ΕΝΤΥΠΑ ΥΠΟΒΟΛΗΣ ΤΕΛΙΚΗΣ ΕΚΘΕΣΗΣ ΠΡΟΟΔΟΥ ΕΡΕΥΝΗΤΙΚΟΥ ΕΡΓΟΥ ΤΗΣ ΔΕΣΜΗΣ 2008

Η **Τελική Έκθεση,** υποβάλλεται σε δύο αντίγραφα, μέχρι και δύο μήνες μετά τη συμπλήρωση της διάρκειας του χρόνου υλοποίησης του Έργου. Η Τελική Έκθεση περιλαμβάνει δύο μέρη:

ΜΕΡΟΣ Α - Τελική Έκθεση Προόδου

Α.1. «Γενικά Στοιχεία Έργου»

Α.2. «Περίληψη» έκτασης 500 λέξεων για την πορεία υλοποίησης του Έργου.

Α.3. «Τελική Έκθεση Υλοποίησης Έργου» Περιλαμβάνει τη συμπλήρωση ενός τυποποιημένου Δελτίου Αναφοράς για κάθε ΔΕ του Έργου.

Α.4. «Συνοπτικός Πίνακας Δεσμών Εργασίας» όπου φαίνεται η πορεία υλοποίησης των Δεσμών Εργασίας και τα Παραδοτέα που προέκυψαν από κάθε μία απ' αυτές.

ΜΕΡΟΣ Β – Παραρτήματα

Β.1. Στο **«Παράρτημα Β1»** της έκθεσης επισυνάπτονται τα παραδοτέα του έργου που μπορούν να δοθούν σε έντυπη μορφή.

Β.2. Στο **«Παράρτημα Β2»** της έκθεσης επισυνάπτονται οποιεσδήποτε άλλες πληροφορίες αναφορικά με το έργο κρίνονται απαραίτητες.

Η Τελική Έκθεση Οικονομικών Πεπραγμένων υποβάλλεται σε ξεχωριστά έντυπα που είναι διαθέσιμα στον Ιστοχώρο του Ιδρύματος Προώθησης Έρευνας σε μορφή αρχείου Excel.

Μ Ε Ρ Ο Σ Α

Α.1. ΓΕΝΙΚΑ ΣΤΟΙΧΕΙΑ ΕΡΓΟΥ

Επιχειρησιακό Πρόγραμμα	Αειφόρος Ανάπτυξη και Ανταγωνιστικότητα
Άξονας Προτεραιότητας	Κοινωνία της Γνώσης και Καινοτομία
Πρόγραμμα	Τεχνολογία
Δράση	Ενέργεια
Αριθμός Πρωτοκόλλου Έργου	ΤΕΧΝΟΛΟΓΙΑ/ΕΝΕΡΓ/0308(ΒΙΕ)/15
Τίτλος Έργου	Investigation and determination of the geothermal parameters of the ground in Cyprus, for use on the design of ground heat exchangers and heat pumps.
Ανάδοχος Φορέας	Cyprus University of Technology
Συντονιστής Έργου	Dr. Georgios Florides
Ημερομηνία Έναρξης Έργου	***15/12/2008***
Ημερομηνία Λήξης Έργου	***14/02/2011***
Ημερομηνία Υποβολής Έκθεσης	***15/4/2011***
Εγκεκριμένη Επιχορήγηση:	***175.000 ΕΥΡΩ***
Ποσό που καταβλήθηκε από το ΙΠΕ: (μέχρι στιγμής)	***127.396 ΕΥΡΩ***
Ποσό που δαπανήθηκε: (μέχρι στιγμής)	***166.539 ΕΥΡΩ***
Στοιχεία επικοινωνίας με τον Συντονιστή Έργου:	
Διεύθυνση:	31 Arch. Kyprianos, Limassol Savings Co-operative Bank Building, PO.Box. 50329
Τηλέφωνα:	25 002554

Τηλεομοιότυπο:	25 002751
Ηλεκτρονικό ταχυδρομείο:	georgios.florides@cut.ac.cy

Α.2. «ΠΕΡΙΛΗΨΗ» (500 λέξεις - 2 σελίδες)

The project's kick off meeting was held by the HO on 12/01/2009 in order to coordinate with all project partners and commenced the project implementation. The responsibilities of each partner were clarified by the project coordinator Dr. Georgios Florides and based on the project time framework, specific tasks were assigned to the parties involved.

Quality Assurance Guidelines as well as a dissemination plan were developed by PA3 in order to firstly set a clear and effective project management process accepted by all partners and secondly to set the tasks for the dissemination and exploitation of results.

The appropriate drilling locations were chosen after taking into consideration the geologic formation, prevailing weather conditions and the population density. The drilling sites are in: Lakatamia (200 metres), Kivides (200 metres), Meneou (100 meters), Ayia Napa (100 meters), Yeroskipou (100 meters) and Prodromi (Polis Chrysochous) (100 metres).

Soil samples were collected from every different geological formation and for each borehole. A number of U-tube heat exchangers made of polyethylene pipe were installed in the boreholes. Also the heat exchangers were fitted with thermocouple wires at various depths for measuring the ground temperature.

From October 2009 to October 2010 the temperature of the ground were recorded along the depth of the boreholes by using the inserted thermocouple wires. The temperatures were measured once a month in order to determine the variation of the temperature, especially to the upper layers.

For the eight boreholes, additional geothermal data were also recorded like the type of ground and thermal conductivities of the various geologic layers. The data collected clearly indicate that there is a potential for the efficient use of Ground Coupled Heat Pumps (GCHPs) in Cyprus leading to significant savings in heating and cooling energy consumption.

Finally a report was prepared consolidating: A Table on geological data of every borehole, the layer thermal conductivity and density; a Table on the ground thermal conductivity and the effective borehole thermal resistance; the Graphical Form of the ground temperature along the depth of every borehole and its variation with time throughout the year and a Comparison and

analysis of the the above results.

Furthermore, a geographic information system (GIS) was applied for analysing, integrating, and display graphs for visualizing Isothermal lines and data concerning the ground, in relation to time of year, depth from the surface and sea surface height.

Iso-geothermal graphs were drawn with the use of artificial neural networks for the various geothermal parameters for Cyprus. More precisely, the data collected were processed in order to provide geothermal and isothermal information on any specific point in Cyprus, beyond those relating only to the points where the holes were drilled. This process let to the production of an isothermal and geothermal map of Cyprus that can be used by national authorities and engineers and other energy-related experts.

In the framework of the dissemination and exploitation strategy the consortium shared the results of the project with the academic, research and industrial community in various ways.

At the early stages of the project an informative leaflet was produced in order to raise awareness and anticipation concerning the project's objective, planned activities and expected results.

Also, a project website was created which was updated regularly in order to provide information concerning the project progress and results although this was not a project obligation.

Based on the project activities and results the HO participated in five international conferences for the presentation of relevant papers.

Additionally, a seminar on Geothermal Systems was organised in Paphos where the HO presented the Cyprus experience and lectures were delivered in Nicosia and Limassol on the same subject.

Furthermore, one paper was sent to the "Energy" journal, based on the project results, for publication.

Also, PA1 prepared a paper accepted for presentation in the International Conference on Energy Systems and Technologies, at Cairo Egypt (14-16/2/11). The conference was not accomplished because of the people unrest.

Moreover, PA2 participated on the 36th Stanford Geothermal Workshop for the presentation of the paper titled 'Investigation and determination of the geothermal parameters of the ground in Cyprus for the exploitation of geothermal Energy and the impact of the results in the design of the geothermal systems.'

In January 2011 PA3 coordinated the organisation of an Information Day in Nicosia for the presentation of the project results. The invitation was sent to all ETEK members, to private

companies from the construction industry and governmental departments related to energy policies. There was a great interest for participation in the information day and approximately 130 participants attended the event. Mr. Kassinis and Dr. Morissau were invited and opened the day. The event was also presented on Sigma News. All presentations were provided to the participants upon their registration and were also made available on the project website.

HO in collaboration with the P1 developed the geothermal maps of Cyprus which were printed and disseminated to stakeholders.

Α.3. «ΤΕΛΙΚΗ ΕΚΘΕΣΗ ΥΛΟΠΟΙΗΣΗΣ ΕΡΓΟΥ» (μέχρι 1500 λέξεις - 5 σελίδες ανά ΔΕ)

Τίτλος Δέσμης Εργασίας	**WP1: Project Management**				
Κωδικός Φορέα	ΑΦ	ΣΦ1	ΣΦ2	ΣΦ3	ΣΦ4
Ανθρωπομήνες για κάθε Φορέα (με βάση το Συμβόλαιο)	10	0.5	0.5	1.5	0.5
Ανθρωπομήνες για κάθε Φορέα (δεδουλευμένοι)	10	0.9	0.7	1.6	1

Στόχοι Δέσμης Εργασίας

Αναφέρονται επιγραμματικά οι **στόχοι** της παρούσας Δέσμης Εργασίας.

The WP1 objectives are:

- To establish means and structures for cooperation, communication and information sharing.
- To ensure the effective exchange of information amongst partners
- To provide the grounds of fruitful cooperation among the participants.
- To ensure the timely and quality production of results and deliverables
- To ensure the normal project development and risk aversion and mitigation

Περιγραφή Εργασίας

Καταγράφονται οι **δραστηριότητες** που αφορούν στη Διαχείριση του Έργου, τυχόν προβλήματα που προέκυψαν στα πλαίσια του Συντονισμού του Δικτύου Συνεργασίας και πως αυτά επιλύθηκαν.

Project Management was an ongoing activity from the beginning until the end of the project. The leading partner carried out the day-to-day administration of the project, provided support to partners, coordinated with the Research Promotion Foundation and resolved technical or other issues that have arisen in this reporting period. A set of Quality Assurance Guidelines was developed by PA3 in order to ensure the quality of project results and deliverables. Five partners' meetings were held during this period for the coordination of the project, for assigning roles and responsibilities to the partners and exchanging ideas and feedback among them. Meeting minutes were produced for each partners' meeting.

Παραδοτέα

Αναφέρονται τα Παραδοτέα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας. Στα πλαίσια της **Δέσμης Εργασίας 1**, ως παραδοτέα περιλαμβάνονται οι **Εκθέσεις Προόδου** (Εξαμηνιαίες, Ενδιάμεση και Τελική Έκθεση Προόδου) που θα πρέπει να υποβληθούν στο ΙΠΕ κατά τη διάρκεια του Έργου.

D1 First bi-annual progress report

D2 Interim Report

D3 Second bi-annual progress report

D4 - Final Report

D5 - Meeting Minutes

Τίτλος Δέσμης Εργασίας	**WP2: Dissemination and exploitation of project results**				
Κωδικός Φορέα	ΑΦ	ΣΦ1	ΣΦ2	ΣΦ3	ΣΦ4
Ανθρωπομήνες για κάθε Φορέα (με βάση το Συμβόλαιο)	4	1	1	3	0
Ανθρωπομήνες για κάθε Φορέα (δεδουλευμένοι)	5.8	0.8	1.2	3.2	0

Στόχοι Δέσμης Εργασίας (όπως περιγράφονται στο Συμβολαίο)

Αναφέρονται επιγραμματικά οι **στόχοι** της παρούσας Δέσμης Εργασίας.
The WP2 objectives are to:

- Share the results of the project with stakeholders i.e. construction industry, engineers, ministries, educational institutions etc.
- Identify and organise the activities to be performed in order to promote the exploitation of the project's results and the widest dissemination of knowledge from the project
- Explore the opportunities for exploitation of the project's results and outputs

Identify additional potential application fields, end-users, customers and business opportunities based on the reactions to the dissemination activity.

Περιγραφή Εργασίας- Βαθμός Υλοποίησης των στόχων της Δέσμης Εργασίας

Καταγράφονται οι **δραστηριότητες** που εντάσσονται στη Διάχυση και Εκμετάλλευση Αποτελεσμάτων. Γίνεται εκτενής αναφορά στο βαθμό υλοποίησής τους, σε πιθανά προβλήματα που προέκυψαν και σε τυχόν αποκλίσεις από τους αρχικούς στόχους. Όπου εφαρμόζεται, γίνονται **αριθμητικές και ποσοτικές αναφορές στα επί μέρους στάδια** της ΔΕ και γίνεται, επίσης, σαφής προσδιορισμός στο **Φορέα** που ανάλαβε και διεκπεραίωσε την κάθε δραστηριότητα.

A dissemination plan was prepared by P3 and finalised after a discussion with all partners in order to organise and assign roles and activities relevant to dissemination.
The consortium shared the results of the project with the academic, research and industrial community in various ways.
At the early stages of the project an informative leaflet was produced in order to raise awareness and anticipation concerning the project's objective, planned activities and expected results. It was disseminated to Engineers, concerned companies and interested persons.
Furthermore, a project website was created which was updated regularly in order to provide information concerning the project progress and results. Based on the project activities and results the HO participated in four international conferences for the presentation of relevant papers. These were:

1. 'Investigation and determination of the geothermal parameters of the ground in Cyprus' presented at the SEEP 2010 -4th International Conference on Sustainable Energy & Environmental Protection.

2. 'Investigation and determination of the geothermal parameters of the ground in Cyprus' presented at the EuroSun 2010 International Conference on Solar Heating, Cooling and Buildings.
3. 'Geothermal properties of the ground in Cyprus and their affect on the efficiency of ground coupled heat pumps' presented at the WREC 2010.
4. 'Comparison of the thermal characteristics and temperature profile of the ground in Cyprus with other Mediterranean countries' presented at the 3rd International Scientific "Energy and Climate Change" Conference
5. 'Artificial Neural Networks for the Generation of Geothermal Maps of Ground Temperature at Various Depths by Considering Land Configuration' to be presented at the 6th Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems, 25-29 Sept. 2011 at Dubrovnik Croatia.

Additionally, a seminar on Geothermal Systems was organised in Paphos where the HO presented the Cyprus experience and lectures were delivered in Nicosia and Limassol on the same subject.
Moreover, PA2 participated on the 36th Stanford Geothermal Workshop for the presentation of the paper titled 'Investigation and determination of the geothermal parameters of the ground in Cyprus for the exploitation of geothermal Energy and the impact of the results in the design of the geothermal systems.'
Though the necessary arrangements were made for the presentation of a paper on the 'Geothermal parameters of the ground in Cyprus' at the International Conference on Energy Systems and Technologies by PA1, due to the political instability in Egypt in early February 2011 it was impossible to proceed with the participation in the conference.

Furthermore, one paper was sent to 'Energy' Journal for publication based on the project results

In January 2011 the P3 coordinated the organisation of an Information Day in Nicosia for the presentation of the project results. The invitation was sent to all ETEK members, to private companies from the construction industry and governmental departments related to energy policies. There was a great interest for participation in the information day and approximately 130 participants attended the event. Mr. Kassinis and Dr. Morissau were invited for the opening of the day. The event was also presented on Sigma News, All presentations were provided to the participants upon their registration and were also made available on the project website.

Furthermore, HO in collaboration with the P1 developed the geothermal map of Cyprus which were printed and disseminated to stakeholders.

Παραδοτέα

Αναφέρονται επιγραμματικά τα Παραδοτέα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας. Στα πλαίσια της **Δέσμης Εργασίας 2**, ως παραδοτέα περιλαμβάνονται οι δημοσιεύσεις σε επιστημονικά περιοδικά, η διοργάνωση τοπικών ημερίδων για παρουσίαση των αποτελεσμάτων του Έργου, οι παρουσιάσεις των αποτελεσμάτων του Έργου σε συνέδρια του εξωτερικού, οι αιτήσεις για κατοχύρωση πνευματικών δικαιωμάτων, κα.

D6 Dissemination Plan
D7 Information leaflets
D8 Paper to be presented in international conference
D9 Participation in international conference

D10 - Information Day - Report

Τίτλος Δέσμης Εργασίας	**WP3: Drilling sampling, logging and equipment installation**				
Κωδικός Φορέα	ΑΦ	ΣΦ1	ΣΦ2	ΣΦ3	ΣΦ4
Ανθρωπομήνες για κάθε Φορέα (με βάση το Συμβόλαιο)	10	2	0.5	0	12.5

Ανθρωπομήνες για κάθε Φορέα (δεδουλευμένοι)	10	2.7	0.5	0	12

Στόχοι Δέσμης Εργασίας (όπως περιγράφονται στο Συμβολαίο)

Αναφέρονται επιγραμματικά οι **στόχοι** της παρούσας Δέσμης Εργασίας.
The WP3 aims to:

- Identify the most representative areas in Cyprus for drilling the six boreholes and perform the drilling
- Collect soil samples from the boreholes
- Install a U-tube heat exchanger in every borehole and thermocouple wires for measuring the temperature of the ground at different depths
- Backfill every borehole with bentonite

Περιγραφή Εργασίας- Βαθμός Υλοποίησης των στόχων της Δέσμης Εργασίας

Καταγράφονται οι **δραστηριότητες** που εντάσσονται στη συγκεκριμένη Δέσμη Εργασίας (ΔΕ). Γίνεται εκτενής αναφορά στο βαθμό υλοποίησής τους, σε πιθανά προβλήματα που προέκυψαν και σε τυχόν αποκλίσεις από τους αρχικούς στόχους.
Όπου εφαρμόζεται, γίνονται **αριθμητικές και ποσοτικές αναφορές στα επί μέρους στάδια** της ΔΕ και γίνεται, επίσης, σαφής προσδιορισμός στο **Φορέα** που ανάλαβε και διεκπεραίωσε την κάθε δραστηριότητα.

The chozen sites where the boreholes were drilled were selected based on their geologic formation, prevailing weather conditions and population density in order to include seaside, inland, semi-mountain and mountainous locations. The drilling sites are in: Lakatamia (200 metres), Kivides (200 metres), Meneou (100 metres Ayia Napa (100 metres), Yeroskipou (100 metres), Prodromi (Polis Chrysochous) (150 metres). All boreholes where also filled with Bentonite. PA4 was responsible for drilling and HO with PA1 and PA2 were responsible for deciding on the drilling locations.

Soil samples have been collected from every different geological formation and for each borehole. A number of U-tube heat exchangers made of polyethylene pipe were installed in the boreholes. Also the heat exchangers were fitted with thermocouple wires at various depths for measuring the ground temperature. More thermocouple wires than initially expected were fitted in each borehole which enables the researchers to collect more data and conduct a greater number of test leading to more accurate results. Furthermore, data from another two boreholes situated in Limassol and Saitas were also collected and were used during testing.

During this WP implementation a number of problems emerged. The first problem was related to the purchase of the machinery. The equipment planned to be purchased for the thermal conductivity measurements was not adequate and it was therefore replaced by equipment which will give sufficient accuracy. The situation was explained in the letter sent to the Research Promotion Foundation on 15 April 2009.
The second challenge faced in this WP was related to the Lakatamia drilling site: It was decided that the borehole in Lakatamia would be of a 200-meter depth. Though the borehole was initially drilled to this depth, it was impossible to insert the U-tube heat exchanger down to this depth because the borehole walls collapsed at the 130 meters due to a high flow of water. The piping and wiring were subsequently removed and the borehole was enlarged again to the 200 meters. Unfortunately, the borehole collapsed for a second time at a depth of 160 meters. After evaluating the damage caused to the wiring and piping when they were removed in the first case for enlarging the borehole it was jointly decided to keep them to the 160 meters.
The third challenge faced was the high cost of U-tube heat exchangers: As the purchasing cost of the U-tube heat exchangers was substantially higher than expected, the CUT group manufactured them using local and imported components. This ensured the lower cost of the U-tube heat exchangers. Furthermore a variety of heat exchangers were manufactured which enables the scientific team to proceed with a combination of observations in the various boreholes.
As some savings had occurred from this WP's budget the HO utilised the remaining amount for the boreholes' maintenance as well as for the travel expenses of the researchers who conducted the monthly

data collection.

Μεθοδολογία και Αποτελέσματα

Περιγράφεται αναλυτικά η μεθοδολογική προσέγγιση που ακολουθήθηκε και αναλύονται τα αποτελέσματα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

Boreholes were drilled and provided with heat exchangers and thermocouples as indicated in the table below:

LOCATION	DEPTH /DIAMETER (m)	Ground Heat exchangers	Filling material	Thermocouple Positions (m)
Geroskipou Paphos	100/0.2	1. PE100, PN16, 32x3mm, 2x100m 2. PE100, PN16, 25x3mm, 2x100m	Bentonite	Ambient, 0, 0.25, 0.5, 0.75, 1, 3, 5, 7, 8, 9, 10, 20, 40, 60, 80, 100.
Kivides Limassol	196/0.15	1. PE100, PN16, 32x3mm, 2x196m 2. PE100, PN16, 32x3mm, 2x96m	Bentonite	Ambient, 0, 0.25, 0.42, 0.67, 0.92, 3, 5, 7, 8, 9, 10, 15, 26, 46, 76, 96, 126, 146, 176, 196.
Agia Napa Famagusta	100.5/0.2	1. PE100, PN16, 32x3mm, 2x100m 2. PE100, PN16, 32x3mm, 2x100m	Bentonite	Ambient, 0, 0.25, 0.5, 0.75, 1, 3, 5, 7, 8, 9, 10, 11, 15, 20, 40, 60, 80, 100
Meneou Larnaca	97/0.2	1. PE100, PN16, 32x3mm, 2x97m 2. PE100, PN16, 40x3mm, 2x97m 3. PE80, PN16, 40x3mm, 2x97m	Bentonite	Ambient, 0, 0.25, 0.5, 0.75, 1, 3, 5, 7, 8, 9, 10, 11, 15, 17, 37, 57, 77, 97
Lakatamia Nicosia	160/0.23	1. PE100, PN16, 32x3mm, 2x160m 2. PE100, PN16, 32x3mm, 2x100m	Bentonite and cement	Ambient, 0, 0.25, 0.5, 0.75, 1, 3, 5, 7, 8, 9, 10, 11, 15, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160.
Prodromi Paphos	100/0.2	1.PE100, PN16, 32x3mm, 2x100m	Bentonite	Ambient, 0, 0.25, 0.5, 0.75, 0.95, 3, 5, 7, 8, 9, 10, 15, 20, 40, 60, 80, 90, 100.

Παραδοτέα

Αναφέρονται επιγραμματικά τα Παραδοτέα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

D11 Report on drilling and sampling

Το Έντυπο αυτό χρησιμοποιείται για την περιγραφή των υπόλοιπων Δεσμών Εργασίας και για κάθε Δέσμη Εργασίας ξεχωριστά (ΔΕ3-ΔΕ12).

Τίτλος Δέσμης Εργασίας	**WP4: Thermal ground data acquisition**				
Κωδικός Φορέα	ΑΦ	ΣΦ1	ΣΦ2	ΣΦ3	ΣΦ4
Ανθρωπομήνες για κάθε Φορέα (με βάση το Συμβόλαιο)	10	2	1	0	0
Ανθρωπομήνες για κάθε Φορέα (δεδουλευμένοι)	10	2	1.6	0	0

Στόχοι Δέσμης Εργασίας (όπως περιγράφονται στο Συμβολαίο)

Αναφέρονται επιγραμματικά οι **στόχοι** της παρούσας Δέσμης Εργασίας.

The main objective of WP4 was to acquire actual thermal ground data in all representative areas in Cyprus, so as to be able to design efficiently geothermal energy systems, calculate effectively heat losses of buildings to the ground and design thermal energy storage equipment.

Περιγραφή Εργασίας- Βαθμός Υλοποίησης των στόχων της Δέσμης Εργασίας

Καταγράφονται οι **δραστηριότητες** που εντάσσονται στη συγκεκριμένη Δέσμη Εργασίας (ΔΕ). Γίνεται εκτενής αναφορά στο βαθμό υλοποίησής τους, σε πιθανά προβλήματα που προέκυψαν και σε τυχόν αποκλίσεις από τους αρχικούς στόχους.
Όπου εφαρμόζεται, γίνονται **αριθμητικές και ποσοτικές αναφορές στα επί μέρους στάδια** της ΔΕ και γίνεται, επίσης, σαφής προσδιορισμός στο **Φορέα** που ανάλαβε και διεκπεραίωσε την κάθε δραστηριότητα.

HO, PA1 and PA2 were involved in this work package. The geological data for every borehole and the collected samples were determined and every ground layer was specified. The layer thermal conductivity, density were measured. To measure the thermal conductivity accurately an Isomet model 2104 heat transfer analyzer was employed. With this instrument the thermal conductivity of a specimen was determined by measuring the heat flow through the specimen and the temperature variation.
By using the inserted thermocouple wires, the temperature of the ground was recorded along the depth of the borehole. The temperature was measured once a month, for one year, in order to determine the variation of the temperature, especially to the upper layers. This was necessary as horizontal heat exchangers are buried to the upper layers of the ground which is affected by seasonal variations. All the data were recorded using a data acquisition module (such a module is the Omega OMB-DAQ 55/65). Additionally, the ambient air temperature was recorded for reference.
Finally, the thermal response test was carried out and the ground thermal conductivity and the effective borehole thermal resistance was determined by using the line source model.
In this way, isothermal layer lines were drawn for Cyprus and thermal data needed for engineers for design purposes became known.
Finally a report was prepared consolidating the findings of the current workpackage as follows:
1. Table on geological data of every borehole, the layer thermal conductivity, density and moisture content.
2. Table on the ground thermal conductivity and the effective borehole thermal resistance.
3. Graphical Form of the ground temperature along the depth of every borehole and its variation with time throughout the year.
4. Comparison and analysis the above results.

Μεθοδολογία και Αποτελέσματα

Περιγράφεται αναλυτικά η μεθοδολογική προσέγγιση που ακολουθήθηκε και αναλύονται τα αποτελέσματα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

For every borehole and once a month temperature measurements are taken and recorded by using the daq-pro data loggers, bought for this reason. The data that are collected are going to be used for preparing graphical presentations of the temperature variation of the ground according to depth for every borehole. Also the data will be used for the WP5.

Additionally for every borehole a number of thermal conductivity tests are carried out in order to specify the borehole thermal response. The ground layers were also recorded during drilling and samples were collected. For every sample, a number of thermal conductivity measurements are taken using the Hukseflux thermal sensor device. Also the specific gravity of the sample is measured. A geological graph of the borehole layers and their thermal properties is being constructed.

When all results are collected comparison and analysis of the results will follow as indicated in WP4.

Regarding the budget allocated to the work, it should be noted that all external works were carried out successfully and within the budget and the only practical work left is the maintenance of the equipment and the travelling to the boreholes for conducting the measurements.

Παραδοτέα

Αναφέρονται επιγραμματικά τα Παραδοτέα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

D12 Report on thermal and geological data

Το Έντυπο αυτό χρησιμοποιείται για την περιγραφή των υπόλοιπων Δεσμών Εργασίας και για κάθε Δέσμη Εργασίας ξεχωριστά (ΔΕ3-ΔΕ12).

Τίτλος Δέσμης Εργασίας	**WP5: Isothermal mapping**				
Κωδικός Φορέα	ΑΦ	ΣΦ1	ΣΦ2	ΣΦ3	ΣΦ4
Ανθρωπομήνες για κάθε Φορέα (με βάση το Συμβόλαιο)	3	3	0	0	0
Ανθρωπομήνες για κάθε Φορέα (δεδουλευμένοι)	3	3	0	0	0

Στόχοι Δέσμης Εργασίας (όπως περιγράφονται στο Συμβολαίο)

Αναφέρονται επιγραμματικά οι **στόχοι** της παρούσας Δέσμης Εργασίας.

The WP's objective was to provide a way for using a geographic information system (GIS) that would analyze, integrate, and display graphs for visualizing Isothermal lines and data concerning the ground, in relation to time of year, depth from the surface and sea surface height.

Περιγραφή Εργασίας- Βαθμός Υλοποίησης των στόχων της Δέσμης Εργασίας

Περιγράφεται αναλυτικά η μεθοδολογική προσέγγιση που ακολουθήθηκε και αναλύονται τα αποτελέσματα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

The HO and PA1 were involved in this work package. The ground temperature was mapped at different locations, elevations, lithologies and during different seasons. The temporal and thermal variations are shown schematically for different depths across the island using maps created with the aid of a GIS. GIS was used for integrating hardware, software, and the data acquired from the boreholes for managing, analyzing, and displaying all required forms of geographically referenced information. The GIS was used for answering questions by looking at the data in a way that is quickly understood and easily shared. The GIS allowed the user to view, understand, interpret, and visualize the acquired data in relation to:

1.the time of year

2. the depth from the surface of the ground

3. the types of ground layers
4. the sea surface height.

Μεθοδολογία και Αποτελέσματα

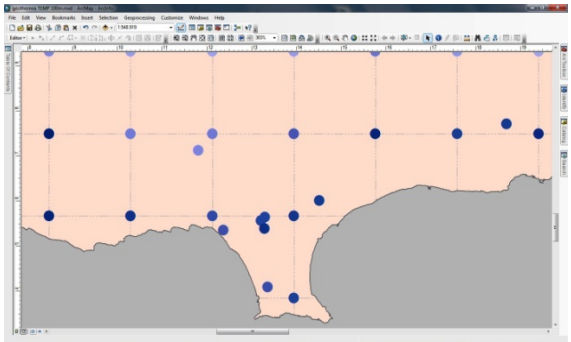
Περιγράφεται αναλυτικά η μεθοδολογική προσέγγιση που ακολουθήθηκε και αναλύονται τα αποτελέσματα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

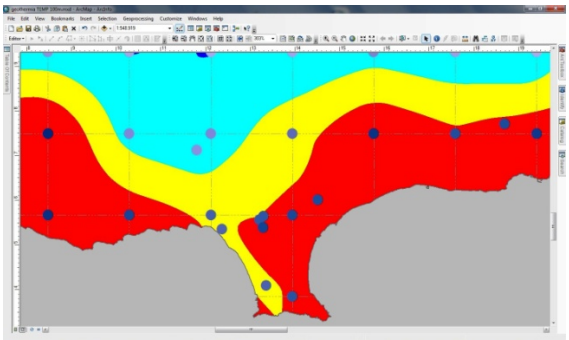
A Geographic Information System (GIS) was used to describe and characterize the properties of the ground in Cyprus. GIS focuses on integrating knowledge from multiple sources and creates a crosscutting environment for collaboration. It combines a visualization environment—using maps to communicate and visualize—with an analytic and modeling framework that is rooted in the science of geography. For this project, we have used the ArcGIS software (product of ESRI) which is capable of:

- Creating and using maps
- Compiling geographic data
- Analyzing mapped information
- Sharing and discovering geographic information
- Using maps and geographic information in a range of applications
- Managing geographic information in a database

We have used the temperature and thermal conductivity data collected from boreholes (35 old ones and 6 new) for differed depths. Neural networks were uded to additionally provite data on a 10x10 km grid. The Natural neighbor interpolation was then used. This method finds the closest subset of input samples to a query point and applies weights to them based on proportionate areas to interpolate a value. Its basic properties are that it is local, using only a subset of samples that surround a query point, and interpolated values are guaranteed to be within the range of the samples used. It does not infer trends and will not produce peaks, pits, ridges, or valleys that are not already represented by the input samples. The output passes through the input samples and is smooth everywhere except at locations of the input samples. It adapts locally to the structure of the input data, requiring no input from the user pertaining to search radius, sample count, or shape. It works equally well with regularly and irregularly distributed data.

Therefore, GIS interpolation tools of the software made predictions using the exiting measurements, for all locations in the output raster dataset, whether or not a measurement has been taken. Values were assigned based on the surrounding measured values and on specified mathematical formulas that were used to determine the smoothness of the resulting model.





In this way four different maps were compiled. The three maps presented the temperatures at 20m, 50m and 100m. The fourth one presented the thermal conductivity of the ground.

Παραδοτέα

Αναφέρονται επιγραμματικά τα Παραδοτέα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

D13 Isothermal graphs and data

Το Έντυπο αυτό χρησιμοποιείται για την περιγραφή των υπόλοιπων Δεσμών Εργασίας και για κάθε Δέσμη Εργασίας ξεχωριστά (ΔΕ3-ΔΕ12).

Τίτλος Δέσμης Εργασίας	**WP6: Development of geothermal graphs for Cyprus using Artificial Neural Networks**				
Κωδικός Φορέα	ΑΦ	ΣΦ1	ΣΦ2	ΣΦ3	ΣΦ4
Ανθρωπομήνες για κάθε Φορέα (με βάση το Συμβόλαιο)	8.5	0.5	0	0	0
Ανθρωπομήνες για κάθε Φορέα (δεδουλευμένοι)	8.5	0.6	0	0	0

Στόχοι Δέσμης Εργασίας (όπως περιγράφονται στο Συμβολαίο)

Αναφέρονται επιγραμματικά οι **στόχοι** της παρούσας Δέσμης Εργασίας.

To make use of artificial neural networks to draw iso-geothermal graphs for the various geothermal parameters for Cyprus.

Περιγραφή Εργασίας- Βαθμός Υλοποίησης των στόχων της Δέσμης Εργασίας

Καταγράφονται οι **δραστηριότητες** που εντάσσονται στη συγκεκριμένη Δέσμη Εργασίας (ΔΕ). Γίνεται εκτενής αναφορά στο βαθμό υλοποίησής τους, σε πιθανά προβλήματα που προέκυψαν και σε τυχόν αποκλίσεις από τους αρχικούς στόχους.
Όπου εφαρμόζεται, γίνονται **αριθμητικές και ποσοτικές αναφορές στα επί μέρους στάδια** της ΔΕ και γίνεται, επίσης, σαφής προσδιορισμός στο **Φορέα** που ανάλαβε και διεκπεραίωσε την κάθε δραστηριότητα.

The objective of this work package was to use the various measurements that were made in the various holes drilled throughout Cyprus as per WP3 together with some geographical information (latitude, longitude, altitude) and type of ground data (known from geophysical maps) to train an available artificial neural network in order to learn the correlation of these data. In effect the current work package used scientific tools to extrapolate the information on the isothermal and geothermal data in the holes to cover the whole island of Cyprus. This process resulted to the production of data that will in effect provided geothermal and isothermal information on any specific point in Cyprus, beyond those relating only to the points where the holes were drilled. This process let to the production of an isothermal and geothermal map of Cyprus that can be used by national authorities and engineers and other energy-related experts.
A number of network architectures will be tested in order to find the one which gives the best overall results. This is usually done by trial and error as there is no science to it.

Μεθοδολογία και Αποτελέσματα

Περιγράφεται αναλυτικά η μεθοδολογική προσέγγιση που ακολουθήθηκε και αναλύονται τα αποτελέσματα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.
For this work the data from the six boreholes were enriched with previous results from the work of Morgan in 1973. The parameters used for the training of the network were the lithology class at the area of each borehole; the borehole elevation; the mean, min. and max. ambient air temperature at the location of the borehole; rainfall at the location of the borehole; the x and y coordinates for each borehole, measured from some reference point; the depth at which temperature is recorded; and the temperature at the particular

depth. A total of 90 patterns were available. From these 81 patterns were used for the training of the network and 9 for its validation. The correlation coefficient obtained between the predicted and training data set is 0.9889. The validation of the network was performed by using the unknown data for 9 cases. The correlation coefficient for the unknown cases was 0.9253. The prediction error for the mean annual rainfall was confined to less than 1.74°C, which is considered quite adequate. In order to broaden the database, the nine patterns used for the validation of the technique were embedded into the training data set and a new training of the network was performed. The architecture and the other parameters of the network were kept the same as for the validation phase. The correlation coefficient value for this case was equal to 0.9818.

A 10x10 km grid was then drawn over a detailed topographic map of Cyprus and the lithology class; elevation; mean, min. and max. ambient air temperature; rainfall and the x and y coordinates for each borehole, measured from the same reference point were recorded. This information was then supplied to the trained network and by doing so the temperature at the same depths as above were predicted at each grid-point. The x and y coordinates and the estimated temperatures at the three depths for both the original boreholes and the grid-points, were then used as input to a specialized contour drawing software in order to draw the geothermal maps.

It is believed that the proposed method of explicitly involving the lithology class, elevation, ambient temperatures and rainfall in drawing geothermal maps realistically produced valid maps of temperatures at the three depths. These maps will be a helpful tool for engineers wanting to apply geothermal heat in Cyprus.

Παραδοτέα

Αναφέρονται επιγραμματικά τα Παραδοτέα που προέκυψαν μέσα από τη συγκεκριμένη Δέσμη Εργασίας.

D14 Iso-geothermal graph and map of Cyprus

Το Έντυπο αυτό χρησιμοποιείται για την περιγραφή των υπόλοιπων Δεσμών Εργασίας και για κάθε Δέσμη Εργασίας ξεχωριστά (ΔΕ3-ΔΕ12).

Α.4. «ΠΙΝΑΚΑΣ ΔΕΣΜΩΝ ΕΡΓΑΣΙΑΣ»

Καταγράφονται οι ΔΕ, ο μήνας έναρξης και υλοποίησης και τα παραδοτέα που προέκυψαν από το Έργο.

Αριθμός Δέσμης Εργασίας	**Τίτλος Δέσμης Εργασίας**	**Έναρξη** (μήνας)	**Ολοκλήρωση** (μήνας)	**Παραδοτέα**
WP1	**Project Management**	M1	M26	D1: First bi-annual progress report D2: Interim Report D3:Second bi-annual progress report D4: Final Report D5: Meeting Minutes

WP2	**Dissemination**	M1	M26	D6 Dissemination Plan D7:Information leaflets D8:Papers presented in international conference D9: Participation in international conference-Report D10: Information Day - Report
WP3	**Drilling sampling, logging and equipment installation**	M3	M12	D11 Report on drilling and sampling
WP4	**Thermal ground data acquisition**	M10	M23	D12 Report on thermal and geological data
WP5	**Isothermal mapping**	M21	M26	D13 Isothermal graphs and data
WP6	**Development of geothermal graphs for Cyprus using Artificial Neural Networks**	M21	M26	D14 Iso-geothermal graph and map of Cyprus

Μ Ε Ρ Ο Σ Γ

ΠΑΡΑΡΤΗΜΑ Γ1

Επισυνάπτονται τα παραδοτέα του έργου που μπορούν να δοθούν σε έντυπη μορφή.

1. Final Report
2. Financial Report
3. First bi-annual Progress Report
4. Interim Report
5. Second bi-annual Progress Report
6. Meeting Minutes
7. Dissemination Plan
8. Information Leaflet
9. Papers presented in international conference (7 No)
10. Participation in international conference-Report (2 No)
11. Information Day – Report
12. Report on drilling and sampling
13. Report on thermal and geological data
14. Iso-thermal graphs and Data
15. Iso-geothermal graph and map of Cyprus

ΠΑΡΑΡΤΗΜΑ Γ2

Επισυνάπτονται οποιεσδήποτε επιπλέον πληροφορίες αναφορικά με το ερευνητικό έργο, οι οποίες θεωρούνται απαραίτητες.

ΣΧΟΛΙΑ ΙΠΕ **Μόνο για χρήση από το ΙΠΕ. Παρακαλώ μη συμπληρώνετε.**			
Αρμόδιος Λειτουργός ΙΠΕ		**Ημερ/νια**	