Chemtex Group

Global Engineering and Project Solutions

PROESA® technology: the industrial solution for cellulosic ethanol projects

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Topics

1. **M&G group**
2. **M&G vision on renewables**
3. **PROESA® Technology: the history**
4. **PROESA® Technology: today**

M&G – Worldwide Locations

- M&G locations
- Chemtex Locations

Gruppo Mossi e Ghisolfi (M&G)

1950 - 1979	1979-2000	2000-2007	2007 & beyond
Packaging Manufacturing Phase	*Chemical Specialty Manufacturing Phase*	*PET Expansion Phase*	*Renewables*
M&G was founded in 1953 by Vittorio Ghisolfi in Tortona, Italy **M&G offered customers packaging from HDPE and PVC**	**Group activities were integrated upstream in the development and production of special resin (PET) for food packaging applications**	**2000** **Acquisition of Shell's PET business**  **2002** **Acquisition of Brazilian controlled Rhodia-ster from Rhone Poulenc** **2003** **Start up of world's largest PET production unit at Altamira (Mexico)** **2004** **Acquisition of the world class engineering group Chemtex from Mitsubishi Corporation** **2007** **Start-up of highest capacity single line PET production plant in Suape, Brazil** ***A Chemtex EPC Project***	**2007** **Testing and development of technology on lab scale for cellulosic ethanol** **2008** **Agronomic testing of energy crops** **2009** **Construction and tests on a continuous pilot plant for cellulosic ethanol** **2011** **Cellulosic Ethanol Demonstration Plant 15 mmgpy Start up**

GRUPPO MOSSI & GHISOLFI

- **Privately held company with deep roots in manufacturing (PET and Acetates)**
- **2600 Employees worldwide**
- **A commitment to R&D (3 Centres) and Process**
- **USD 2.5 billion annual revenue**
- **Operations in the USA, Italy, Mexico and Brazil**

M&G R&D on renewables

Locations:

- Rivalta, ITALY
- Sharon Center, Ohio – USA
- (Italy)

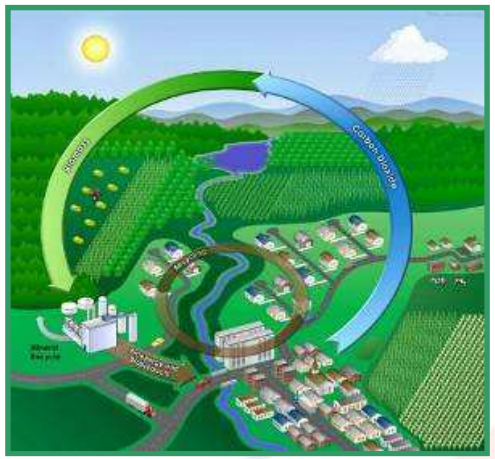
Scope of Activities:

- R&D on biofuel and biochemicals from renewable resources
- Operational pilot plants
- Agronomic evaluation
- Product applications support

M&G Vision on renewables

For both **Bio-Fuels** and **Bio-based Chemicals** the solution is based on the same key fundamentals:

1. **Competitive** pricing compared to products from Black Route (at oil prices in the USD $60-$70/Bbl range);
2. **Environmentally sustainable** with respect to Green House Gases: overall GHG sequestration balance (including biomass feedstock farming, transportation, chemicals or biofuels production processes);



3. **Agronomically sustainable** on the long term (i.e. no competition with food)
4. **Profitable** for farmers to grow biomass feedstock

Second generation technology: PROESA®

- ✓ More than USD $200m investment into R&D since 2006.
- ✓ Extensive agronomic studies and supply chain logistics to support downstream plant development.
- ✓ A continuous 1 T/D Biomass pilot facility operational since 2009.
- ✓ A 40,000 ton/y Bioethanol demonstration plant being built in Italy (targeted completion end 2012).
- ✓ Intellectual Property – multiple patent applications filed.
- ✓ Collaboration with Amyris, Genomatica, Codexis, Gevo and others for the joint development of drop-in fuels and bio-based chemicals using PROESA® Technology.
- ✓ Commitment of M&G/Chemtex and its partners to continuous development and improvement.
- ✓ Beta Renawables: joint venture Chemtex-TPG
- ✓ Strategic partnership making Novozymes the preferred enzyme supplier for Beta Renewables' current and future cellulosic biofuel projects.

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Key advantages of PROESA®

Financial:

- ✓ Lower capital investment as a result of minimum handling of biomass, simplified flow schemes and no special materials of construction;
- ✓ Cash cost of fermentable sugars at ~10 ¢/lb;
- ✓ Cash cost of ethanol of <$ 1.50/USG ($ 0.40/L);
- ✓ Cost-effective at modest scale; short supply chains.

Flexibility:

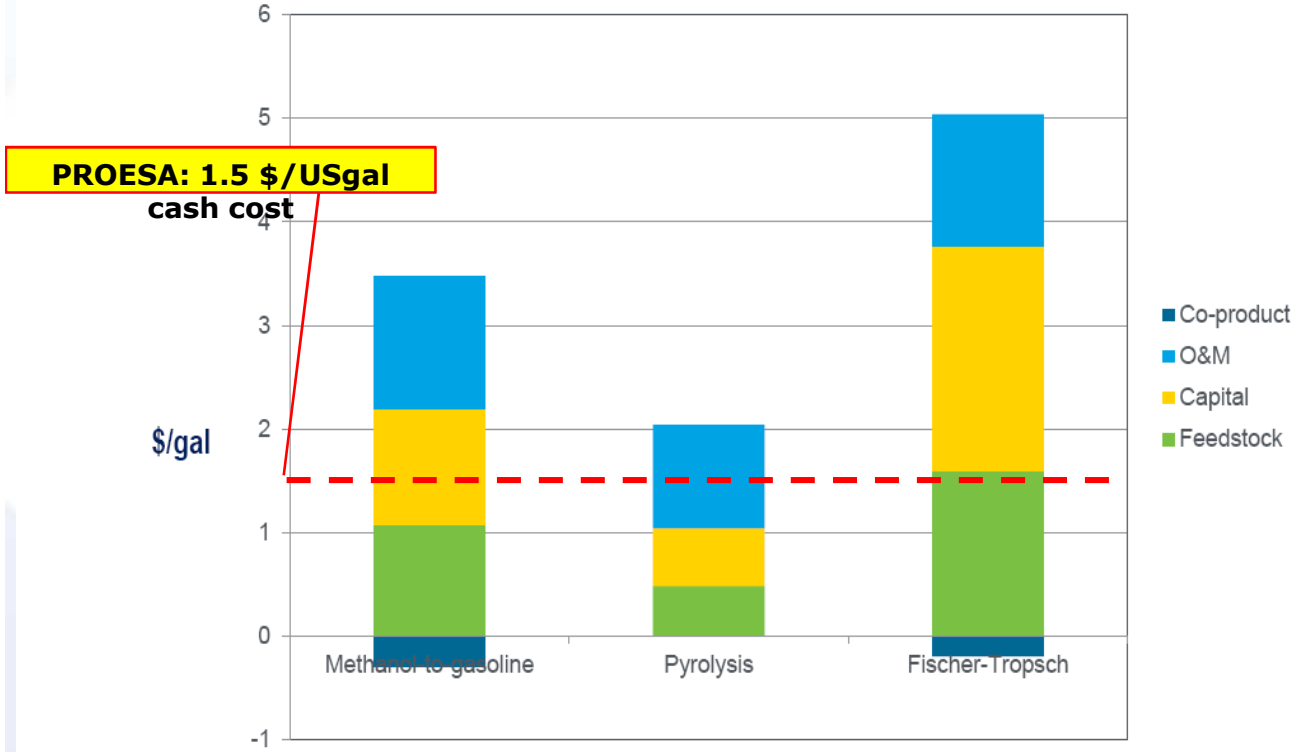
- ✓ Feedstock-agnostic: energy crops, agricultural residues, organic waste, woody biomass, bagasse;
- ✓ Deployable worldwide;
- ✓ Pure lignin by-product;
- ✓ Power from lignin output to run plant.

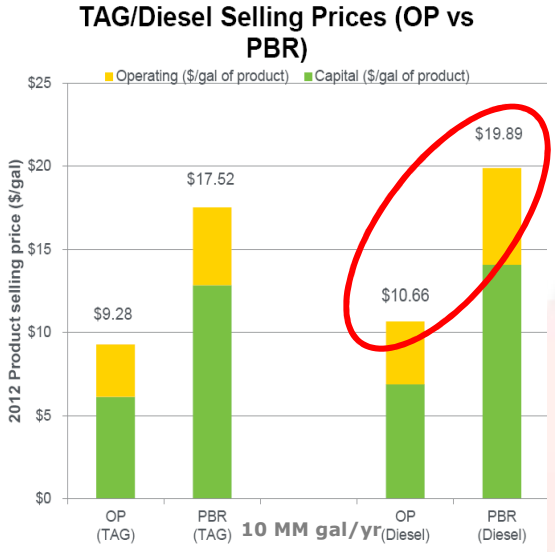
Competitive and attractive economics without subsidies

PROESA® scale up

Cost of Production for Hydrocarbon Biofuels

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





Source: Davis R et. al., "Techno-Economic Analysis of Autotrophic Microalgae for Fuel Production", Applied Energy 88 (2011) 3524 – 31.

- Other economically viable technology routes for hydrocarbon biofuels exist, such as conversion of waste and plant oils, and sugar-to-hydrocarbons
- These costs are projected for the Nth Biorefinery Plant, after operation of initial commercial-scale Pioneer Plants!!!!

PROESA® scale up

2006-2008

- Scouting of Technologies
- Agronomic testing on energy crops
- Generation of key inventions
- Proof of unit operation in labs

2009-2010

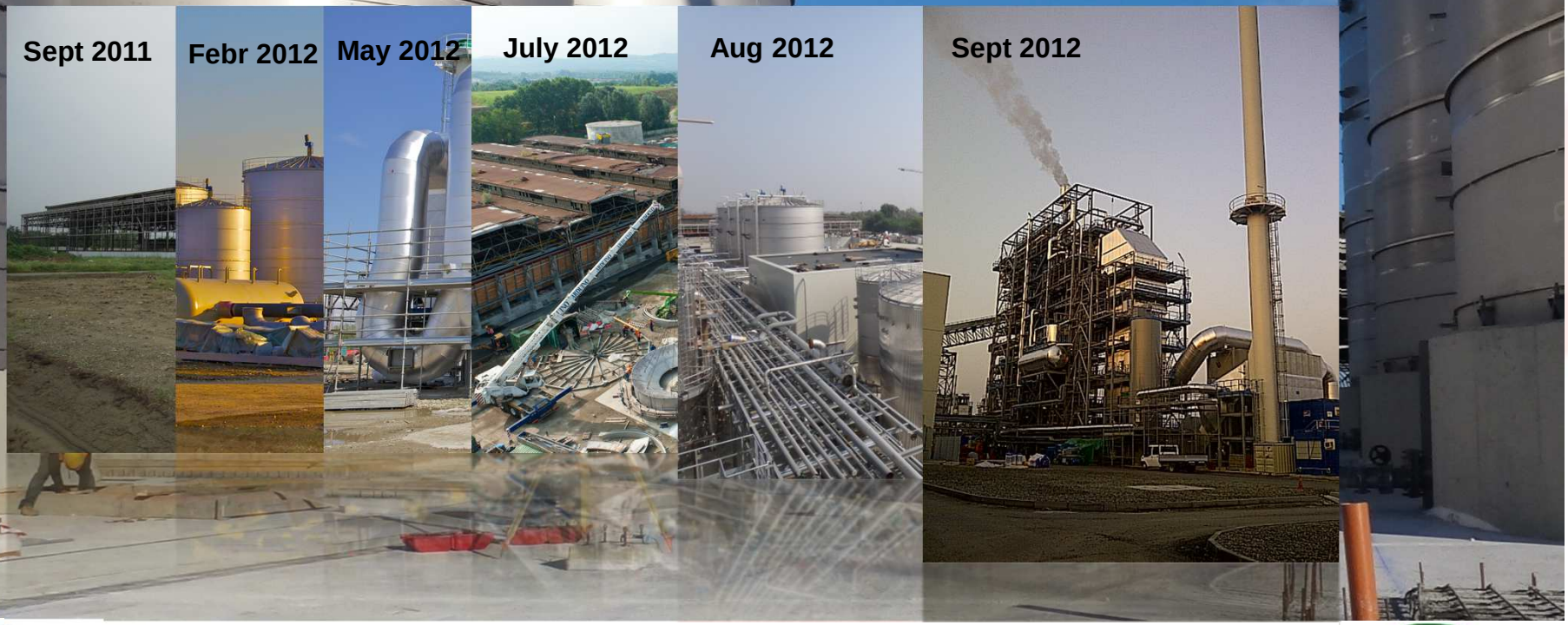
- PILOT PLANT construction & start up (June 2009)
- Pilot Plant operation and Data gathering
- Test of Plant flexibility using multiple biomasses

2011-2012

- Crescentino 40,000 ton/y INDUSTRIAL DEMONSTRATION ETHANOL PLANT
- Technology licensing

Three points that will change the industry

- ✓ **Commercial-scale** cellulosic ethanol plant, Q3 2012: 40,000 ton/y, Crescentino - Italy (ready to start)
- ✓ Cellulosic **costs less**
- ✓ **No subsidies** required



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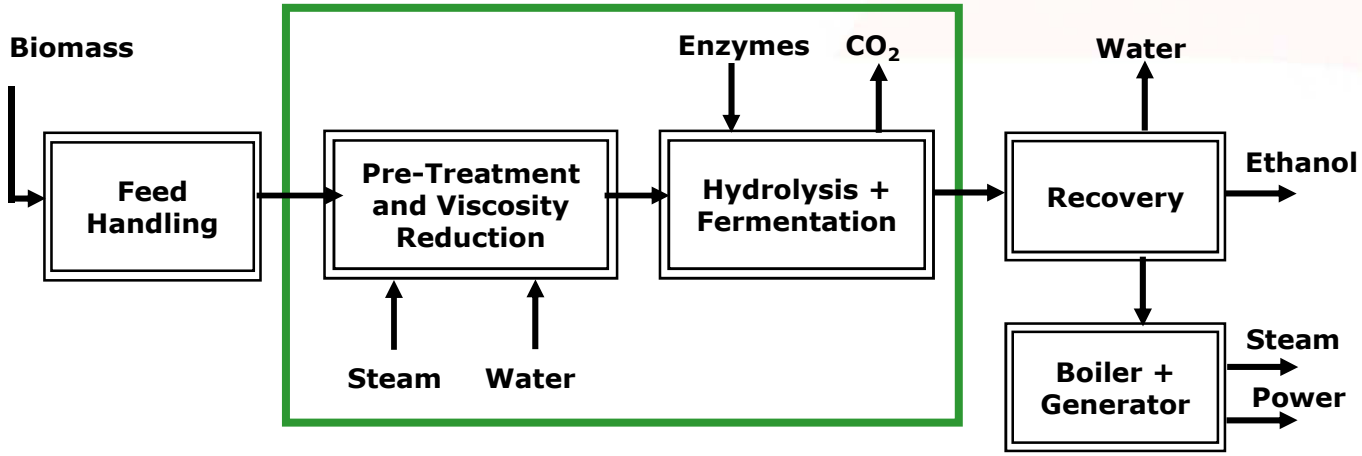
PROESA® - The Technology



The Pillars of PROESA™ are:

1. **Agronomy**: Field experimentation and best energy crops identified and characterized.
2. **Biomass Pre-Treatment and Viscosity Reduction**: Continuous process developed and piloted to produce cost-effective and clean fermentable sugars.
3. **Hydrolysis and Fermentation**: Unique hybrid SSCF process scheme yielding high ethanol concentrations
4. **Valorization of secondary streams and co-products**.

Agronomy

Large-scale production	Low inputs
Low production cost	High CO_2 sequestration
High fuel yield per hectare	Positive fossil fuel ratio

Energy crops

- ✓ *Arundo donax (Giant reed)*
- ✓ *Miscanthus giganteus*
- ✓ *Panicum virgatum (Switchgrass)*

Agricultural and industrial residues

- ✓ *Wheat straw*
- ✓ *Rice straw*
- ✓ *Corn stover*
- ✓ *Sugarcane bagasse*

Woody species

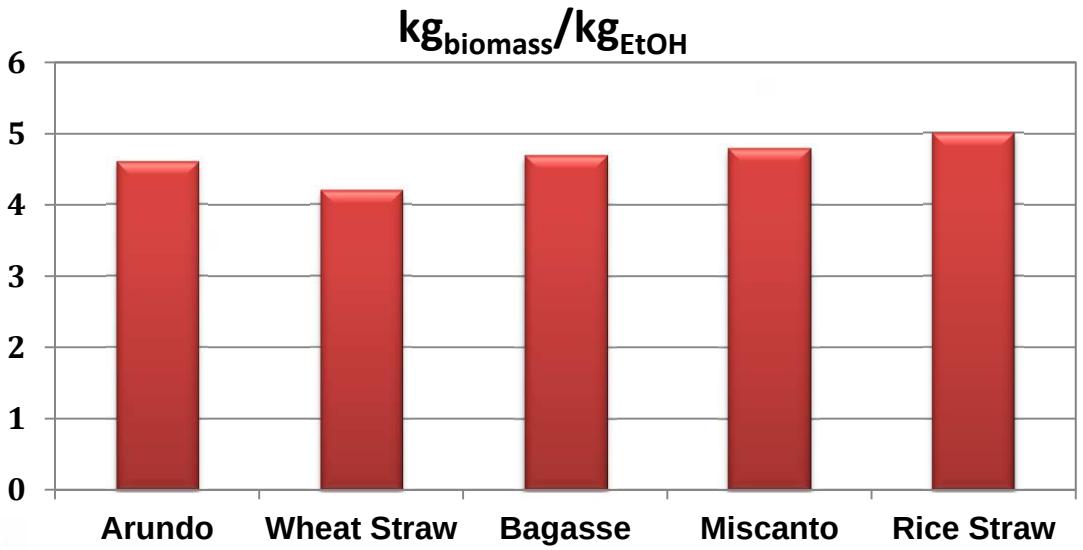
- ✓ *Eucalyptus*
- ✓ *Poplar*

- ✓ Shorter supply chains;
- ✓ Simple process and equipment solutions;
- ✓ Closer to customer.

- ✓ What counts on biomass cost is logistics.
- ✓ Therefore it is WAY BETTER bringing the plant to the biomass rather than the biomass to the plant.
- ✓ If then the plant is fed with multiple feestocks, the optimization is complete.

PROESA® Pre-treatment

- New Pre-treatment Process has been successfully tested by Chemtex on the continuous pilot plant since June 2009 (covered by a patent application)
- Long run continuous tests (24h/day operation for more than a month) with several feedstock, for investigating process stability and system behavior
- 500 days (more than 3.500 h) of operation in total

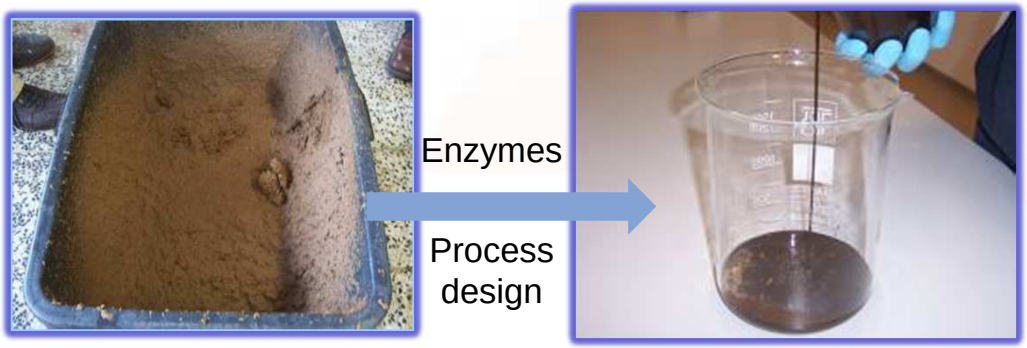


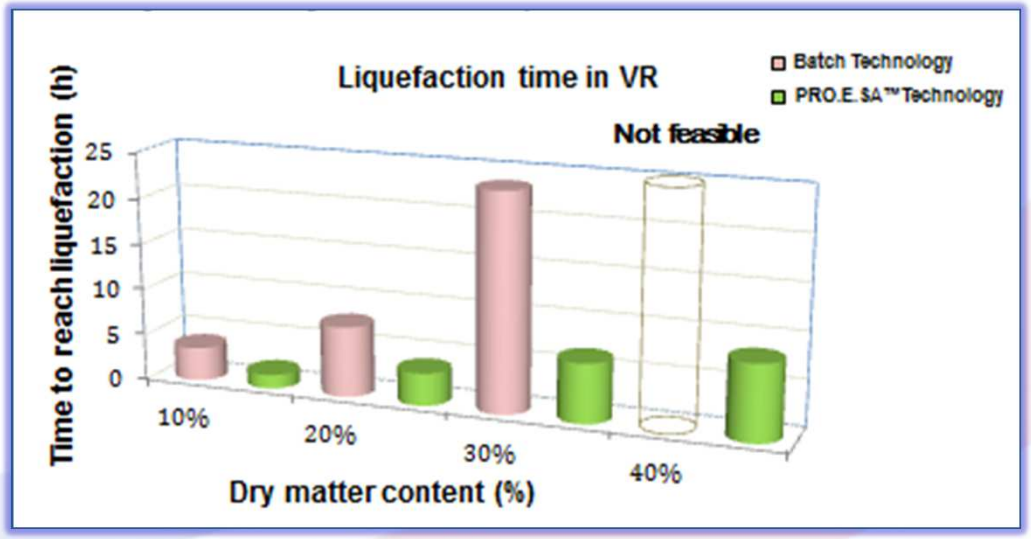
Process yield (kg biomass/ kg EtOH)			
target	min	max	Average
4,3	3,9	4,5	4,2± 0,2

Composition of the material entering the viscosity reduction section is constant.

PROESA® VR - Hydrolysis and Fermentation

- ✓ A **unique hybrid SSCF process**
- ✓ Possibility to work at dry matter contents up to 40% (potential to yield 12% ethanol in fermentation).
- ✓ Material is liquefied after few hours (< 8 h) even at low enzyme load
- ✓ Efficient use of enzyme cocktails; flexible to multiple biotech solutions.
- ✓ Low energy consumption for agitation.
- ✓ Easy pH and temperature control
- ✓ Low Capex and Opex





Results confirm PROESA™ hydrolysate can be a suitable sugar substrate for a wide range of fermentative route to biochemicals based products

The continuous Pilot Plant on 2G tech…

HOW IT OPERATES

- BIOMASS AGNOSTIC (12 kinds of biomasse tested)
- NO BIOMASS DRYING/GRINDING REQUIRED
- LOW LEVEL OF INHIBITOR (lower then in P.O.C.)
- NO USE OF CHEMICALS (only steam is added)
- REDUCED ENZYME LOADS
- RAPID LIQUEFACTION OF THE SOLID MATERIAL
- HIGH SOLID CONCENTRATION (> 40%) IN THE HYDROLYSIS STEP

Crescentino 2nd gen. 40.000 ton/y Ethanol Plant

- In April 2011, M&G and Chemtex broke ground for a 40 ktpa / 13.4 mmgpy nameplate cellulosic ethanol plant based on Arundo Donax & wheat straw.
- Crescentino will generate 13MW of "green" power from lignin to the grid and will sell ethanol to a major oil company.
- Design incorporates state-of-the-art wastewater treatment facility for maximum recycle of water.
- Start-up: end 2012.

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Crescentino: some figures

- **40’000** Mtons bioethanol
- **13 MW** power
- **300** pieces of equipment
- **1’500** tons of steel
- **1’400** tons of pipes and valves
- **30’000** m^3 of concrete
- **18 km** of underground piping
- **4’000 ha** of lignocellulosic biomass
- (Arundo donax and/or agro-residues)
- More than **150 persons** involved directly

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Next projects

SUSTAINABLE BIOMASS

LOW COST PROESA «GREEN» SUGARS CONVERSION

SECOND GENERATION CO-PRODUT (LIGNIN) VALORIZATION

…a cost competitive, low carbon alternative to petroleum derived jet fuel and biochemicals in a short term horizon


THANK YOU
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