Contract N°: COOP-CT-2004-512877

WACOSYS

- Monitoring and Control System for Wastewater irrigated Energy Plantations -

Instrument: Co-operative research project

Thematic Priority: Specific research activities for SMEs

Publishable final activity report

– Part of D26: Progress Report 4 & Final Report–
–M9 Final Review –

Due date of deliverable: 31st December 2006
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Start date of project: 1st October 2004 Duration: 27months

Organisation name of lead contractor for this deliverable: BIOAZUL

(Final version)

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission	
CO	Confidential, only for members of the consortium (including the Commission Services)	**X**

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1. PROJECT EXECUTION

PROJECT SUMMARY

A main objective of the European Commissions energy policy is to raise the amount of renewable energies from currently about 6% up to 12% from total energy generation until 2010. Therefore a huge potential is seen in the application of biomass, which is competitive, storable, CO2-neutral and in connection with wastewater an extreme low-cost fuel for heat and power generation.

The current main biomass sources like forest-wood, recycle-wood and biogas can not meet the future demand for heat and power generation in Europe. Therefore, it is necessary to develop high efficient and low-cost biomass production systems. Wastewater irrigated Short Rotation Plantations (SRP) can contribute to meet these requirements because they use the advantages of communal wastewater as a source for cheap fertilisation and irrigation for the cultivation of fast growing combustible energy crops (e.g. willows, poplars). Due to this procedure these SRP's also can contribute to a low-cost and environmentally safe biological wastewater treatment for about 25.000 small communities in Europe (135 million citizen) which are not yet connected to central wastewater treatment systems but soon have to fulfil new EU environmental legislation.

The aim of the WACOSYS-project is to develop, test and optimise a monitoring and control system (WACOSYS-system) for wastewater irrigation of SRP's which guarantees SRP-operators a safe and more efficient production in their plantations. The WACOSYS-System consists of a combined sensor-detector-dosage system which includes a monitoring, control and distribution unit which enables the dosing and distribution of the wastewater in accordance to the plantations demand for optimum plant growth and maximum uptake rates while observing critical loads in the effluent to avoid environmental pollution. That will strengthen the competitiveness of SRP produced biomass against other fuels and combustibles and will ensure the compliance with European and national environmental legislation.

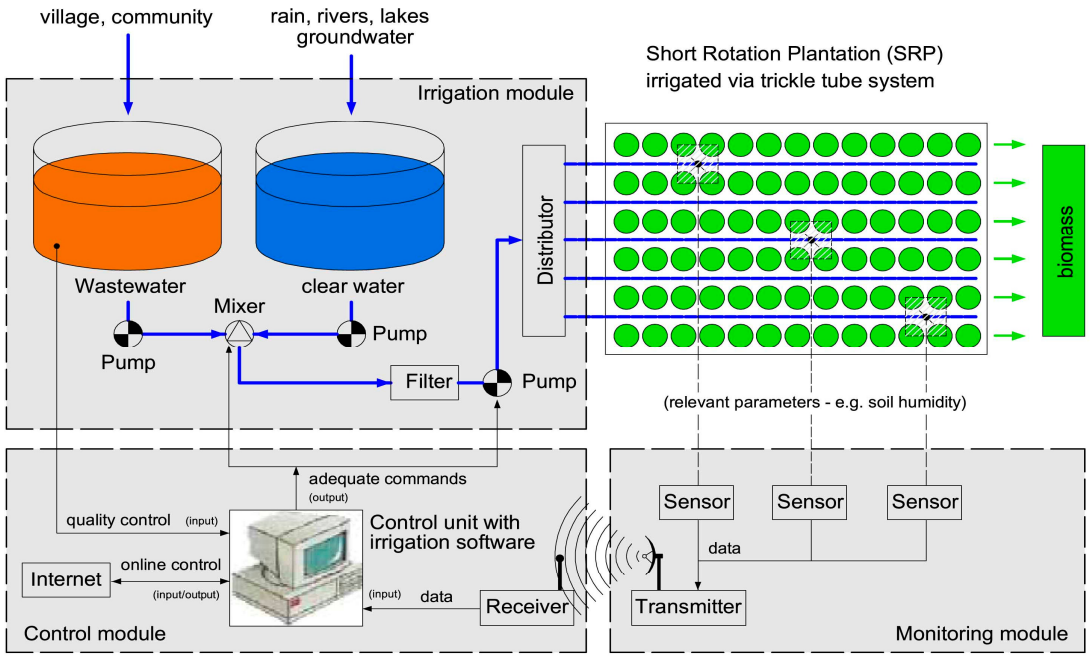

Figure 1. WACOSYS system scheme

The WACOSYS project has tested the performance efficiency of the WACOSYS system for its practical and commercial application within existing Short Rotation Plantations working with different clones from willows and poplars under different climatic conditions (Estonia and Spain). In the case of Spain, a mixture of waste and clear water has been used, while in Estonia the willows were irrigated only with wastewater.

PROJECT OBJECTIVES

The industrial main objectives of the WACOSYS project can be summarised as follows:

- to develop, test and optimise an innovative and economic monitoring and control system for irrigation and fertilisation of biomass producing Short-Rotation-Plantations with wastewater,
- to guarantee high efficient, low-cost and sustainable production of combustible biomass products (e.g. wood pellets),
- to reduce wastewater treatment costs for small communities up to 80%.

The environmental objectives of the WACOSYS project are:

- to generate a local, renewable and CO2 neutral source of energy (Kyoto protocol),
- to avoid pollution of surface water and groundwater resources,
- to improve the quality of surface waters in areas where a high percentage of the population currently has no connection to wastewater treatment facilities (especially in Eastern Europe),
- to save scarce water resources by enabling the re-use of wastewater for agricultural irrigation,
- to develop a system which is closing the nutrient loop on local level, by producing biomass for certain purposes with economic value.

The social objectives of the WACOSYS project comprise:

- to strengthen rural areas (create employment, local products, push local economy),
- to promote the creation of new employments in the European renewable energy sector,
- to open up new markets for renewable energy consumption.

CONTRACTORS LIST

The contractors involved in the project are shown in the following list:

Partic. Role*	Partic. Type	Partic. no.	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	SMEP	1	HYDRO-AIR GmbH Jüterbog	HYDRO-AIR	Germany	1	27
CR	SMEP	2	BIOAZUL S.L.	BIOAZUL	Spain	1	27
CR	SMEP	3	STAB Tratamento de Águas e Biotecnologia LDA	STAB	Portugal	1	27
CR	SMEP	4	Munitsipaalasutus Karjäär	MAK	Estonia	1	27
CR	SMEP	5	Antonio Ramos Fernández	RAMOS	Spain	1	27
CR	SMEP	6	Parkanon Oy	PARKANON	Finland	1	27
CR	RTD	7	Estonian Agricultural University	EAU	Estonia	1	27
CR	RTD	8	Warsaw Agricultural University	WAU	Poland	1	27

CR	RTD	9	Verein zur Förderung des Technologietransfers an der Hochschule Bremerhaven e.V.	TTZ	Germany	1	27

Table 1: Contractors list

*CO = Coordinator / CR = Contractor

The contact details of the co-ordinator of the project are the following:

HYDRO-AIR GmbH Jüterbog
Flugplatzweg 1
Niedergörsdorf, 14901, Germany
Telephone: 0049 33741 6206 0
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E.mail: info@hydro-air.de

WORK PERFORMED

WACOSYS project pretends to develop, test and optimise a monitoring and control system for wastewater irrigation of Short Rotation Plantations (SRPs) which guarantees their operators a more efficient and environmentally-hygienically safe production of renewable biomass in their plantations, consisting of a combined sensor-detector-dosage system which includes a monitoring, control and distribution unit that enables the dosing and distribution of the wastewater in accordance to the plantations demand for optimum plant growth and maximum uptake rates while observing critical loads in the effluent to avoid environmental pollution. The system is proposed to be tested using several clones and under different climatic conditions in Spain and Estonia

The work carried out in WACOSYS was organized into 7 workpackages (WP). Each workpackage can be broken down into a number of tasks to be carried out by teams from within the total consortium. The project flow diagram below illustrates the sequence of major events. The six first WPs correspond to reaserch and innovation activities, and number 7 is the management workpackage.

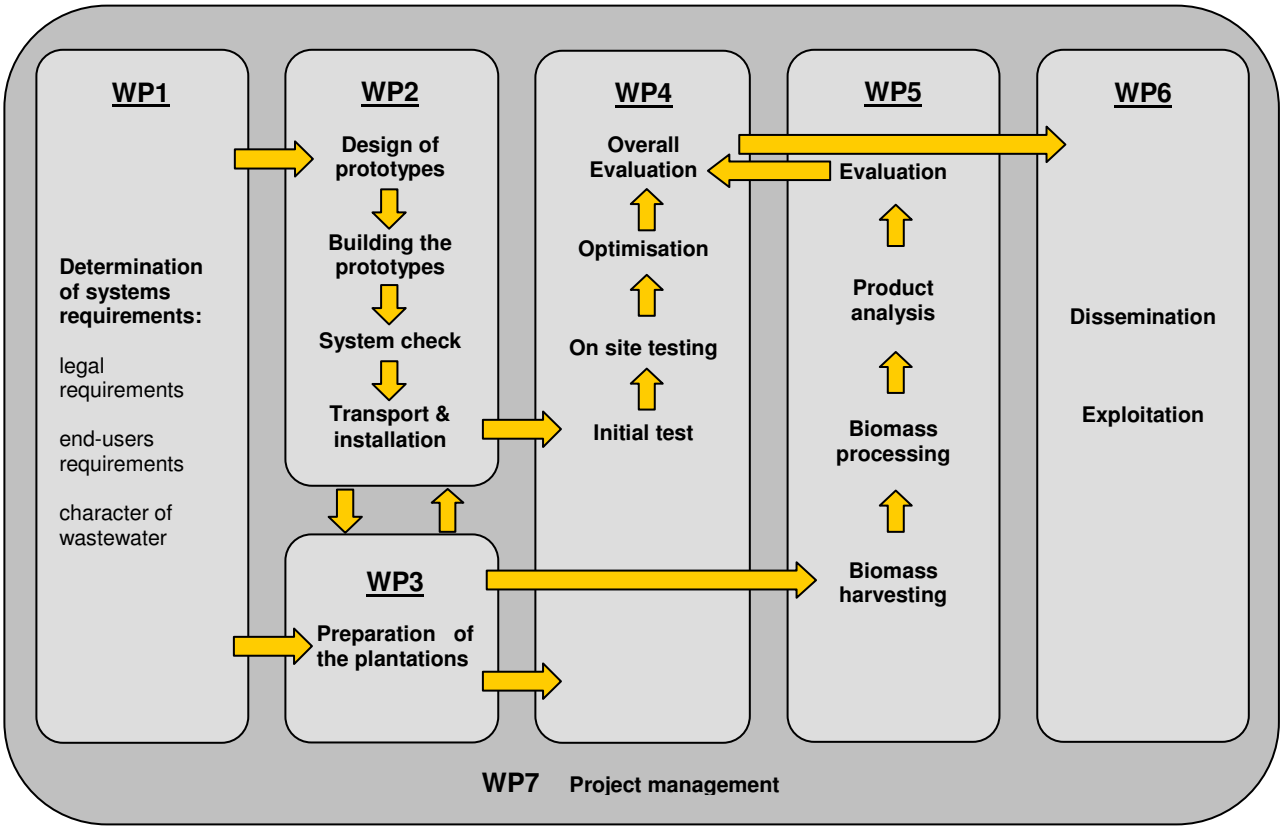

Figure 2. Interdependencies between workpackages

These workpackages were time-distributed according to the following diagram:

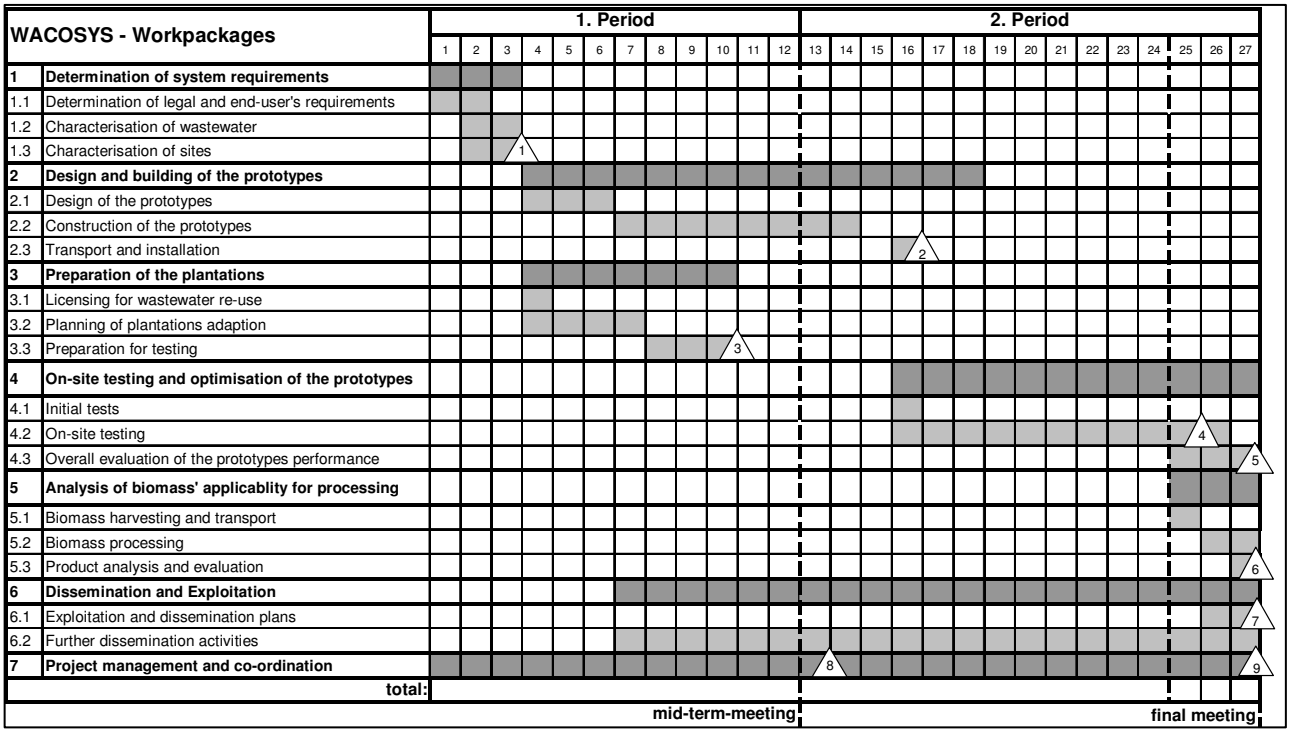

Figure 3. Diagram of the time distribution of the workpackages

The explanation of the development of every workpackage (per task) is offered bellow:

Workpackage no.	**WP 1 – Determination of system requirements**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

Workpackage objectives

The aim of this WP is to develop the sheet of requirements for the WACOSYS system which will be the basis for the later design of the system in WP2.

Task 1.1: Determination of legal and end users' requirements

A previous survey on the situation of the legislation regarding the re-use of wastewater for irrigation of SRP's at regional, national and European levels was necessary in order to determine the legal restrictions to be met by the WACOSYS prototypes and the foreseen commercial units.

The legal requirements for wastewater discharge at European, national and local level were surveyed, as well as the discharge limits parameters. In order to get a deeper approach to the specific needs of the end-users business a questionnaire was elaborated and filled in by the end-users and pellet producer of the consortium, experiences and reluctances from their business.

After this legal survey, it was determined that during the WACOSYS project the legal requirements will be fulfilled for both test fields, in Estonia and Spain. In both countries no regulation exists that definitely excludes any application of wastewater and sludge for irrigating and fertilising non-food crops on agricultural land. Accumulation of heavy metals and other pollutants in the soil, as well as avoiding the wastewater reach directly what is

known as the “public wastewater domain” in Spain was a concern during the project, being constantly monitored.

Task 1.2: Characterisation of the wastewaters applied for irrigation

The wastewater to be used for irrigating the constructed plantations at the end-user’s was characterised, allowed to have exact information on the relevant monitoring and control parameters of the system.

In the case of Spain, the wastewater quality appeared to behave rather constant without major changes in properties, according to the analyses performed. However in all cases, values on BOD, COD, suspended solids, total phosphorus and nitrogen were above the threshold established by Spanish legislations for discharge into receiving water bodies. A wastewater treatment system is therefore strongly required before discharging it. Heavy metal presence in the wastewater was almost not detectable.

In the case of Estonia, BOD was higher than the legislation limits in some samples of winter months. This could be explained with the decrease of microbial activity during low temperatures. In some cases also the phosphorus content is above limits. However, concentration of both of the above-mentioned compounds is low enough for usage in the experimental prototype without hygienic risks.

Task 1.3: Characterisation of the sites used for irrigation

A thorough characterisation of the fields to be used for the installation and test of WACOSYS prototypes was carried out, including climatic conditions, natural site conditions, cultivation conditions, infrastructure, and short socio-economic analysis.

The CAD plans of both prototypes areas can be observed below:

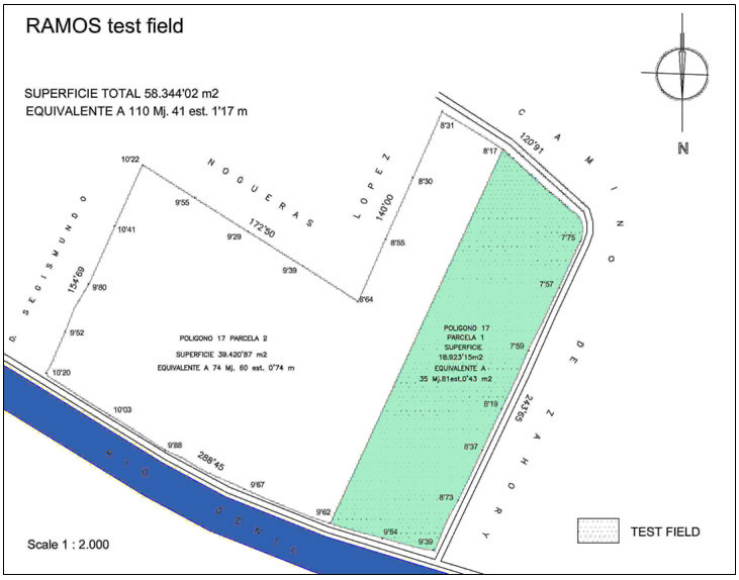

Figure 4.CAD plan of test field in Spain

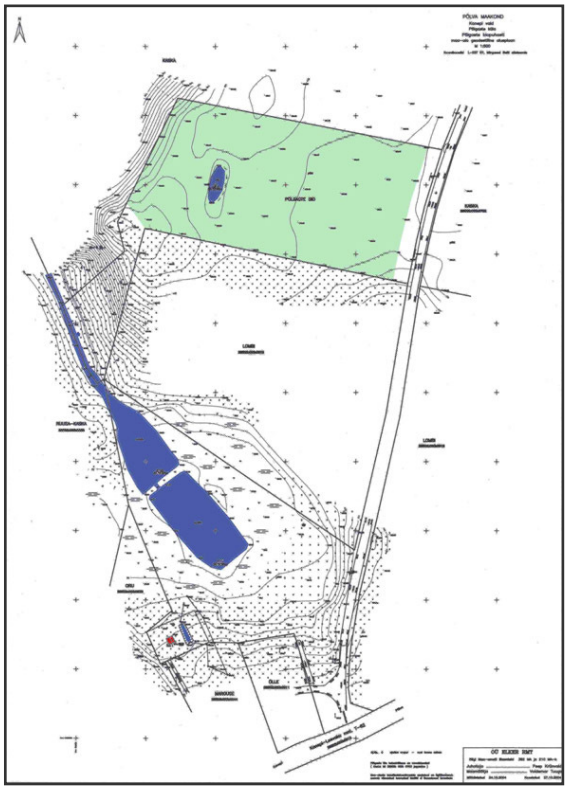

Figure 5 and 6. CAD plans and photo of test field in Estonia

Workpackage conclusions:

WACOSYS, as a decentralised wastewater treatment method with additional biomass generation from fast growing tree species, seems to be a good method for purifying the characterized wastewater by using Short Rotation Plantations and test fields are suitable areas for the project tests.

Workpackage no.	**WP 2 – Design and building of the prototypes**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

Workpackages objectives

The aim is to design and build the WACOSYS prototypes which will be later taken to the end users for onsite testing.

Task 2.1: Design of the prototypes

CAD plans on the design of the prototypes were elaborated and all material for the building of the prototype was identified and listed. In a report, it was explain in detail the plan for the final construction of the systems by modules (Irrigation, control and monitoring), including power supply, dosage unit, etc.

Task 2.2: Construction of the prototypes

According to the designs produced previously both prototypes were constructed. A thorough system check was carried out before the prototypes installation in order to ensure the proper functioning of all components.

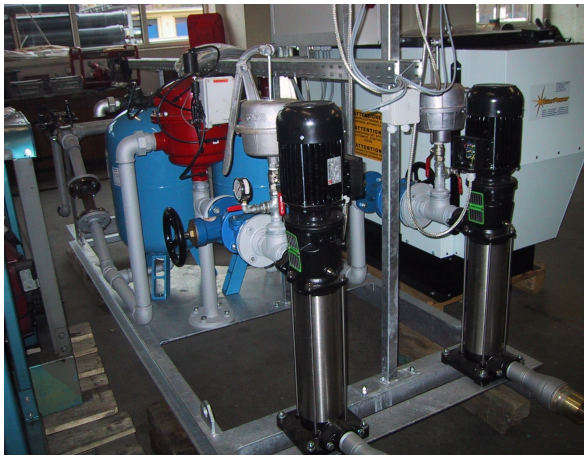

Figure 7 and 8. Estonian and Spanish prototypes under construction

Task 2.3: Transport and installation

After the finalization of its construction, both prototypes were transported to the test areas: Granada (Spain) and Põlgaste (Estonia). After the installation, an irrigation check was performed (with clear water in Granada) in order to ensure the good connection between components and a safe and efficient use of the prototypes.

The prototype was installed into a pumping house in Estonia and into a container in Granada. This measure was undertaken in Spain in order to protect the system from the high temperatures in summer and the theft attempts.

Figure 9 and 10: Spanish prototype inside the container and sensor probe with the battery surrounded by poplars.

Figure 11: container, solar panel and sending antenna in the Spainish testing site

Figure 12 and 13. Estonian prototype in the puma house and installation of sensors

Workpackage conclusions:

The prototypes were duly constructed according to the local requirements of the end-users. The installation was performed in the areas prepared with this purpose (see WP 3)

Workpackage no.	**WP 3 – Preparation of the plantations**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

Objectives

The aim of the third workpackage is the preparation of the two plantations for appropriate testing conditions of the WACOSYS prototypes.

Task 3.1: Licensing for wastewater re-use

In order to ensure conformity with local legal requirements the local authority was asked for specific operational warranties for the testing sites. Regarding the use of wastewater for crops irrigation, no license was required for this kind of experimental tests, according to the local authorities. Nevertheless, a radio-wave emission licence was necessary in both cases (Põlgaste and Granada) in order to be capable to send the collected data from the sensor in the field to the control unit (situated in a PC, installed in the end-users private dependencies).

Task 3.2: Planning of plantations adaptation

In this task, a preparation plan to adapt the testing sites before installing the prototypes (to be followed in task 3.3) was elaborated, concerning aspects like necessary measures against vandalism (fencing), measures to ensure public safety and environmental warranties (fence, warning signs), power and clear water supply, necessary infrastructure, cultivation activities, etc.

Task 3.3: Preparation for testing

The plan produced in the previous task was put into practice. Thus, once the prototypes were transported and installed, the plantations were already adapted (protection and warning measures, trees already planted and stable, wastewater and storage containers and ponds installed, etc.) and ready to start with the test.

In Spain, two poplar plots were irrigated with the WACOSYS system. One of them was irrigated only with clear water, and the other with a mixture of waste and clear water. In the case of Estonia three plots were irrigated with wastewater.

Workpackage conclusions

Although some of the preparation measures were not foreseen in the initial Technical Annex of the project, their application was needed and the result was a complete preparation of the test fields. Nevertheless, all measures mentioned in the initial plan were undertaken.

Workpackage no.	**WP 4 – On-site testing and optimisation of the prototypes**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

Objectives

The aim of the fourth workpackage is to test the whole system under different local conditions for different crops (willows and poplars) as they can be found in the Estonian and Spanish plantations.

Task 4.1: Initial tests

Once the prototypes were installed in both plantations, the first system check was performed.

This initial test comprised a thorough checking of the system components and their performance in system combination. All the programmes were run with fresh water checking the following:

- Irrigation grid: Optimal distribution of the water.
- Maximum capacity: Maximum capacity of pumps, pipes and trickle tubes.
- Leaching: Control measures for the soil fields capacity.
- Leakage: Optimal work of pipes and tubes.

The system programmes available for the irrigation of the fields combine the use of fresh and wastewater in Spain, irrigating both fields simultaneously or consecutive. The mentioned programmes are detailed in the following table:

Programme	Description	Total water flow
1	Consecutive irrigation of Field 1 and Field 2 with fresh water	Fresh water: 10,4 m^3/h each Field
2	Simultaneous irrigation of both Fields: *Field 1:* with fresh water *Field 2: mixture 1:1 of fresh and waste water*	Fresh water: 15,6 m^3/h Waste water: 5,2 m^3/h
3	Consecutive irrigation of the Fields: *Field 1:* with fresh water *Field 2:* mixture 1:1 of fresh and waste water	*(Field 1):* Fresh water: 10,4 m^3/h *(Field 2):* Waste water: 5,2 m^3/h Fresh water: 5,2 m^3/h

Table 2. Irrigation programmes in Spanish WACOSYS prototype.

Regarding Estonia, the following table shows a description of the irrigation programme used, which irrigates the three fields at different times:

	Time	Water Flow
Field 1	23:00 – 02:55	4 m^3/h
Field 2	03:00 – 06:55	4 m^3/h
Field 3	07:00 – 11:00	4 m^3/h

Table 3. Irrigation programmes in Estonian WACOSYS prototype.

Task 4.2: On-site testing

This task is focused on the testing of the whole system under different local conditions and for the different crops (poplars in Spain and willows in Estonia) that were planted in both test fields. The testing mainly consisted on operating the prototypes, analysing the system behaviour and evolution, while overcoming the emerging technical challenges to optimise the prototype and its performance that the consortium is facing since the installation of the system.

The overall performance of the system was determined by periodical measurements of different parameters (soil, water and biomass parameters). The complementary experience of the consortium partners allows an accurate optimisation of the prototypes and its performance. The performance of the system was optimized along the vegetation period and expecting a smooth operation of the prototype and its components by the end of the project.

An example of the irrigation monitoring, two tables of Ramos and MAK plantations respectively are provided below:

Date		N° of irrigations /week	Programme	Water volume applied			Flowmeter	
Month	Week (from-to)			Field 1	Field 2		Fresh water	Waste water
				Fresh water	Fresh water	Wastewater		
March	13-19	1	1	17´5	17´5	0	35	0
	20-26	1	1	17´5	17´5	0	70	0
	27-02	1	1	17´5	17´5	0	105	0
April	03-09	1	1	17´5	17´5	0	140	0
	10-16	1	1	17´5	17´5	0	175	0
	17-23	1	1	17´5	17´5	0	210	0
	24-30	1	1	17´5	17´5	0	245	0
May	01-07	1	1	17´5	17´5	0	280	0
	08-14	1	1	17´5	17´5	0	315	0
	15-21	1	1	17´5	17´5	0	350	0
	22-28	2	2	35	17´5	17´5	367,5	17,5
	29-04	2	2	35	17´5	17´5	385	35
June	05-11	2	2	35	17´5	17´5	402,5	52,5
	12-18	2	2	35	17´5	17´5	420	70
	19-25	2	2	35	17´5	17´5	437,5	87,5
	26-02	2	2	35	17´5	17´5	455	105
July	03-09	2	2	35	17´5	17´5	472,5	122,5
	10-16	2	2	35	17´5	17´5	490	140
	17-23	1	2	17´50	8,75	8,75	507,5	148,75
	24-30	1	3	10,00	0	0	517,5	148,75
August	31-06	2	1	17,5	17,5	0	552,5	148,75
	07-13	2	1	17,5	17,5	0	587,5	148,75
	14-20	2	1	17,5	17,5	0	622,5	148,75
	21-27	2	1	17,5	17,5	0	657,5	148,75
Septe mber	28-03	1	2	17,5	8,75	8,75	683,75	157,5
	04-10	1	2	17,5	8,75	8,75	710	166,25
	11-17	1	2	17,5	8,75	8,75	736,25	175
Total volume of water applied by WACOSYS prototype /[m^3]							**736,25**	**175**

Table 4. Irrigation monitoring in RAMOS plantation

Date	Time	Water meter indication m^3	Water volume m^3	Comment
			78	Installation and test period
6.06.2006	16.00	78		Pump stopped, dry run indication
7.06.2006	13.00			Pump does not switch on, dry run indication
7.06.2006	21.00			Dry run indication
8.06.2006	9.00			Dry run indication
8.06.2006	11.30	132,72	54,72	OK
9.06.2006	9.45	132,72	0	Pump stopped, dry run indication
9.06.2006	11.10	137,33	4,61	
9.06.2006	13.00	137,46	0,13	Pump stopped, test regime
12.06.2006	8.27	137,59	0,13	Pump stopped, dry run indication, manual pumping needed
12.06.2006	19.25	183	45,41	1 plot irrigated, during over switch leakage of pipe in pump house
13.06.2006		218,51	35,51	OK
13.06.2006		219,13	0,62	Red lamp on
13.06.2006	23.00	219,13	0	Red lamp on
14.06.2006	9.00	260,09	40,96	OK
14.06.2006	13.15	266,89	6,8	Pump stopped, dry run indication
14.06.2006	17.42	266,89	0	Pump stopped, dry run indication
14.06.2006	18.10	267,14	0,25	OK
14.06.2006	22.45	267,14	0	Pump stopped, dry run indication
15.06.2006	18.45	314,51	47,37	Pump stopped, dry run indication
15.06.2006	21.05	314,68	0,17	Pump stopped, dry run indication
16.06.2006	10.00	314,98	0,3	Pump stopped, dry run indication
16.06.2006	14.00	318,73	3,75	Pump stopped, dry run indication
18.06.2006	8.05	365,11	46,38	Pump stopped, dry run indication
19.06.2006	8.05	375,94	10,83	Pump stopped, dry run indication
19.06.2006	12.40	395,23	19,29	OK
19.06.2006	22.37	437,86	42,63	System operational
20.06.2006	8.40	476,35	38,49	System operational
20.06.2006	12.20	484,79	8,44	
20.06.2006	16.50	485,2	0,41	Pump stopped, dry run indication, manual irrigation control regime
21.06.2006	8.10	550,94	65,74	System operational
				Water shortage, system switched off
12.07.2006	11.20	802,42	251,48	System stopped
12.07.2006	20.00	842,35	39,93	II plot irrigated, system switched to automatic regime
13.07.2006	8.00	842,35	0	Pump stopped

17.07.2006	7.20	853,27	10,92	Pump stopped, I plot automatic irrigation switched on
18.07.2006	8.45	927,4	74,13	Pump stopped
18.07.2006	9.05	929,64	2,24	System operational, III plot irrigated
18.07.2006	10.30	934,3	4,66	System operational, III plot irrigated
18.07.2006	10.45			Filter back flush
18.07.2006	11.00	935,77	1,47	Pump stopped, dry run indication, high pressure in system (3,4 bar)
18.07.2006	11.18	935,77	0	System tries to switch on, dry run indication blinks, does not start to irrigate
18.07.2006	11.21	935,77	0	Pump runs, dry run indication blinks, water is not pumped
18.07.2006	11.23	935,77	0	Pump stopped, dry run indication
25.07.2006	13.16	935,77	0	Pump stopped, dry run indication
				Water shortage, system switched off
15.08.2006	11.18			Manual switch on, three plots irrigated
15.08.2006	14.00	947,05	11,28	System operational
16.08.2006	8.30	1025,38	78,33	System switched to automatic regime
16.08.2006	11.20	1033,43	8,05	System operational
17.08.2006	10.05	1076,67	43,24	
23.08.2006	18.05	1080,27	3,6	System switched to automatic regime
24.08.2006	18.10	1126,71	46,44	System operational
25.08.2006	9.30	1167,68	40,97	System operational
28.08.2006	10.30	1313,29	145,61	System operational
28.08.2006	18.00	1343,86	30,57	System switched off, water shortage
14.09.2006	8.45	1343,86	0	System switched on
15.09.2006	11.05	1399,35	55,49	Pump stopped
18.09.2006	10.45	1399,35	0	System switched on
19.09.2006	9.50	1492,26	92,91	OK
21.09.2006	12.40	1548,5	56,24	System switched off, water shortage
4.10.2006	10.05	1570,49	21,99	OK
9.10.2005	14.35	1601,52	31,03	System switched off for this year, night frosts.
		Total	**1601,52**	

Table 5. Irrigation monitoring in MAK plantation

The technical setbacks arisen concerning the operation of the systems during the project were duly overcome and a proper functioning of the prototypes was achieved.

The data collected by the sensor probes in the fields, was transferred through the datalogger to the control unit (PC in end-users dependencies) via radiowaves. This information was processed by an irrigation software called IRRIMAX, producing two kind of graphics. Both graphics show the water content in the soil at different times (every 30 minutes). The graphic “Summed” represents the total (summed) water content present in

the first metre of the soil, while the graphic “Single” represents the water content every 10 cm, from the surface to one metre depth. This information is provided from only one or from each one of the 4 probes installed in Estonia and Spain installed, depending on the graphic. Thanks to this information provided by the irrigation software, the farmer is able to analyse the plantation requirements and to decide the best moment to irrigate.

Some examples of graphic produced by this system are shown below:

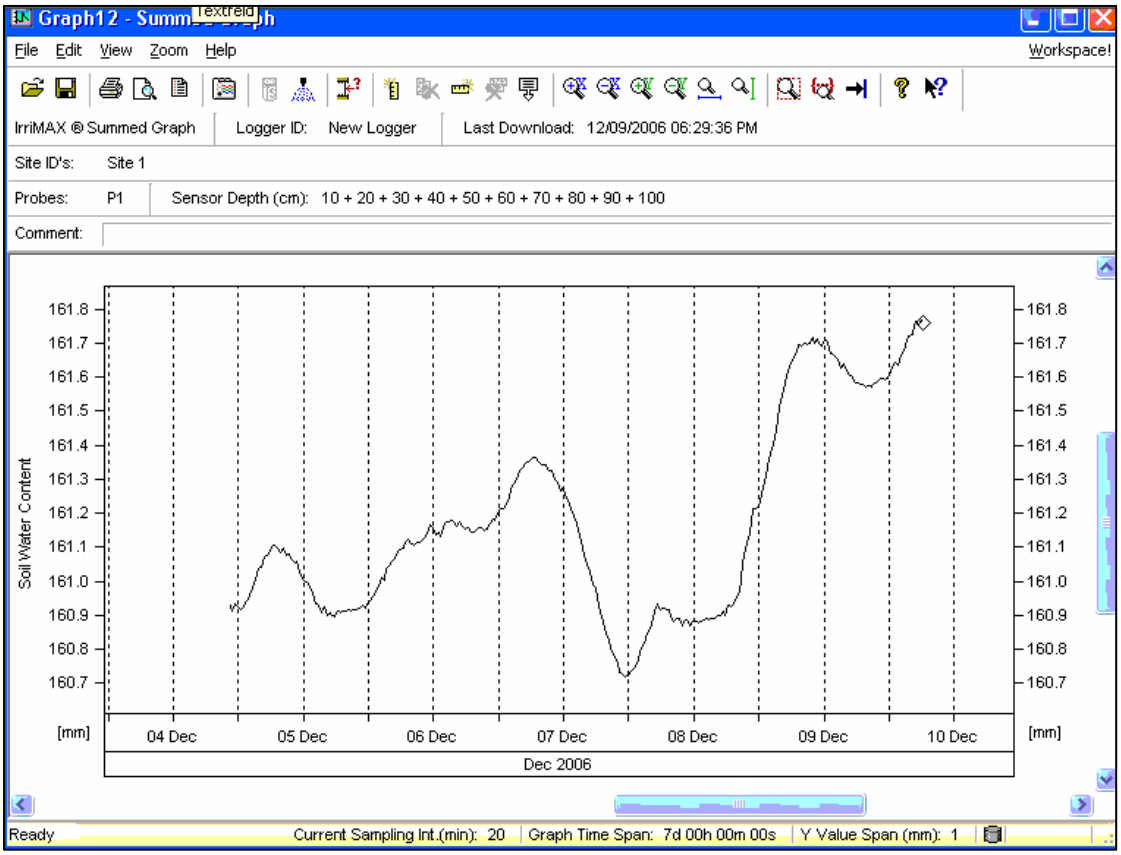

Figure 14. Example of monitoring results received in Ramos’ PC

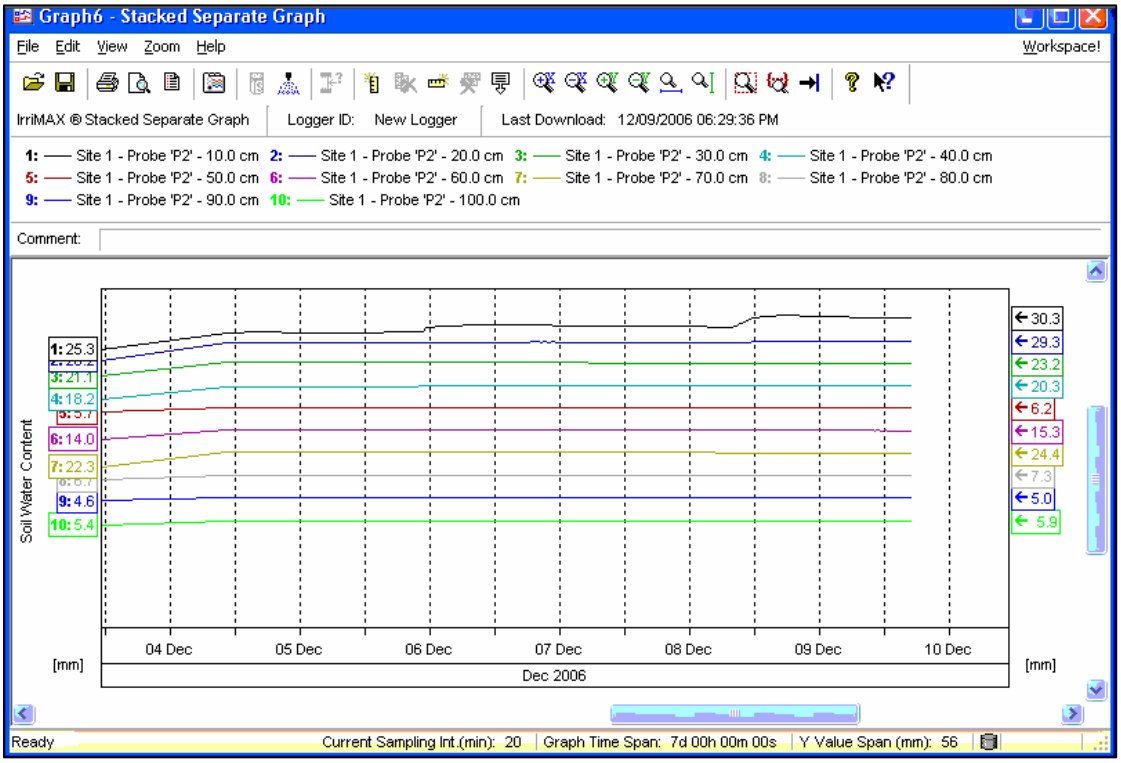

Figure 15. Example of monitoring results received in Ramos’ PC

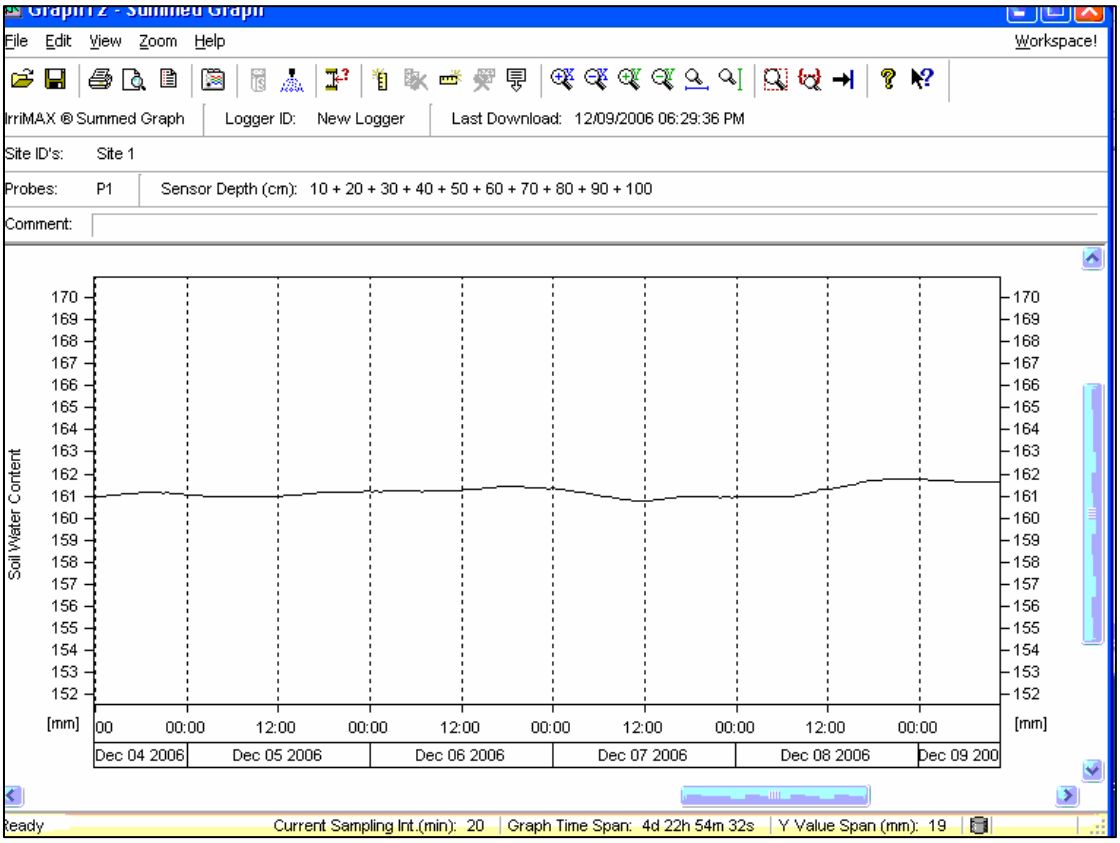

Figure 16. Example of monitoring results received in Ramos' PC

Task 4.3: Overall evaluation of the prototypes performance

In spite of the technical setbacks arisen, promising results in relation to the prototype performance, wastewater purification, soil state, biomass yield and pellets quality and applicability were achieved.

Parameters concerning the overall system check, water, soil and biomass were gathered during the tests in order to evaluate the prototype performance and ensure a safe practice.

Once the biomass was processed into pellets, also this material was analysed and evaluated. More information concerning the pellets can be found in WP5.

Figure 14. Example of soil simple taken in the plantation of Granada

Further more, an overall assessment of the system including irrigation and fertilization performance, treatment performance, biomass applicability, operating costs, maintenance operations, ease of use, etc., with a view on the potential market, in order to evaluate the suitability of the WACOSYS system developed (Economic Feasibility Calculation).

Workpackage conclusions

Despite of some small required adjustments on the irrigation module regarding the wastewater intake method (Estonia), the biogas formation inside the wastewater intake pipe and the clogging of the magnetic valve (Spain), its performance turned out

to fulfil the expectations of the partners.

The monitoring module required the most comprehensive modifications against the original plans. These changes, mainly performed in the module's control box cabling were crucial in order to obtain an overall system's operation. Due to difficulties to identify and correct these malfunctions, the monitoring module could not be long-term tested and operated but once the monitoring module was completely optimised, it performed sophisticated.

The control module could not be finalised in a way that allows full control of the prototype via internet as it was originally one aim of the project. An alternative solution was adapted and installed in Estonia via GSM technology, but due to specific on-site conditions of the Estonian test plantation, which led to the cellular phones being permanently out of coverage, its performance could not be properly studied. In the Spanish test plantation, due to the lack of electrical power supply, a GSM-control was not possible.

By taking into account the specific on-site testing conditions the whole WACOSYS system performed properly as a "monitoring and control system for wastewater irrigated energy plantations". Moreover, during the tests in Spain and Estonia the adaptability of the WACOSYS system to different site conditions was proved.

During the test and optimisation phase, the partners found that there are some site specific aspects that are especially to be taken into consideration prior the installation of the WACOSYS system. In order to get fully operative WACOSYS systems, electrical and wastewater supply should be always available. The geographical plantations conditions are to be carefully analysed in order to avoid transmission problems with the radio transmission between monitoring and control module. Also vandalism has shown to be an important limiting factor of the WACOSYS system, and all protective measures like fencing, or surveillance systems are strongly recommended.

Workpackage no.	**WP 5 – Analysis of the biomass' applicability for further processing**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

Objectives

The aim of the fifth workpackage is to ensure the applicability of the WACOSYS biomass for further processing which will have an enormous influence on further commercialisation.

Task 5.1: Biomass harvesting and transport

After the finalization of the tests, the biomass produced was harvested in both plantations with the help of the traditional means. Below, some images of the harvesting work.

Figures 15 and 16: Willows harvest in Estonia

Figures 17 and 18: Poplars harvest in Spain

The harvested biomass was packed and sent to the partner devoted to pellet production.

Task 5.2: Biomass processing

Although the pelletization was rather difficult due to the unusual water content of the material the objective was successfully achieved. Before the pelletization process, a drying pre-treatment of the biomass was required.

The result of the pelletization process is shown in the image bellow.

Figure 19: Willows (left) and poplar pellets (right)

Task 5.3: Product analysis and evaluation

The pellets produced were analysed taken into account the water content, heavy metal content, heating value, gross density and pour weight abrasion, ash content and recycle.

Some of the results obtained after the mentioned analyses are shown in the table below.

Some of the results obtained after the mentioned analyses are highlighted below.

- The average moisture found for willows and poplars were 48% and 60% respectively. While its pellets count just with 12% and 18% moisture respectively.
- The average effective heating values for willows and poplars for bark and xylem were 11855 J/g and 11218 J/g respectively. While the processed pellets were found to be 21029 J/g for willows and 20962 J/g for poplars.
- The density of willows biomass was calculated to be 1,178 g/cc, while the poplar pellets had an average density of 0,885 g/cc.

- As it was expected due to the wastewater analysis, no significant accumulation of heavy metals were found neither in the biomass samples, nor in the processed pellets for both test plantations.

Workpackage conclusions

The poplars from the Spanish test plantation irrigated with wastewater accumulated more elements than poplars irrigated with fresh water. Although the difference between them were not considerable. It was hard to process poplar crops into pellets even after the drying, since poplar is among the wettest woods when freshly felled. Willow biomass had about 19% water content after drying and it was suitable for further processing into pellets. Despite some problems with high biomass water content of willows and poplars, the pelletisation was successful accomplished. Comparing the parameters of pellets processed from plant sticks from two different WACOSYS plantations it might be stated that pellets made from willow sticks generally had better physic-chemical properties as they contained less nitrogen than pellets made from poplar wood. In general, WACOSYS pellets seem to be applicable on large scale on European markets providing that the burning characteristics of pellets are controlled to avoid the risk with the incomplete combustion, which may lead to uncontrolled emissions of environmental and hazardous compounds.

Workpackage no.	**WP 6 – Dissemination and exploitation**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

Objectives

The aim of this work package is to disseminate the project results for the later commercialisation and exploitation of the WACOSYS system and system components.

Task 6.1: Exploitation and dissemination plans

After the development of the system, the consortium decided the future commercial exploitation of the WACOSYS system and the prototype system components. With this purposed, a plan for exploitation and dissemination of the system was included in the final "Plan for using and disseminating the knowledge".

According to the experience of the partners, WACOSYS prototypes could be further optimised in some aspects in order to get a fully tested and effective product. Thus, the consortium agreed in the last meeting to leave the prototypes in their current locations (test plantations) in order to continue with the tests after the finalization of the WACOSYS project. These tests will be carried out among the same partners of WACOSYS consortium in close cooperation.

More information concerning the commercial and exploitable future of the WACOSYS prototypes can be found in *section 2 "Dissemination and use".*

Task 6.2: Further dissemination activities

The project objectives and results have been continuously disseminated by the members of the WACOSYS consortium. Some of the activities carried out are publications in magazines, publication in related websites, presentation at ferias and seminars, meetings with interested actors, etc.

The most important dissemination tool developed under the WACOSYS frame is the project website: www.wacosys.info

Figure 20. WACOSYS web-site.

This website gathers general information about the project and partners, deliverables produced, pictures, etc. as well as a member restricted area with confidential information only for WACOSYS partners.

Apart from the activities already performed, numerous dissemination actions are planned to be carried out by the partners after the project finalization (publications, meetings presentation at conferences). This activities will enable the disclosing of the final results of the project and the overall assessment (not accomplish until the very end of the project).

Workpackage no.	**WP 7 – Project management and coordination**								
Participant Short name	HYDRO-AIR	BIOAZUL	STAB	MAK	RAMOS	PARKANON	EAU	WAU	TTZ

The management workpackage has had an active involvement from the beginning of the project. In this workpackage aspects like the general and financial coordination (including procedures concerning the contract, bank guarantees, payments, etc.) communication, organization meetings and elaboration of periodic and final reports have been developed. The communication among partners with the coordinator as well as with the European Commission has been also one of the main duties of this workpackage.

The mentioned assignments have been developed through the whole duration of the project, as well as after the end of the period until the submission of the final documents to the European Commission.

ACHIVEMENT OF PROJEC OBJECTIVES

In the following table, the achievement degree of the project objectives is provided.

Workpackage	WP objectives	Degree of achievement
WP1	To develop the sheet of requirements for the WACOSYS system which will be the basis for the later design of the system in WP2.	This objective was fully achieved and enabled the execution of the next WP.
WP2	To design and build the WACOSYS prototypes which will be later taken to the end users for onsite testing	This objective was fully achieved and enabled the execution of the next WP.
WP3	Preparation of the two plantations for appropriate testing conditions of the WACOSYS prototypes.	This objective was fully achieved and enabled the accomplishment of the test once the prototypes arrived to the test locations.
WP4	To test the whole system under different local conditions for different crops (willows and poplars) as they can be found in the Estonian and Spanish plantations.	This objective was fully achieved and enabled the execution of the next WP.
WP5	To ensure the applicability of the WACOSYS biomass for further processing which will have an enormous influence on further commercialisation.	Although the applicability of the biomass produced in WACOSYS project was fully characterised, its future will depend on the evolution of the use of biomass as renewable energy source
WP6	To disseminate the project results for the later commercialisation and exploitation of the WACOSYS system and system components.	Thanks to the active attitude of WACOSYS partners, this objective was fully achieved.
WP7	To ensure the correct co-ordination, communication and co-operation between the partners themselves and the Commission.	The full achievement of the objectives of this WP enabled a smooth project evolution.

Table 6. Achievement of project objectives

As a general conclusion, it can be stated that the objectives of WACOSYS project have been satisfactorily achieved.

WACOSYS system represents an innovative and economic solution for adequate irrigation and fertilization of SRPs with wastewater while avoiding negative environmental impacts, and with limited maintenance and operating costs. Additionally, it enables a safe biological decentralised wastewater treatment with reduced costs compared to common tertiary treatment plants and other decentralised solutions.

It is of an outstanding importance to raise the amount of biomass production with low costs to ensure the competitiveness with other, mainly fossil fuels. Within this frame, WACOSYS system is without a doubt one of the most realistic and feasible solutions. Furthermore, the system has a strong potential in the decentralised wastewater market.

2. DISSEMINATION AND USE

In order to disseminate the project and its main outcomes to a wider extent, different activities have been carried out during the whole project. These activities are briefly described below:

- BIOAZUL presented the project in the workshop about Energy and sustainable Development in the "1er Foro de la Innovación y la Modernización de Andalucía" (First Forum of the Innovation and Modernization of Andalusia) organised by the Consejería de Innovación, Ciencia y Empresa. It was held on 14/12/2004 at the" Palacio de Ferias y Congresos" in Málaga
- A press release was prepared by RAMOS and BIOAZUL: "Dos Proyectos de Investigación sobre usos energéticos alternativos : producción de biomasa". It was published on 13/01/05 in www.agroinformacion.com , www.agrodigital.com and in www.asajanet.com. Those are three websites very visited by farmers and farmer associations that could be interested in energetic agriculture.
- Another press release was prepared by RAMOS: "Los chopos de la vega granadina serán regados con aguas fecales para comprobar su crecimiento y producir biomasa.", and it was published in www.granadadigital.com on 13/01/05. The mentioned website is a commonly visited information mean that hold current information and news of Granada (Spain), a province with a deeply-rooted about poplars cultivation.
- Another press release: "ASAJA Granada presenta dos proyectos de investigación sobre usos energéticos alternativos", was publisehd on14/01/05 in www.agricultura.org by RAMOS as well as two additional press releases in two newspapers of Granada. One of them ("Aplican el riego con agues fecales para la producción de biomasa") was published in "Granada Hoy" and the other ("La Vega acoge un proyecto pionero para producir biomasa a partir de chopos") in "La Opinión de Granada".
- The project was introduced in the Master on Technology Management and Innovation, in the frame of the paper presentation "Gestión de Proyectos de Desarrollo de nuevos productos intensivos en tecnología: el ejemplo de BIOAZUL" on 17/03/2005. BIOAZUL also presented the project in a seminar about its experience at participating in European Projects like WACOSYS, given at the Córdoba University within the ANI+D initiative ("Programa de animación en I+D+I en Andalucía")and held the 28th March 2005. Wacosys was given as an example of a productive research project, standing out the importance of the SME's participation.
- The official project website (www.wacosys.info), deliverable 22, was set in April 2005 according to the description of work ,containing relevant information about the WACOSYS project, its main objectives, workplan description , partnership, progress made, etc. The site is available in English and Spanish. The website is a meeting point in which partners can access to all information related to the project. It is also a strong dissemination tool with a wide type of audience
- In the International Seminar "Alternativne sposoby cistenia odpadovych vod v malych obciach" held in Nitra Slovakia in April 2005 WAU accomplished a presentation of "Possibilities of wastewater irrigation and sludge utilization for energy plantation- a case study from Łódź Region" in which the WACOSYS project was introduced. Also in April 2005 WAU presented the WACOSYS project in the International Conference on "Urban and rural agro-food systems as a factor of local sustainable development" hosted by Opole Univesity in Poland. The presentation was focused on "Biomass energy plantations together with sludge and sewage utilization as a factor of local sustainable development".
- TTZ responsibles had a meeting with Dr. Martin Hoffmann (Research Institute for Fast Growing). He has several experiences in breeding and cultivating different species of populus and Salix. He did compare several different native and foreign species related to their growth rate, nutrient uptake and their sensitivity related to pest animals. The

meeting was also attended by Rolf Schulzke, (Forst-Director of the Regional Council Kassel, Germany, who participated in a 12 years populus research project in China in Jinshatan, province Shanxi, in order to test their growth behaviour especially in dry areas) and with Jörg Albrecht, (Forst-Director of Hessen-Forst, Germany, responsible for international cooperation with high interest in fast growing trees). The meeting was held at the "Forschungsinstitut für schnellwachsende Baumarten (FSB)" facilities in Hann. Münden, the 12th May 2005. In the meeting technical aspects were discussed related to the plant growth.

- In 17th May 2005 a press release was Publisher by BIOAZUL in the website www.energías-renovables.com : "WACOSYS y BIOPROS, aguas residuales y lodos para plantaciones energéticas". This website offers recent information about interesting issues always related to renewable energies. A brief description of the advances accomplished in the project to date was provided.
- In the International Workshop "Pollutant pathways and mitigation strategies of their impact on the ecosystems" held in Kazimierz Dolny (Poland) in July 2005, WAU presented "Wastewater treatment combined with nutrient reuse" in reference to the WACOSYS project, in which presentation the importance of the closed loop of nutrients was stood out.
- TTZ attended the "CONBIOT" International Conference held in Wisla (Poland) in July 2005, where the WACOSYS project was presented as well as a general approach behind it. The conference was focused in the exchange of practical experience between electricity and heat producers using biomass and alternative fuels in processes of co-firing, as well as comparing operational information with theoretical knowledge provided by representatives of scientific centres.
- A seminar for master course in Sustainable Agriculture and Environmental Health was given by WAU in Vilnius (Lithuania) in September 2005. During the seminar the WACOSYS project was presented including its aims and main achievements to date.
- In the Conference "Renewable resources and biorefineries" held in Ghent (19. -21. September), WACOSYS and the general approach behind it were presented by TTZ. The objective was to find out the market potential for Salix as renewable resource for the chemical industry, and to make further research connections in order to exploit the project approach from WACOSYS and to develop further research activities out of it.
- BIOAZUL held a meeting the 20th September 2005 with the responsible persons of the CENTA (Centro de Nuevas Tecnologías del Agua) in Seville (Spain). The CENTA, which belongs to the regional Andalusian government, is in charge of assessing, comparing and recommending different wastewater treatment methods for their implementation in Southern Spain. The WACOSYS project was presented as an alternative method for wastewater treatment. Attendees: Juan José Salas Rodríguez (Responsible for Applied Research Department) and Juan Ramón Pidre Bocardo (General Coordinator).
- WAU attended the International Symposium on ECOHYDROLOGY held in Vienna (Austria) from 23rd to 25th October 2005 where a discussion about WACOSYS and its background was engaged standing out the importance of a sustainable treatment of water.
- International conference "CONBIOT" held in Wisla, Poland in July 2005. WACOSYS and the general approach behind it was presented by ttz.
- Meeting with the responsible persons from the CENTA (Centro de Nuevas Tecnologías del Agua) in Seville. The CENTA, which belongs to the regional Andalusian government, is in charge of assessing, comparing and recommending different wastewater treatment methods for their implementation in Southern Spain. Attendees: Juan José Salas Rodríguez (Responsible for Applied Research Department) and Juan Ramón Pidre Bocardo (General Coordinator) held the 20th September 2005, engaged by BIOAZUL.

- Seminar about the experience of Bioazul at participating in European Projects like WACOSYS, given at the Córdoba University within the ANI+D initiative ("Programa de animación en I+D+I en Andalucía") held the 28th March 2005.
- TTZ responsibles' meeting with Dr. Martin Hoffmann (Research institute for fast growing, with several experiences in breeding and cultivating different species of populus and Salix. He did compare several different native and foreign species related to their growth rate, nutrient uptake and their sensitivity related to pest animals), with Rolf Schulzke, (Forst-Director of the Regional Council Kassel, Germany, who participated in a 12 years populus research project in China in Jinshatan, province Shanxi, in order to test their growth behaviour especially in dry areas) and with Jörg Albrecht, (Forst-Director of Hessen-Forst, Germany, responsible for international cooperation with high interest in fast growing trees) held at the "Forschungsinstitut für schnellwachsende Baumarten (FSB)" facilities in Hann. Münden the 12th May 2005, engaged by TTZ.
- Conference "Renewable resources and biorefineries" in Ghent (19. -21. September 05). WACOSYS and the general approach behind it was presented by TTZ. The objective was to find out the market potential for Salix as renewable resource for the chemical industry, and to make further research connections in order to exploit the project approach from WACOSYS and to develop further research activities out of it. Covering TTZ all the expenses.
- Poster presentation at the international "SCIENTIFIC CONFERENCE on WATER IN LANDSCAPE ENGINEERING" organized on the occasion of 60th Anniversary of the Faculty of Engineering and Environmental Science Warsaw Agricultural University, Warsaw, June 28 to July 01 2006, presented by WAU.
- WACOSYS was widespread through the project flyer in a seminar focused in the presentation of the results of another European project related to the treatment of the wastewater. The mentioned seminar gathered relevant companies and local authorities interested in the wastewater management. Performed the 23.06.2006 by BIOAZUL.
- The project was introduced to the municipality of Luumaki (Finland) by PARKANON on 19.04.2006, with an audience of 21 persons representing the municipality.
- Presentation of WACOSYS to Finnish entrepreneurs on 03.05.2006, engaged by PARKANON.
- WACOSYS was introduced to 24 farmers belonging the "Asociación Granadina de cultivadores de chopos" Association of poplar growers of Granada, engaged by RAMOS on 27/06/06
- WACOSYS flyer presentation at the international "World Bioenergy Conference and Exhibition 2006" presented by TTZ from May 30th to June 1st 2006 in Jönkoping, Sweden.
- TTZ'S poster presentation at the "Waste to Energy" International Conference and exhibition held on December 7th-8th 2005 in Bremen, Germany.
- Flyer presentation at the "Integrated European Network for Biomass Co-firing workshop". Held at the "Universitatea Politehinca Timisoara" held by TTZ on July 15th in Timisoara, Romania.
- Presentation at "Kalmar ECO-TECH ´05- Waste to Energy, Bioremediation and Leachate Treatment" and the Second Baltic Symposium on environmental chemistry. Held by Wau from November 28th to 30th 2005 in Kalmar, Sweden.
- RAMOS disseminated the project results in the presentation meeting (10.02.06) of an energy project regarding the commercial implementation of the energy crops in Spain called "Proyecto Singular Enegético", attended by 24 organizations (researches, companies, associations).
- In a meeting held on June 27th 2006 by 24 farmers in the "Poplar farmers association of Granada" to discuss different irrigation methods including the use of the wastewater, RAMOS presented the progresses achieve in WACOSYS project.

- In the Kick-off meeting of the Nacional Project CONSOLIDER, with the aim of irrigating with wastewater coming from wastewater treatment plants, on 10th July 2006, RAMOS made WACOSYS project known to the 122 attendees, showing the results achieved to date.
- Four representatives of the IDAE (Nacional Institute for the saving and diversification of the energy) visited WACOSYS plantation in Granada guided by RAMOS, on 14th July 2006. The visitors were explained the purpose of the project and its progress and future options.
- An article regarding WACOSYS project was published by BIOAZUL in the online journal www.mundoenergia.com, 18th January 2006. The mentioned energy site, is a well known webpage in Spain that gathers the most actual and relevant information in relation of the energy situation, including renewable energy.
- In a meeting held on 27th June 2006 by 24 farmers in the "Poplar farmers association of Granada" to discuss different irrigation methods including the use of the wastewater, RAMOS presented the progresses achieve in WACOSYS project.
- On 20/08/2006 BIOAZUL held a meeting in Málaga with a company devoted to wastewater management in order to present them the WACOSYS concept and try to meet agreements for a future cooperation.
- The project was disseminated by BIOAZUL with the help of the WACOSYS flyer in a seminar focused in the presentation of the results of another European project related to the treatment of the wastewater on 23/05/2006 . The mentioned seminar gathered relevant companies and local authorities interested in the wastewater management.
- WACOSYS flyer presentation at the international "World Bioenergy Conference and Exhibition 2006" presented by TTZ from May 30th to June 1st 2006 in Jönkoping, Sweden.
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- Flyer presentation at the "Integrated European Network for Biomass Co-firing workshop". Held at the "Universitatea Politehinca Timisoara" held by TTZ on July 15th in Timisoara, Romania.
- Presentation and publication of two articles: "The impact of pollutants discharched from Łódź region on Ner and Warta river water quality" and "The efficiency of wastewater treatment in constructed wetlands, on the example of reed beds with horizontal flow" carried out by WAU within ENVIRO Conference on 25-26.09.2006 in Dobczyce Poland. WACOSYS was mentioned in the presentation as an example of wastewater reuse example.
- WAU attended III Scientific-Technical Conference "Biofuels as an opportunity for Poland" held on 29-30/09/06 in Warsaw Poland, general project presentation.

- Presentation of WACOSYS poster and leaflets carried out by WAU on Renewable Energy Exhibition within International Ecological Fair POLEKO 2006 held on 21-24/11/2006 in Poznań Poland.
- EAU presented in a TV programme the WACOSYS project on 10/12/2006, highlighting the results achieved and the plans for the future of the prototype. (http://www.vedur.ee/akadeemia/alam_lk.php?aID=1480)
- EAU published a journal article also in relation to the project on 12/12/2006. (http://www.loodusajakiri.ee/eesti_loodus/index.php?artikkel=1749).
- On 12-14/12/2006 BIOAZUL held a meeting with a company devoted to wastewater management in Murcia / Alicante order to present them the WACOSYS concept and try to meet agreements for a future cooperation.

As commented before, several dissemination activities are planed to be taken into account after the finalisation of the project. Once of is the attendance to the 15th European Biomass and Conference and Exhibition, in Berlin, Germany (7-11/05/2007).

RAMOS plans to organize a workshop to show and explain to other local SRP-operators. The prototype will be use as a demonstrator material in this meeting. BIOAZUL will support RAMOS in the organization of this workshop.

A table listing the dissemination activities carried out by the consortium can be found in D18 “Plan for using and disseminating the knowledge