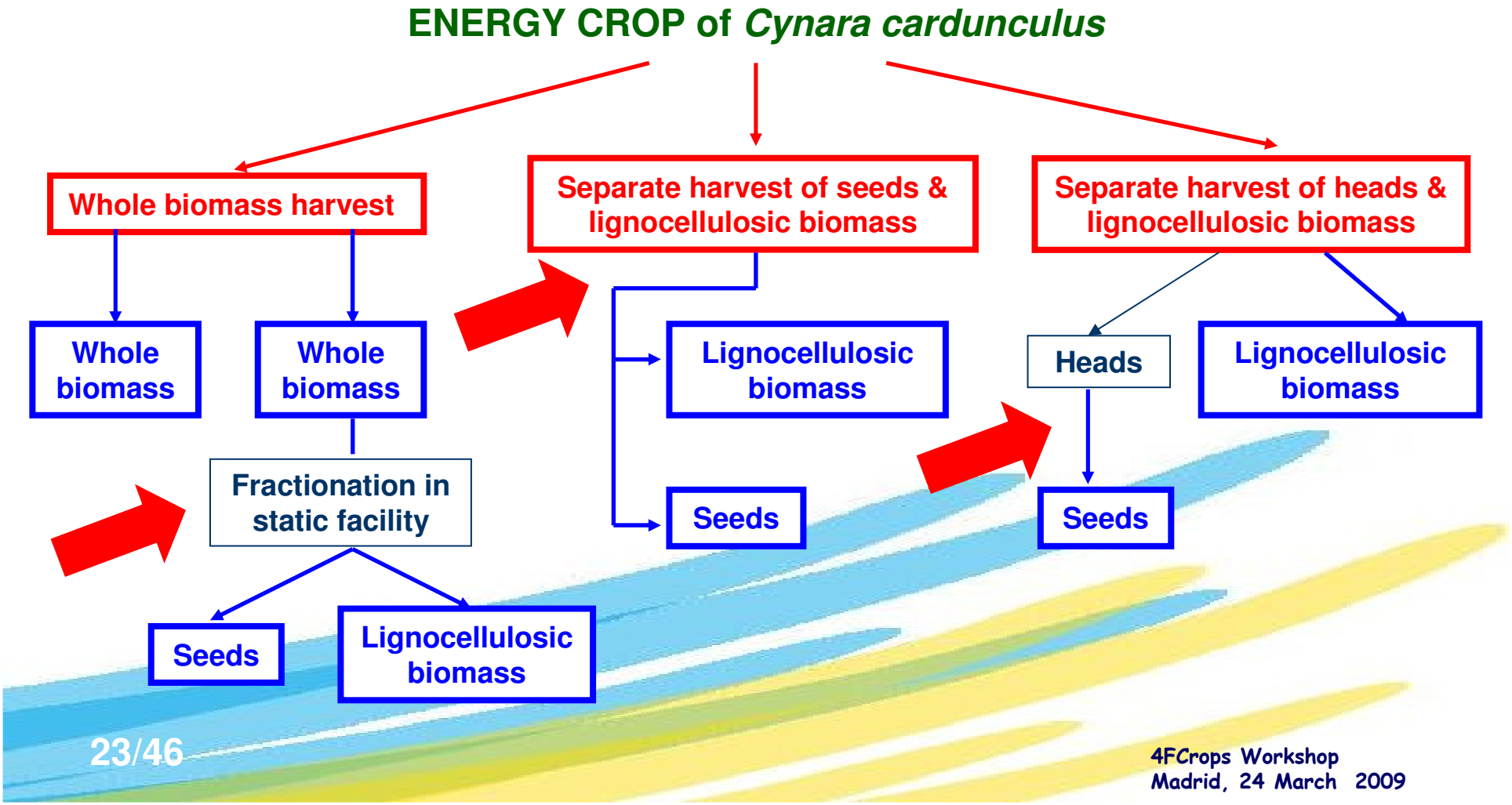


Heads with oil seeds

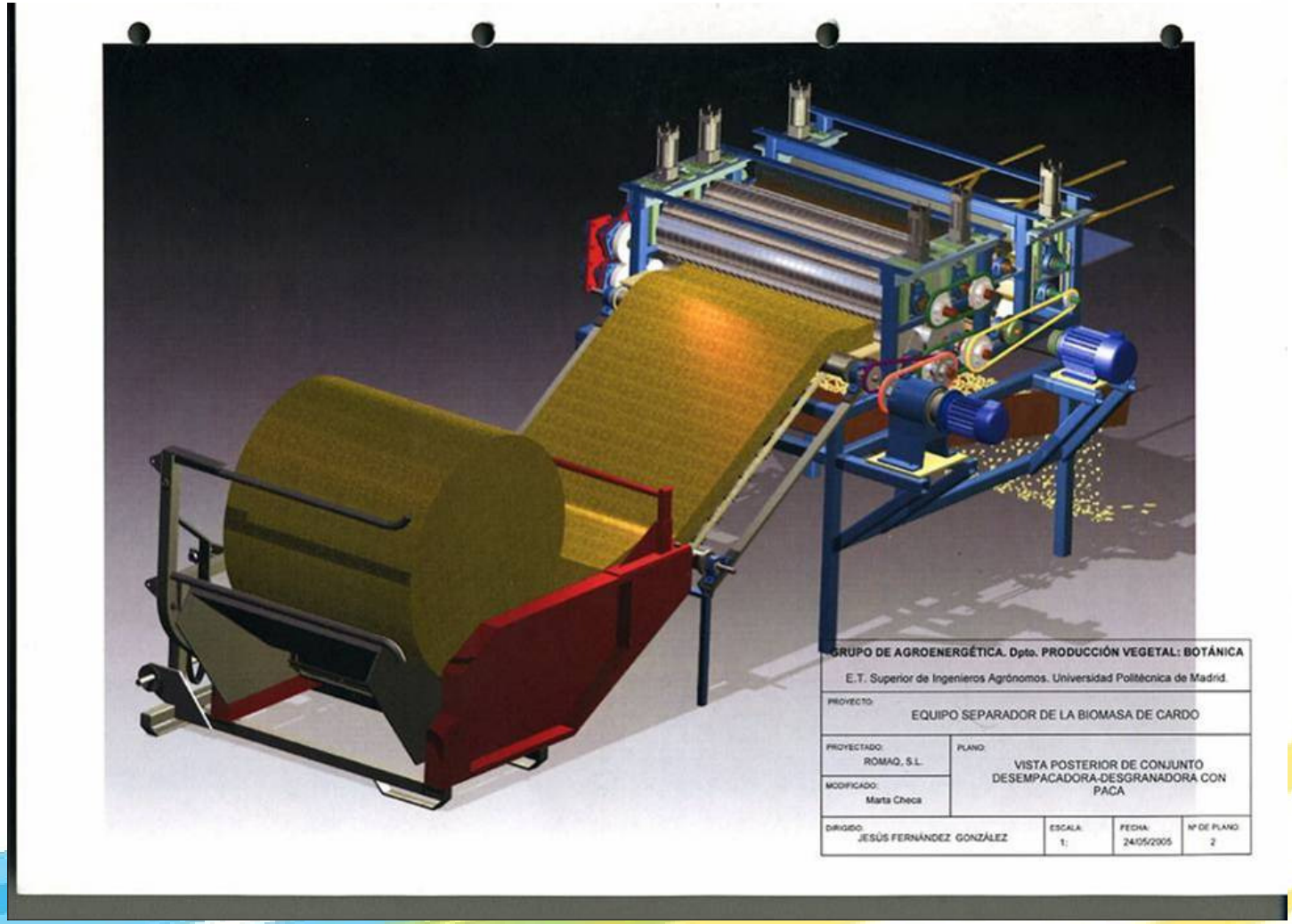
Lignocellulosic biomass

oil seeds

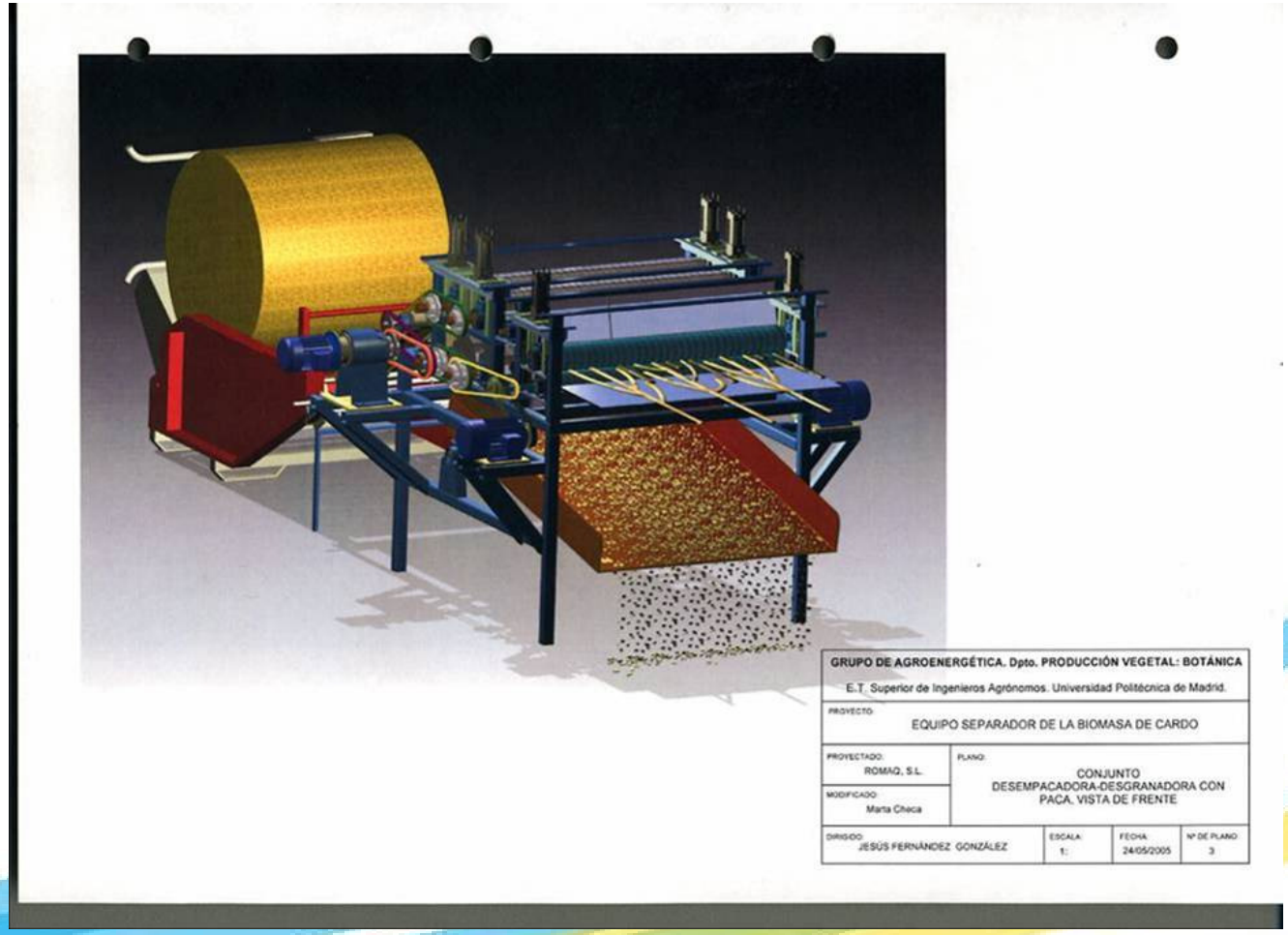
STRATEGIES FOR HARVEST MECHANIZATION



► DEVELOPMENT OF STATIONARY MACHINERY CHAIN FOR THE SEPARATION OF VALUE-ADDED CYNARA BIOMASS FRACTIONS



► *DEVELOPMENT OF STATIONARY MACHINERY CHAIN FOR THE SEPARATION OF VALUE-ADDED CYNARA BIOMASS FRACTIONS*



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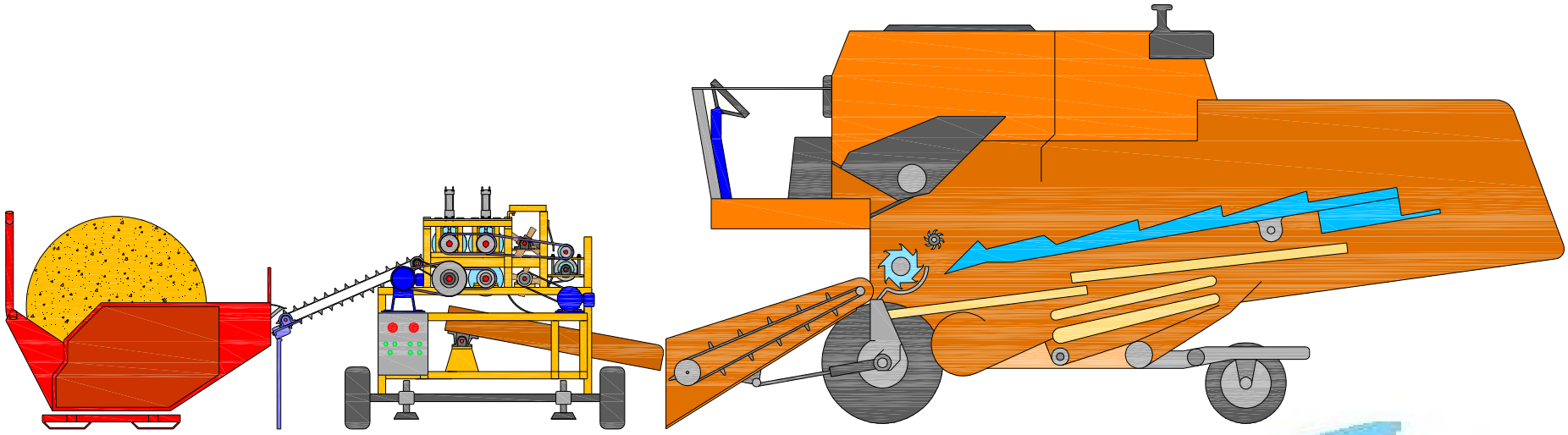

PUBL. REPORT: RESULT #2 (by GA, SP)

► ***DEVELOPMENT OF STATIONARY MACHINERY CHAIN FOR THE SEPARATION OF VALUE-ADDED CYNARA BIOMASS FRACTIONS***

RESULT #2B (by CRA-ISMA, IT)

► *DEVELOPMENT OF A CAPITULA-DETACHER HEAD*

RESULT #2C (by CRA-ISMA, IT)

► *DEVELOPMENT OF A HARVESTER HEAD*

Upper part

~Maize head → to detach the capitula

In the harvester

Detached capitula, are moved towards the threshing device → seeds

Lower part

~Mower → to mow the stalks

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5. Analysis of low-cost pre-treatments for Cynara

WP1 Objectives (IV)

- Chips
- Pellet
- Briquettes

UPM pellet press

UPM biquetting machine

Test of pelletisation at UPM facilities

Milled cynara biomass

~0.20 g/cm^3

Pelletized cynara biomass

~1.12 g/cm3

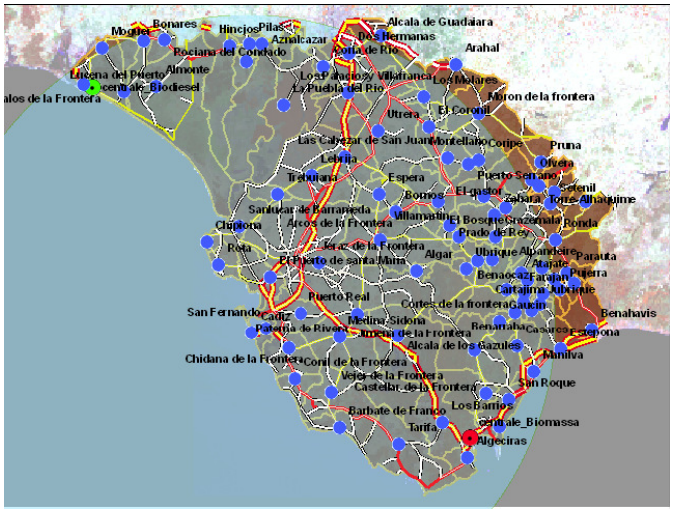
WP1 Objectives

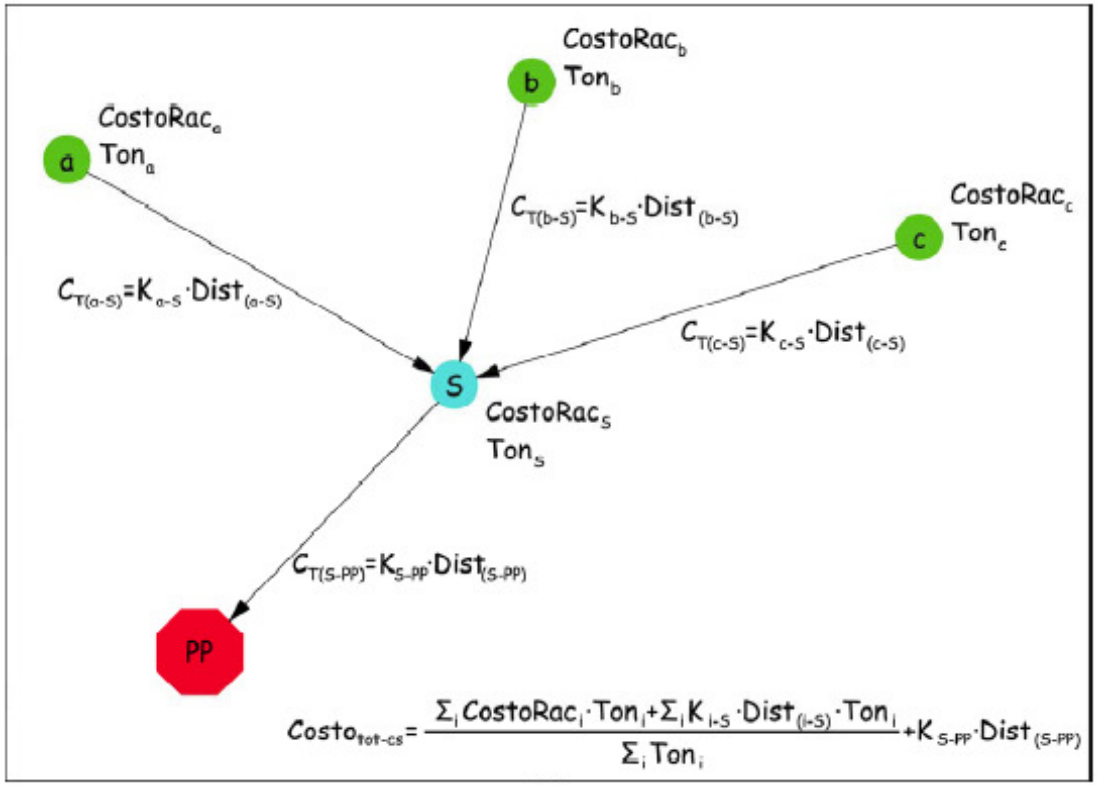
6. Cynara biomass logistics

Logistics analysis (CRA-ISMA, UPM, TECNATOM)

Objective: To structure a product handling and transport logistic network with the support of GIS in a 100 km radius area around Cádiz

Logistics : Results → Software tool





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WP4. Overall technical and economical evaluation. Feasibility study (TECNATOM, UPM, CIRCE, GAIKER)

WP5. Dissemination and exploitation (All)

WP2- LIGN. BIOMASS: Objectives

1. **Evaluation of various combustion technologies** *(swirl burners, grate-fired boiler, fluidised bed)* **for cynara biomass and cynara-coal blends by pilot scale testing**

2. **Detection of possible operational problems**

3. **Determination of the suitable combustion technology for cynara biomass**

4. **Obtaining the necessary information to burn the biomass and coal at full scale**

WP2- LIGN. BIOMASS: Main results

► *Design, construction and operation of a new constant temperature deposition probe for evaluating ash deposition in combustion flue gases*

► *Cynara cannot be burnt alone in effective power plants with steam values >420ºc*

► *Cynara can be burnt with al silicate rich coals with shares 10% energy basis in maximum without risks to superheater corrosion if the the cynara feeding is even.*

► *Even low shares of sulphur rich spanish lignite mixed with cynara can protect the superheaters against corrosion. Such lignite may enable cynara shares up to 50-70% energy basis.*

► *Evaluation of the combustion and emissions characteristics of cynara biomass during grate-firing and identification of potential operational problems*

WP3- SEEDS: Objectives

1. Pre-treatment of Cynara oil and characterization for trans-esterification
2. Pilot test of biodiesel production by homogeneous catalytic reaction
3. Production of biodiesel by heterogeneous catalyst. New catalytic process design and bench scale test
4. Biodiesel characterization test for applications in stationary engines power production

WP3- SEED OIL: Main results

► A durable acid catalyst for the esterification of free fatty acids in vegetale oil using a fixed bed reactor

► A development of an optimization methodology for biodiesel production reactors based on different ways to generate the liquid-liquid dispersion using traditional agitation systems and innovative devices.

► A development of a enhaced separation plant for the liquid-liquid based on plate pack, coalescer, coalescer plus plate pack

WP4- FEASIBILITY STUDY

Objectives

1. Technical and economical evaluation of the crop management
2. Biomass technical and economical evaluation: most promising technology
3. Biodiesel production process: technical and economical evaluation
4. Feasibility study of the overall process

Deliverables

D-4.1: Techno-economic evaluation report on Cynara crop management

D-4.2: Biomass technical and economical evaluation report D-4.3: Biofuel production process evaluation report

D-4.4: Feasibility study report

WP5: DISSEMINATION

Papers Published

- ***"Primeras experiencias a gran escala en la recolección de Cynara"*** J. Oliveira, A. Benito, L. Márquez., 'Agrotecnica' (2007)
- ***"Cynara Cardunculus: Coltura non-food per produrre energia"***, L. Pari. 'Tecnica' (2006)
- ***"Prototype Development for Capitula Harvesting of Cynara Cardunculus"*** L.Pari, M. Fedrizzi, L. Pansini, F. Gallucci. ,15th European Biomass Conference (2007).
- ***"Strategies for the Mechanical Harvest of Cynara"*** by Jesús Fernández, L.Pari, M. García Müller, L. Márquez, M.Fedrizzi, M.D.Curt, 15th European Biomass Conference, (2007).
- ***"A pilot-scale fireside deposit study of co-firing Cynara with two coals in a fluidised bed "***, by M.Aho, A.Gil, R.Taipale, P.Vainikka, H.Vesala, Fuel 87 (2008) 58-69.
- ***"Kinetics of devolatilization and oxidation of pulverised biomass and coal: a requirement for the correct design of combustion and co-combustion plants"*** World Energy Council 2007

Papers Published

- ***"Biodiesel from sunflower oil by using activated calcium oxide"***, M. López Granados, M. D. Zafra Poves, D. Martín Alonso, R. Mariscal, F. Cabello Galisteo, R. Moreno-Tost, J. Santamaría y J. L. G. Fierro, Appl. Catal B: Environmental 73(2007): 317-326.
- ***"Biodiesel preparation using Li/CaO catalysts: activation process and homogeneous contribution"***, M. Martin-Alonso, R. Mariscal, M. López Granados, P.Maireles-Torres , Catalisis Today (2009).
- ***"Potassium leaching during triglyceride transesterification using K/γ-Al2O3 catalysts"***, D. Martín Alonso, R. Mariscal, R. Moreno-Tost, M. D. Zafra Poves y M. López Granados, Catal. Commun. 8(2007): 2080-2086.
- ***"Esterification of free fatty acids in sunflower oil over solid acid catalysts using batch and fixed bed reactors"***. J.Ni, F.C. Meunier, Applied Catalysis 333 (2007):122-130.

Papers Published

- ***"Future of biofuels: use of Cynara cardunculus biomass in fossil power plants"***, S.Ruiz, A.Gil, C.Cortés, M.Aho, A.J.Pedersen, A. Sánchez-Biezma, J. Azcue. Power-Gen Europe Conferense (2008)
- ***"Caracterization of cynara biomass residues for thermal energy conversion"***, C.Bartolomé, A.Gil, M.Aho, A.J. Pedersen, A. Sánchez-Biezma. 16th European Biomass Conference (2008) .
- ***"Solid-biofuels production and energy self-sufficient facilities in the college of Agricultural Engineering of Madrid, Spain"***, Fernández J., Curt M.D., Aguado P.L., Sanz M. 16th European Biomass Conference (2008).
- "***Cynara Cardunculus exploitation for energy applications: development of a combine head for threshing and concurrent residues collecting and utilization",*** Pari L., Fedrizzi M., Gallucci F., Pansini L. 16th European Biomass Conference (2008).
- ***"Development of a GIS tool to analyse Cynara Cardunculus biomass logistics in Southern Spain",*** Pari L., Pepe M., Pansini L., Fedrizzi M. 16th European Biomass Conference (2008).