

A SELF-SUFFICIENT SYSTEM (“ENERGY ISLAND”) FED ONLY WITH BIO-OIL FROM LOCAL CROPS

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SUMMARY

The paper summarizes a project for an experimental energy system to be developed as a strategic measure to enhance global competitiveness of the Industrial Development Area (ASI) of Aragona - Favara in Agrigento Province. The aim of the project is to achieve a self-sufficient system (“Energy Island”) fed only with bio-oil from local crops.

Planned duration of the experiment is four years, and the final goal is to establish new and profitable enterprises taking advantage from a cost-effective and sustainable energy supply chain: planned activities, in fact, involve farming and oil production ventures as well as the energy intensive food industries already settled in the area. Industrial-scale benefits will be achieved by expanding experimental plants, in line with the original concept, once satisfactory profitability has been demonstrated on small scale.

Strategic principles of the project, in particular the “short supply chain” concept, are illustrated first. The Industrial Development Area of Aragona-Favara is then examined as to its energy demand, which should be met by renewable energy. The supply side is subsequently analyzed, focusing on how a short supply chain for oleaginous crops (sunflower and rapeseed) could be structured by appointing some set-aside agricultural areas to industrial crops. Incentives and national legislation on renewable energy are presented to outline market opportunities for energy and for produced biofuel once the experimental phase is concluded.

Technical details of the project are then given, with process description and an account of how the experimental plants have been sized, deriving energy and mass flow balances and estimating avoided GHG emissions within the experimental timeframe. Agronomic and energy conversion activities related to construction and operation of the experimental systems are illustrated and future developments and strategic implications are outlined.

The project has been conceived by the CIFRA - Interdepartment Center for Environmental Research and Education of Udine University - on behalf and with the cooperation of the Unione Industriali - Agrigento.

Key words: sunflower, experimental energy system, price, food production, biodiesel production plant

FUEL PRICES EVOLUTION AND "SHORT PATHWAY" CHAIN CONCEPT

The price of energy in all of its forms (electric, thermal) grows inexorably because of the high demand of the industrialized countries. In the past two years the oil barrel price was doubled, increasing from 35 to over 70 euros. In the last ten years the consumption of methane was doubled and it has put in jeopardy the safety of energy supply (see the recent stories about the Russian methane).

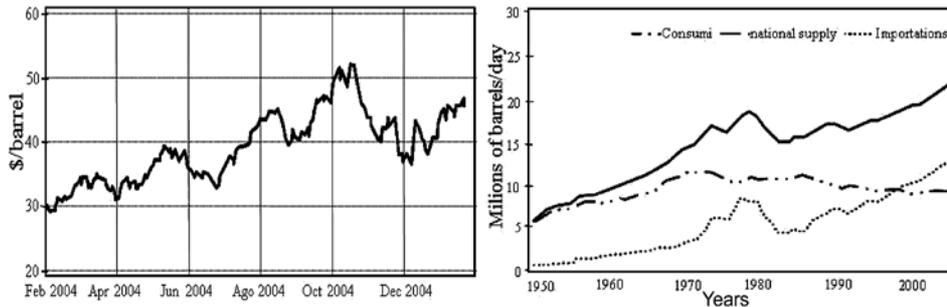


Figure 1: Energy consumption trend (left) and oil price trend (right) [1]

The tendency in recent years has been to manage the production and economic problems, keeping in mind only marginally some local territorial realities. The "globalization" estranges the economic centers of local management with negative implications on the local economy. Products, energy resources, services and knowledge are furnished to a territory from the outside and the territory remunerates the outside through its own social structure (see Figure 2).



Figure 2: Traditional pathway or "long chain"

The local social and economic structures must realize initiatives directed at exploiting the specific characteristics of the territory in order to satisfy territorial demands for products, services and knowledge by making use of the resources already available or potentially available on the territory.

It is, therefore, necessary to realize pathways of products, services and knowledge in energy matters which are born, develop and find their function inside the territory, thus realizing the so-called "short pathway" or "short chain".

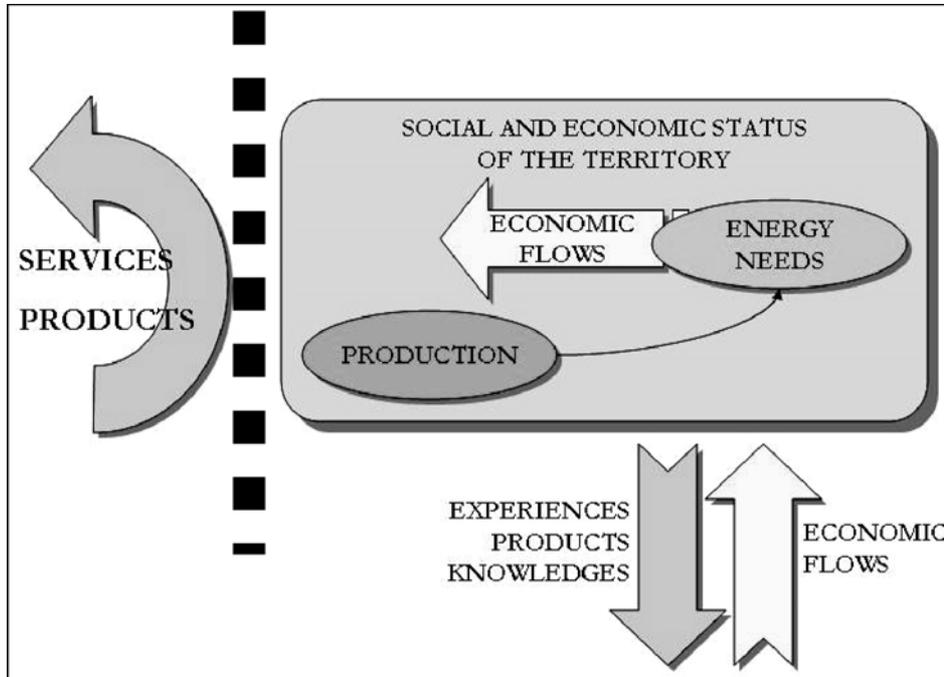


Figure 3: Short pathway or short chain

The short chain expresses itself in the realization of internal synergies of the territory, by using the previously unexploited aspects (knowledge, techniques, climate, etc.) and by bringing some products or services actually in crisis (for instance, agricultural crops) to new positions of use: the purpose is to create local energy pools by exploiting the local agricultural resources. On one side, the price of energy crops is defined to reward the agriculturists, and on the other side to make the energy conversion economically acceptable. The prices will be lower than the prices of corresponding products on the national agrarian market because these crops will be sold locally, therefore eliminating the transport, distribution and transaction costs.

The short chain has a special advantage that, once realized, it can economically self-sustain itself. It reduces the territory's needs by producing occupational and economic advantages; besides, it produces indirect advantages in consequence to the availability of the economic flows, realized inside the territory.

The short pathway has specific characteristics of the territory, because it exploits its specificities (climate, agro-industrial status, soil characteristics, scien-

tific centers, *etc.*). It also produces concrete experiences and knowledge that can be exported to other territories. In this optics of the development of know-how and transfer of knowledge, the short pathway has to be so structured as to allow a dynamic growth of experience and knowledge.

ENERGY DEMAND AND REGIONAL ANALYSIS OF THE INDUSTRIAL DEVELOPMENT AREA OF ARAGONA-FAVARA (AGRIGENTO-SICILY)

The industrial area is constituted of one hundred plots in which some productive installations (partly operational and partly available for new business activities) are built. The industrial zone (Z.I.) is well developed: it has a network for water supply including wells and filtering systems and a gas supply network. Currently the Z.I. is served by two electric distribution networks: one in medium voltage (for energy-intensive activities) and one in low voltage (for less intensive activities). The technological networks are partly developed.

The area is clearly oriented to the agricultural and food processing activities: of 97 plots, about 20 are assigned to food production activities, especially in the meat and fish processing sectors, in the pastry production sector and in the ice-creams and frozen foods production sectors. Adjacent to this area are a large logistics center for the industrial-size catering service, a cold storage and a plant for making industrial refrigerators. There are also possibilities for thermal loads absorption, for instance from the plastics recycling enterprises. Such opportunities must be considered in terms of energy demands: for low temperature demands (water up to 90°C), supply is possible through thermally insulated regional networks, while for higher temperatures, the problems related to water pressure or steam transport generally make the local generation of thermal carrier fluid more convenient.

Concerning to the heat requirements, there is a hospital near the interested area. The hospitals can represent an important basin of heat absorption also in mild climates, both for the relatively high internal temperatures that must be maintained in these type of structures (22-24°C), both for the heat processing requirement (Washings *etc.*), both, for the summer conditioning demands, more meaningful than in the industrial buildings and which can be satisfied through lithium bromide absorption groups.

Concerning the possibility to realize an example of short pathway in the industrial development area, the presence of an alimentary oils transformation industry is underlined, as well as two oil manufactures devoted to the olive oil production; it would be interesting to diversify the market (from the food to the non-food production), in a technologically similar sector.

EXPERIMENTAL PLANT DESCRIPTION AND ENERGY AND ENVIRONMENTAL BENEFITS

With this project we propose an experimental plant that introduces completeness and immediate utility and can also form the base for the progressive development of a wider integrated energy system to realize in the industrial development area of Aragon-Favara. The plant can be installed without burdens in one of the existing buildings that are not currently used. Such buildings must be chosen so that they will respect the conditions of mutual proximity with the activities that will use of the produced energy services.

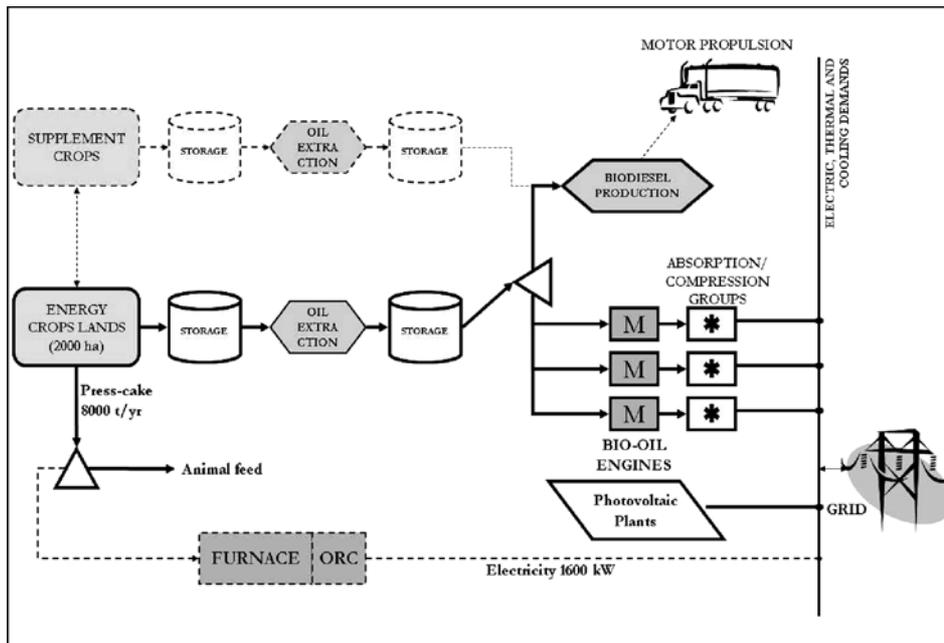


Figure 4: Experimental integrated energy system in Aragon Favara

The system (see Figure 4) is constituted by an oil processing section, which can find position inside the experimental installation, or, in more integrated way with the existing logistics and more profit to the future development of the territory, inside already installed firms in the area that process alimentary oils. Two sections follow this one and they have two different energy pathways of use.

The first pathway is represented by the biodiesel production to put on the national market or on the local market; the local market is constituted by the logistics of the firms of the industrial area and by the local public transports of Agrigento. In this way it will be possible to increase the renewable energy rates in the transport sector and to reach a progressive energy self-sufficiency.

The second pathway is represented by the direct energy conversion of the refined vegetable oil in stationary CHP engines, devoted to the combined production of electricity and thermal energy, integrated by the solar energy conversion through photovoltaic systems that can be installed on the roof of the industrial buildings.

As the main industrial activity is that of the food products processing, the most greater part of the industries (pastry, ice creams and frozen industries *etc.*) have important cooling energy demands both for freezing (that needs temperatures around the -30°C) both for refrigeration (that needs temperatures around the -6°C). There should be also moderate local demands of simple environmental conditioning, finalized to the maintenance of environment temperatures of $10-12^{\circ}\text{C}$; such demands could also be satisfied with the production of refrigerant mixtures at low temperature and with thermal exchanges with environment temperature water for the attainment of the opportune conditions.

Considering the general greater economic convenience to use the electricity produced rather than to sell it to the network and considering that the purchase costs are clearly higher than the selling prices, the whole energy conversion will be addressed to the cooling energy production and dome centralized refrigerating stores will be realized. Some industrial refrigerators will be installed inside the industrial buildings in which the plant will be situated; those insulated refrigerators will be fed by steam compression groups and, partly, by water-ammonia absorption groups whose commercial standardization is very recent and whose installation in direct combining to bio-oil engine would represent an interesting joining to experimentally study in terms of energy economic and reliability performances.

The sizing of the experimental system, finalized to the definition of the budgets and the time horizons has been driven by the followings principles:

- 1) Full energy conversion in cooling energy, which is more useful to the reference industrial area.
- 2) Infrastructure facilities centralization.
- 3) Energetic production driven by the renewable resources availability and the development of the energetic crops.
- 4) Modularity and subdivision of the plants.

EXPERIMENTAL PLANT DIMENSIONING AND COMPONENTS

Bio-oil production plant

Cold pressing plants for oil extraction [12] are constituted by:

- an initial storage that allows to harmonize the discontinuous course of the production and the arrival of the oil seeds from the continuous regime of production of the oil,
- a filtering/separation system (sieve and magnetic separator), mainly to eliminate the stones and the little metallic parts that would damage pressing

systems,

- a screw pressing system that extracts the oil and transports the press-cake to a dedicated storage container for the following transformation in feeding stuffs,
- an homogenization and oil filtering system, with automatic cleaning by compressed air,
- a tank for the final storage of the refining oil. The production of an extraction plant of this type is about 38%; so it's possible to obtain 0,38 kg of oil for every kg of treated seed.

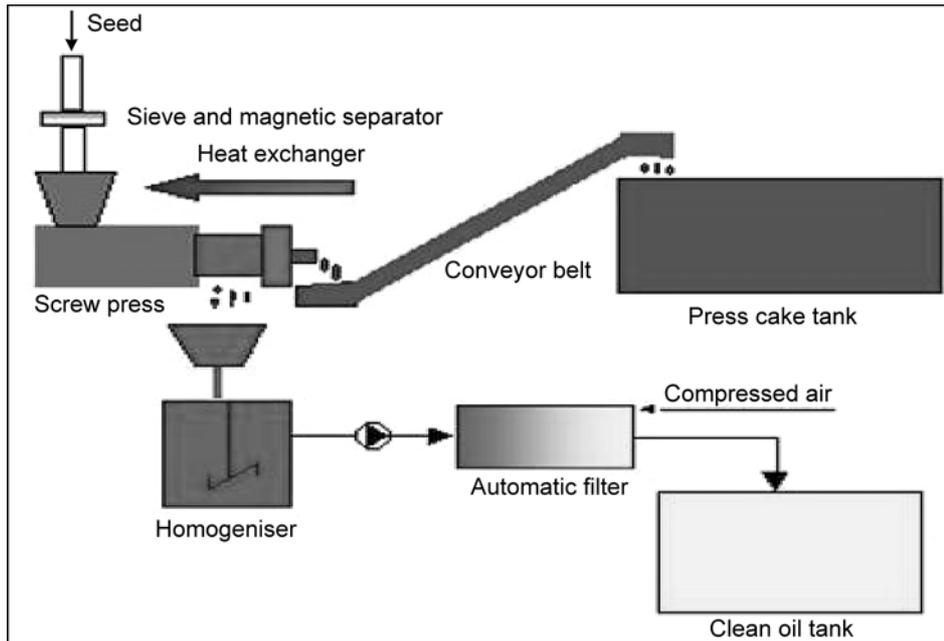


Figure 5: Bio-oil production plant scheme

In the experimental phase the plant is dimensioned to satisfy the processing of the sunflower seeds that can be produced from about 2.000 ha of lands (see Table 1).

Table 1: Main operating data of the vegetable oils pressing system

| Plant component | Operating Characteristics |
|------------------------------------|---------------------------------------|
| Oil seeds production [2 t/(ha·yr)] | 2000 ha → 4.000 t/yr |
| Operating hp | 2 shifts/day → 16 h/day (360 days/yr) |
| Plant capacity | 694,4 kg/h |

By hypothesizing an availability of the system of about 92%, a capacity plant of 750 kg/h is chosen. An automated plant will be realized, as it is recommended by the technical literature for bio-oil production systems over a 700 kg/h capacity: a system suitable for continuous operation requiring just 1 man-hour a day for

supervision is selected. With a 38% output, the plant will allow to get a production of oil equal to 1520 t/yr.

The refined sunflower oil has a lower heating value equal to 37 MJ/kg, therefore the amount produced has an heating value for combustion and energy conversion equal to 15.625.000 kWh/year.

Trigeneration system

A system is presented for the production of electric and thermal energy combined with cooling machines exploiting the greatest part of the available heating value. During the experiments, by assessing the energy outputs and the reliability of the system's components, it will be possible to give some information about the economic convenience of various alternatives and on the optimal configuration, and it will be possible to choose the most economically efficient production system of the cooling energy (as described in this section) and of the biodiesel production (as described in the following section).

The application of the vegetable oils in Diesel engines dates back to the beginnings of history of these engines. Compared with motors for automotive propulsion, where requirements for compactness and performance are binding, changes to be brought to the modern engines for static applications with the purpose to use directly some vegetable oils are rather contained, and they mainly concern the installation of preheating systems to confer the necessary fluidity.

Some cogenerating standardized modular equipments are available on the market for the potentiality equal to 125 kW with a 41% nominal electric output and a 92% first principle global output. A 35% electric output is assumed, comprehensive of the consumptions for the auxiliary.

In the hypothesis of combining engines with cooling systems, which should be operated almost uninterruptedly, engines operating characteristics can be assumed equal to 8000 h/year.

The electricity that can be theoretically obtained, if all the chemical energy of the oil was used, would be equal to 5.468.960 kWh/year. In the hypothesis of continuous work for 8000 h a year, this would correspond to a total engine capacity of 684 kW.

Our choice in this case is to install around the 50% of this theoretical capacity, so that remaining oil is available for biodiesel production. Our goal is that, moving from these starting values, biodiesel production may grow in time, thanks to a parallel expansion of crops beyond conservative estimates used for this study.

Choosing among commercially available engines, we decide to install three engines of 125 kW_{el} capacity each (total capacity of 375 kW_{el}). We thus achieve desired modularity too, which is one of the basic principles guiding our design choices.

Once engines are installed, two options are available for refrigeration [13]:

- a) traditional option: we would install vapor compression refrigerators, characterized by very high COPs: even accounting for all losses, we estimate actual COP for vapor compression cycles (COP_c) at 1,27, according to technical norms;
- b) innovative option: we would adopt recently industrialized technologies [13-14], that is to say water/ammonia absorption groups exploiting flue gases from bio oil engines; such systems allow to reach low temperatures suitable for industrial refrigeration and meat processing (-6°C) and freezing (-30°C). COP is lower in this case, about 48% for low temperature applications (COP_{At-30}) and 58% for refrigeration (COP_{At-6}). Low water consumption systems exploiting air based rather than water based cooling systems are already available on the market, which would match the climatic conditions of the area.

As we are conceiving an experimental installation, we will take the chance to evaluate both technologies, assessing their energy performance as well as their reliability/availability performance, so that applicability conditions and optimal combinations of these technologies options with bio-oil based CHP systems can be generalized.

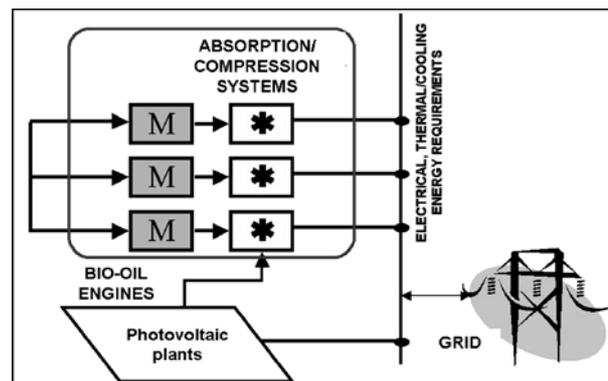


Figura 6: Schematic view of the direct energy conversion of the refined vegetable oil in stationary CHP engines.

Hence, our intention is to install three diesel engines of 125 kW_{el} capacity fed with bio-oil, having a nominal electric efficiency of 41% (average estimated 35%). Assuming a 92% overall efficiency, we could recover some 156 kW_{th} heat from each engine in peak load conditions (total: 468 kW_{th}), while more heat could be recovered in average conditions, when electric efficiency is lower. We can then reasonably assume to recover some average 520 kW_{th}, which is enough to feed two standard absorption refrigeration units of 150 kW_f (COP_{A-6} 58%), serving refrigeration cells at -6°C. Steam compression systems will be used, on the other hand, for freezing at -30°C: absorbing the whole generated power some 476 kW_f will be obtained for freezing.

According to constructors, a refrigeration cell at -30°C with a medium to high rotation index requires about $40 \text{ W}_f/\text{m}^3$. Neglecting possible causes of requirement reduction, this would mean that the described system could supply some 19400 m^3 , which could fit into cells of about 5 m height (average, larger values are required for meat processing and cold storage, smaller heights are used in freezing cells), that is some 3900 m^2 ground area. At normal operation, some 3000 MWh/year of power will be produced, using some 2195 t/year of sunflower seeds, corresponding to some 1100 ha crops. Refrigerating energy production is estimated about 6208 MWh/year; thanks to enhanced efficiency due to absorption refrigeration, a power demand of some 4890 MWh/year is thus avoided. Referring to average power production in Italy, this corresponds to some 1100 TOE/year of primary energy savings and about 2700 t/year avoided GHG emissions (CO_2 equivalents).

Biodiesel production plant

As to biodiesel generation plants, we refer to literature [16-19] for standard plant configuration and sizing.

The Aragona-Favara biodiesel production plant should have an input capacity of about 2000 t/year oil: in this way, yearly production as of estimates could be theoretically absorbed by the biodiesel production facility alone, in case market conditions particularly foster biodiesel production compared to power generation from bio-oil.

On the other hand, power generation from biomass could be continued and enhanced in the area, even if more bio-oil is used for biodiesel production, by exploiting residual biomass from sunflower crops as a main energy source for the described trigeneration system.

Assuming a 98% yield, this means that a theoretical production of 1960 t/year could be achieved, while during experiments we estimate that some 670 t/year could be obtained, thus consuming some 1800 t/year sunflower seeds, *i.e.* the yield of some 900 ha crops.

Literature [16-19] shows that for each kg of biodiesel, we avoid the emission of 2,4 kg CO_2eq : at normal operation, we estimate that a reduction of 1610 t/year of GHG emissions can be achieved.

CONCLUSIONS

While waiting for the project realization and the connected experiences, the pre-disposed project is the demonstration of the synergy between Industry, University and Research Centres that can collaborate for the realization of concrete projects with strong application possibilities, without neglecting the scientific technical innovative aspects.

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**SISTEMA AUT NOMO ("ISLA ENERG TICA") QUE
UTILIZA S LO BIOACEITE DE LAS PLANTACIONES
PRODUCIDAS LOCALMENTE**

RESUMEN

Este trabajo resume el proyecto del sistema energ tico experimental que debe ser desarrollado como medida estrat gica de mejoramiento de la competencia estrat gica de la Zona de Desarrollo Industrial (ASI) de Arag n - Favara en la provincia Agrigento. El objetivo del Proyecto es desarrollar un sistema autosuficiente ("isla energ tica") que utilice solamente bioaceite de las plantaciones cultivadas localmente.

La duraci n del experimento es planificada de cuatro a os, y el objetivo final es establecer nuevas empresas lucrativas, que utilicen las ventajas de la cadena racional y sostenible para el abastecimiento de energ a. Las actividades planificadas incluyen, de hecho, la producci n agr cola y el procesamiento

de aceite, tanto como las industrias intensas energéticamente, que ya se encuentran en esta zona. Los beneficios en la escala industrial, de acuerdo con el concepto pensado, serán logrados por amplificación de planes experimentales una vez probada la rentabilidad satisfactoria en la escala menor.

En el trabajo, primero se describen los principios estratégicos del proyecto, sobre todo el concepto de "cadena de abastecimiento abreviada". Luego se considera la Zona de Desarrollo industrial (ASI) Aragona-Favara, con vista a las necesidades energéticas, que deben ser satisfechas con la energía renovable. Después de ello se analiza el lado abastecedor, concentrándose en cómo estructurar la cadena de abastecimiento abreviada para los cultivos oleaginosos (girasol y colza) reservando ciertas superficies agrícolas para la producción de cultivos industriales. Se consideran también los estímulos y la promulgación de leyes a nivel nacional en el ámbito de energía renovable, para presentar las posibilidades de mercado para la comercialización de energía y biocombustible, que se produzcan tras la finalización de la fase experimental.

Luego fueron presentados los detalles técnicos del Proyecto, con la descripción del proceso y explicación cómo fue determinado el tamaño de las plantas experimentales, para que lograra el balance energético del flujo, evitando el empeoramiento de situación con el calentamiento global en el marco temporal dado del experimento. Es dada la descripción de las actividades vinculadas con la construcción y el funcionamiento de los sistemas experimentales, tanto como los futuros planes y sus consecuencias estratégicas.

El Proyecto ha sido conceptualizado por parte de CIFRA – Centro Interdepartamental de Investigaciones Ecológicas y Formación de la Universidad de Udine, en el nombre y colaboración con la Unión Industrial de Agrigento.

SYSTÈME AUTONOME ("ÎLE ÉNERGÉTIQUE") UTILISANT UNIQUEMENT DE L'HUILE BIO DE CULTURES PRODUITES LOCALEMENT

RÉSUMÉ

Cet article résume le projet de système énergétique expérimental qu'il faut développer en tant que mesure stratégique d'amélioration de la compétitivité du Secteur de Développement Industriel (ASI) d'Aragona – Favara dans la province d'Agrigento. Le but de ce projet est de développer un système autosuffisant ("une île énergétique") qui utiliserait uniquement de l'huile bio des cultures locales.

La durée de l'expérience projetée est de quatre ans et son but ultime est l'établissement d'entreprises nouvelles rentables qui utiliseraient les avantages de la chaîne rationnelle et durable pour se fournir en énergie. Les activités projetées incluent, en fait, la production agricole et la transformation de l'huile ainsi que des industries à industrie énergétique qui se trouvent déjà dans cette région. Les bénéfices sur une échelle industrielle seront atteints par le développement d'usines expérimentales correspondant au concept original quand une rentabilité satisfaisante aura été démontrée sur une échelle réduite.

L'article décrit d'abord les principes stratégiques du projet, surtout le concept de "chaîne d'approvisionnement abrégée". Puis, il observe le Secteur de Développement Industriel (ASI) d'Aragona-Favara du point de vue des besoins énergétiques qui doivent être satisfaits par l'énergie renouvelable. Puis, il analyse le sujet de l'approvisionnement se concentrant sur la manière de

structurer une chaîne d'approvisionnement abrégée pour les cultures oléagineuses (tournesol et colza) en réservant des surfaces agricoles déterminées pour la production de cultures industrielles. Il observe aussi les stimulants et la législation nationale dans le domaine de l'énergie renouvelable pour définir les possibilités du marché dans le placement de l'énergie et du biocarburant qui sera produit après la phase expérimentale.

Puis, il présente les détails techniques du projet avec une description du procédé et un compte-rendu de la manière dont les dimensions des usines expérimentales ont été déterminées pour atteindre le bilan énergétique de développement de la production tout en évitant une détérioration de la situation dans le cadre temporel de l'expérience. Il décrit les activités liées à la construction et au fonctionnement des systèmes expérimentaux ainsi que les projets à venir et leurs conséquences stratégiques.

Le projet est conçu par le CIFRA – Centre interdépartemental pour la recherche et l'éducation écologiques de l'Université d'Udine – au nom et en collaboration avec l'Union Industrielle – Agrigento.

