LIFE Project Number

LIFE05 ENV/DE/197

TECHNICAL FINAL REPORT

Reporting Date

24/02/2009

LIFE PROJECT NAME

LEADFREE

Data Project

Project location	Itzehoe
Project start date:	15/04/2005
Project end date:	14/04/2008 **Extension date:** 14/10/2008
Total Project duration (in months)	42 months **Extension months** 06 months
Total budget	total € 4.248.800,00 (eligible: 3.323.550,00)
EC contribution:	€ 1.661.775,00
(%) of total costs	39,1 %
(%) of eligible costs	50 %

Data Beneficiary

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1. LIST OF KEY-WORDS AND ABBREVIATIONS

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RoHS	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment. Directive 2002/95/EG
WEEE	Waste Electrical and Electronic Equipment. Directive 2002/96/EG
EMAS	Environmental Management and Audit Scheme
SME	Small and medium enterprises
SMD	Surface Mount Device (Type of electronic component to be mounted on top of a PCB)
SMT	Surface Mount Technology
IPC	“Association Connecting Electronic Industries”, see www.ipc.org
FED	“Fachverband Elektronik-Design”, see www.fed.de
ISO	International Organization for Standardization
AOI	Automatic optical inspection
PCB	Printed circuit board

2. EXECUTIVE SUMMARY

The new EU legislation on electronic waste stream and restriction of hazardous substances presents consequences for all parties involved in the electronics products supply chain: product development and manufacturing, equipment, materials and component supplier, recycling companies and communal waste management. All steps of development, choice of technology, materials and process specifications, procurements, assembly, inspection, and rework of RoHS compatible products have to be established from basics, revisiting all issues, even for running products. The costs for integration of this enforced law are especially harsh for SME assembly houses, as customers expect no extra charge for implementation.

The main objective of the Life-LEADFREE project is assistance of SMEs with implementation of environment-friendly electronics assembly, thus enabling them not only to cope with the new EU environmental legislation, but to benefit from technological advantage gained on the global market. The part actions & deliverables are

- Set-Up of a non-for-profit, pre-competitive European competence centre for demonstration, training and exercises to be used by European electronics manufacturers (achieved)
- Establishment of training modules in cooperation with equipment manufacturers and logistics experts for industry approved seminars (second year curriculum overview complete). In 2006, a shift of training requests from companies was recognized towards training for manual lead-free soldering and and increased demand towards on-site training.
- Layout and manufacture of a lead-free test vehicle showing a typical RoHS compatible SMD (surface mounted device) component spectrum, demonstrating the specifications necessary to be included in device selection during design and procurement (achieved = GO/NOGO criterium). The market request for manual soldering is met by development of an additional test vehicle, namely a training board for manual soldering including rework.
- Matrix plan of line usage: prepared for Life-LEADFREE internet pages as resource allocation plan and part of marketing structure and advertisement (available, with fabline specifications, see www.life-leadfree.de). For planning and documentation, a spread sheet is used from 2006 on. For marketing, exploitation and transfer purposes, a LEADFREE Training Line documentation was established including a video presentation on CD-ROM (included).
- Marketing and advertisement structure in addition to internet presence is based on mailing actions to personal contacts, joint seminar marketing with FED (Fachverband Elektronik-Design), Berlin; publications in journals and newspapers, invitations to demonstration events, participation in trade fairs (productronica Nov. 14-18, 2005, and use of multiplication factors by cooperation with equipment manufacturers; the LEADFREE inauguration event was held on Dec. 06, 2005; a regional demonstration event on March 1, 2006.
- SMT&Hybrid May 30 – June 01, 2006), the 4th International IPC/Soldertec Conference “RoHS Compliance and Beyond” in Malmö April 25-27, 2006; technology transfer meetings as held at ISIT on June 27 and October 31, 2006, Process Simulation February 27-28, 2007, Essen; Methods for Quality Assessment and Defect Analysis on Electronic Assemblies, March 21-25, 2007, St. Jordi; Technology and Logistics of RoHS Transformation of Electronics Assembly, April 17, Hamburger Lötzirkel Meeting at ISIT, Itzehoe; Effect of

Voids on CSP Reliability May 31, 2007, Sibiu, Romania, FED-conference, 13-15 September 2007 in Bremen (seminar on 13th of September, seminar 6:"RoHS-konforme Baugruppen fehlerfrei und produktiv produzieren"), "Technologieseminar Herausforderung Speziallöttechnik" on 26 September 2007 in Freudenstadt, „6. Technologietag KSG Leiterplatten" on 27 September in Chemnitz, „1. Balver Zinn & Cobar Herbstseminar" on 12 October 2007 in Eisborn, „Weichlöten – die wichtigste Verbindungstechnologie in der Elektronik" on 17 – 18 October 2007 in Regensburg, „1. Technologietag" on 30 November 2007 in Friedrichshafen at inovel.

To date, the assembly and analysis competence center has been active and performed in 2006 with eleven demonstration and training events, serving 202 participants from 136 different electronics manufacturing companies. In addition, 55 participants from 33 companies visited the two technology transfer meeting. Lists of participants are available upon request. One DVD data disc is added in the appendix which contains accumulated handouts and course material of the 2006 events.

In 2007 until September, nine demonstration and training events, serving 162 participants from 103 different electronics manufacturing companies took place. In addition, by presentations given on external events held by other organisations, over 300 participants from more than 200 companies were reached and informed about process, qualification, and reliability topics with regard to RoHS compliant electronic products (programmes and lists of participants available upon request).

In the last three months of the year six additional demonstration and training events took place from October until December, serving 123 participants from 75 different electronics manufacturing companies.

For the extention of the training programme for 2008 see the list in chapter 6
"Description of State of Play" for task E.

Up to and including the Octobre solder seminar, 203 participants visited the LEADFREE seminar events in 2008; in addition, 50 different applications = line uses were counted in the LEADFREE training line in this period.

3. INTRODUCTION

The new EU legislation on electronic waste stream and restriction of hazardous substances presents consequences for all parties involved in the electronics products supply chain: OEM manufacturer, contract assembly houses, equipment manufacturer, solder and flux manufacturer, PCB manufacturer, component manufacturer and distributor, and other consumables (gas/nitrogen, tooling) manufacturer, and, last not least, recycling companies and communal waste management.

The arising problems of this enforced law are especially harsh for SME assembly houses:

- Substantial cost factor due to necessary investments in new equipment
- Incomplete availability of RoHS and process compliant components
- Lack of compatibility of lead-free processing at higher temperature with existing device specifications
- Lack of experience with lead-free-specific inspection and repair routines
- strong deficits of personnel skills regarding lead-free soldering
- disruption of running commercial production during experimental introduction, feasibility tests and in-house training lead-free technologies not only in RoHS relevant, but also RoHS exempted applications.

The solution which was built-up in this project is a non-for-profit, pre-competitive European competence and training centre for environment-friendly electronics assembly. The centre was established in the basement of the Fraunhofer ISIT clean room facility, for demonstration and training purposes, to be used by European electronics manufacturers, who bring their own materials and test vehicles to practice with state-of-the-art lead-free soldering equipment, assisted by scientific engineering supervision and analysis including hands-on training. The background of this project was more than four years of intensive applied research on lead-free soldering and analysis together with a range of manufacturing companies and other research institutions paired with more than 10 years of experience in training industry personnel in soldering and inspection.

4. LIFE-PROJECT FRAMEWORK

- Description and schematic presentation of working method, including overview of: (i) project-phases, (ii) activities/tasks per phase and (iii) planning;

Tasks	Foreseen start-date	Actual start-date	Foreseen end-date	Actual end-date	Status
A) Demonstration Fabline Set-Up	April 2005	April 2005	Jan. 2006	Feb. 2006	Line completed
B) Data Mining for Environment-Friendly Production Parameters	April 2005	April 2005	Dec. 2005	Oct. 2007	completed
C) Demonstration and Training Preparation	April 2005	April 2005	Dec 2005	Dec. 2006	Completed in German
D) Hands-on Demonstration and Training on the Demonstration Fabline	Oct. 2005	March 2006	Oct 2008	Oct 2008	Complete training course available *
E) Acquisition and Dissemination	July 2005	July 2005	Oct 2008	Oct 2008	Completed *
F) Reproduction, Transfer and Exploitation	April 2006	April 2006	Oct 2008	Oct 2008	Completed *
G) Project Management	April 2005	April 2005	Oct 2008	Oct 2008	Completed

* To continue the activities beyond the project duration the training program was transferred to a start-up company and reproduction of training sites has begun to spread environment friendly production know-how to assembly personnel

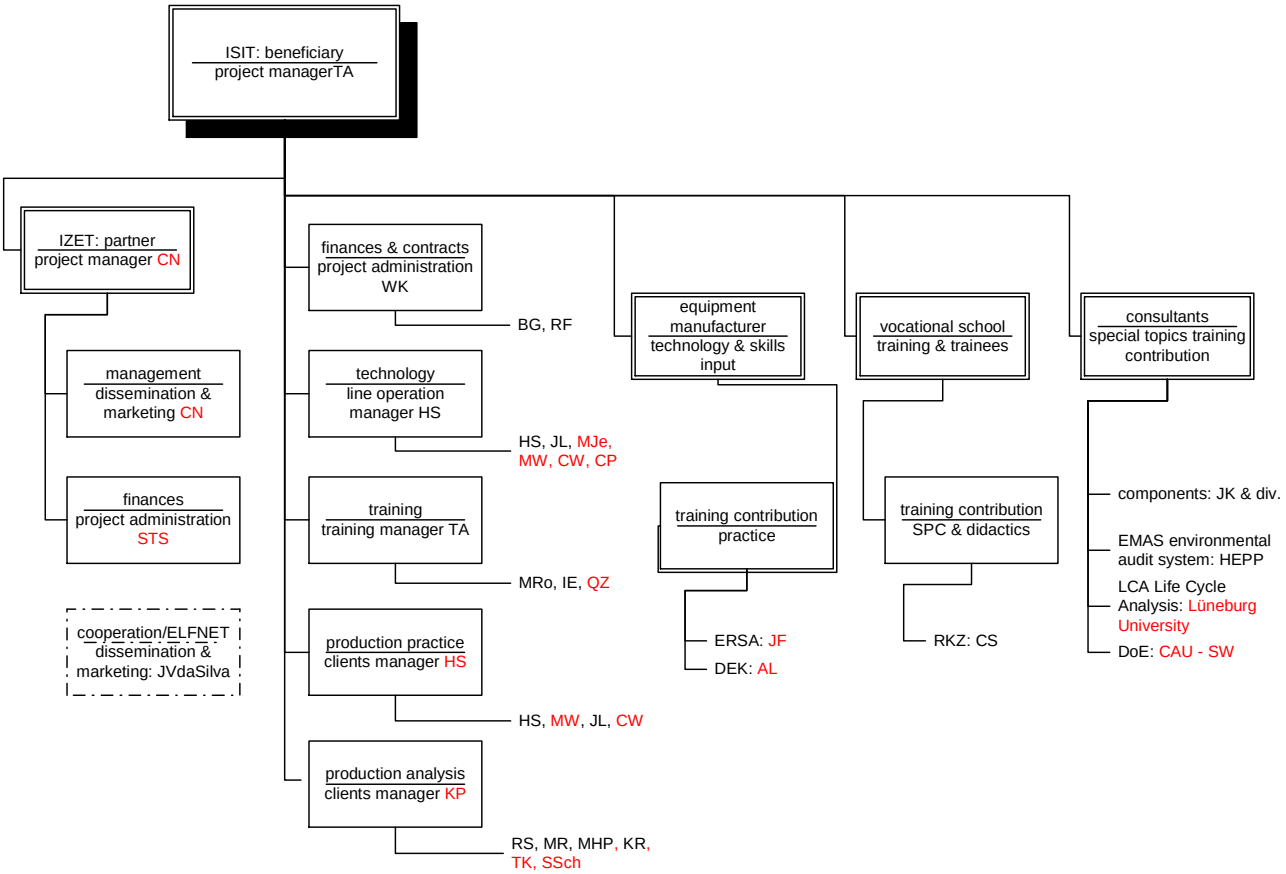
The Fraunhofer-Institut für Siliziumtechnologie (ISIT, http://www.isit.fraunhofer.de) located in Itzehoe, Germany works on design, development and production of microelectronic components as well as on microsensors, microactuators and other parts for Microsystems technology. All components of this kind can be delivered either being prototypes or customer specific series. The IC-technology department works on process development for silicon based circuits. The institute is closely collaborating with Vishay Semiconductor Itzehoe GmbH. The company uses part of the institute's facilities for the production of microelectronic components (PowerMOS) and develops new semiconductor technologies together with ISIT. Two further services offered by ISIT are analysis and technology development pertaining to quality and reliability of electronic assemblies as well as packaging and mounting technology for Microsystems, sensors and multichip modules. The institue is certified according ISO 9001. The complete ISIT staff consists of about 130 employees.

ISIT assembly analysis, research and technology development is disseminated in periodic seminar and practical training sessions for industry clients as a wide spread technology transfer. ISIT has a strong background on innovative materials science and analysis methods, together with experience on process metrology and process simulation. This enables ISIT to assist the clients taking part in training and exercises in a product/customer specific way, while elucidating the EU environmental goals to the partaking candidates and demonstrating the ways to integrate environmental

friendly electronics assembly with optimised material and process parameter selection. An innovation lies in the approach to mediate this environmental and product friendly approach also to single clients, thus presenting the possibility for SME to practice on their own discretion without the need to prior investment. The aim is to assist in evolution of sustaining technology in economically weak regions. In this way, the acceptance of environmental goals will be further increased, when it is demonstrated that environmental and economic goals do not exclude each other.

Partner IZET Innovationszentrum Itzehoe is a communal non-profit company with 94% public shareholders, founded 1993 on the initiative of the City of Itzehoe (47 %) and the County of Steinburg, (47 %) managed by the Gesellschaft für Technologieförderung Itzehoe mbH. IZET share capital amounts to EUR 256,000 and the turnover in 2003 was Euro 1.8 m with present total assets of balance sheet amounting to EUR 8.9. The Team of IZET Innovationszentrum Itzehoe comprises at present 10 employees. IZET´s mission is to: increase the economic power of the region and local community by supporting start-up companies in the field of new technology applications; maintain a co-operation with the Fraunhofer ISIT with respect to technologies up-take and transfer; encourage technology development and technology transfer, preferably of microtechnologies and their applications; maintain a co-operation with entrepreneurship institutions, educational institutions and universities. IZET is the manager of the cluster for microtechnologies of Schleswig-Holstein Hightech ItzehoeTM on site currently comprising 50 companies and in this function IZET supports the growing of the cluster by entrepreneurial support, information, mediation and networking services.

The following shows the project management organigram.



5. TECHNOLOGY

The single process step of lead-free soldering in itself is already a manageable task, though to be mastered with narrow process tolerances; assistance for this single step in electronics production is given e. g. by equipment manufacturers for individual users. The novel approach presented here is the linkage of the complete process flow with the materials and design information available on environment-friendly technologies, including and beyond legislative boundaries. These include many more materials than just the list of restricted substances as presented in RoHS. In particular, the following indicators are employed to quantify successful product and process design:

Indicator 1: Pb, Cd and Hg to be reduced to below 0.1% by weight in homogeneous material (0.01% for Cd)

Indicator 2: Br and other halides used as flame retardant and colour pigments in laminates to be reduced by 99%.

Indicator 3: Green house emissions to be reduced by 50-90% using VOC-free flux and better energy efficiency.

During the past five years, ISIT took part in several public and industry sponsored applied research projects with regard to fabrication and analysis of lead-free soldering processes. The new and innovative knowledge gained in these projects is essential for allowing ISIT to build up an environment-friendly process flow demonstration line by: 1) choice of equipment (better insulated ovens), 2) set up and installation (heat exchanger air flow), 3) combination with process parameters (more efficient up-time use), 4) operation of equipment in industry scale serial production, and 5) hands-on training on a wide range of applications (personnel awareness of energy conservation).

LEADFREE goes beyond the former projects in that they were examining different aspects of the industrial electronics assembly soldering methods, and now for the first time a complete demonstration line is to be run in accord with an integrated production policy (IPP) based on life cycle thinking. The project is absolutely innovative and unique by pioneering the application and translation of integrated production life cycle thinking into practice.

Years of development work and partial efforts have been integrated to this end of achieving a mastery of details that add up to optimal results in life cycle environmental inventories and thus achieve a break through in environmentally friendly electronics production on an unprecedented scale. The demonstration line demonstrates for the first time such a conceptual breakthrough. The innovation lies in the integration of materials management and dynamic information database systems with the design stage and the production line material traceability system. The environmental impact information and the process fitness of the material for the new parameters will be correlated, thus aiding the staff in design, procurement and process, plus allowing a legislation conformance test “on-demand”. This performance and knowledge is demonstrated and transferred to participating SMEs which enables them to meet the most stringent environmental legislation coming into force in the next years and at the same time ensure their own survival and competitiveness.

The LEADFREE demonstration line comprises the following innovative technical elements physically implemented in the Basement Section of the Fraunhofer ISIT Clean Room (the infrastructure building have been granted by the Fraunhofer Building

Management, so that no external costs were incurred – for this reason the originally proposed and granted support fram EC contribution was not used):

A) Industrial LEADFREE surface mount assembly line suited for innovative reflow and wave soldering. The scheduling, operation, maintenance and materials management of the entire demonstration assembly line composite process stations (including rework centre), was monitored by using special computer hardware and software ("Umberto") for realising the model of "transparent production" for display of the economical and ecological efficiency in use of materials and energy.

B) Selective innovative soldering process technologies featured: Laser soldering, Light soldering, Mini wave soldering for reduced effort in automated soldering in comparison to wave soldering

C) Rework centre comprising several stations with innovative process equipment, such as top and bottom heating, hot gas, and infrared soldering/de-soldering; competent rework instead of disposal saves material and energy.

D) Inspection and analysis centre for quality control, comprising optical inspection microscope table, endoscope-optical inspection of hidden solder joints underneath components, AOI (Automated Optical Inspection), X-ray transmission radiography with microfocus resolution. SEM/EDX (Scanning Electron Microscope with energy dispersive element analysis), and Ultrasonic microscope; needed for material qualification for lead-free soldering.

E) Special Training facilities and demonstration lab with work spaces for theoretical and practical training in mass production and manual soldering; best practice production and repair means increased reliability and less waste.

From a technical perspective, LEADFREE is the first European initiative of demonstrating an innovative complete electronics assembly line suitable for the production of electronic goods compliant with the spirit of the EU Integrated Product Policy (IPP) agenda based on life cycle analysis, and specifically going beyond the RoHS (elimination of hazardous substances) and WEEE (recycling of electronics products) directives. The assembly lines further demonstrates techniques of logistics and a philosophy of transparent production, meeting most advanced requirements of process control, traceability, materials management, and documentation, to allow for rapid set-up and transfer of "green" production parameters to current or later client owned assembly lines. A minimum of 300 SME participants (20% of which are international) will be enabled by demonstration and training to transfer this knowledge to their own production. Based on background know how specific to ISIT and the insights gained from interactions with the SMEs trained, who make successful transformations of products to "green" products, there will be captured best practice knowledge and this best practice shall be demonstrated for reproduction, transfer and exploitation, guaranteeing a sustainable impact of the project.

Starting from month six, the workplan of LEADFREE foresees Actions in Task E that have the purpose of dealing directly with planning and implementation of dissemination objectives and creating local, national and international publicity for the project in dissemination target groups. The LEADFREE budget includes appropriate personnel, travel, and consumables expenditures that are dedicated to the dissemination effort. The beneficiary ISIT in teamwork with partner IZET will be planning and co-ordinating all dissemination activities. The objectives of the dissemination effort are:

1) to make acquisition of a minimum of 300 clients, 20% of which are international, operate LEADFREE lecture seminars and demonstration line training at full capacity. Thereby the impact of the LEADFREE project is maximised.

2) to spread knowledge and awareness of accomplished LEADFREE best practice, models, patterns and success stories as to achieve reproducibility and transferability.

The consortium carried out a continuous effort on dissemination both jointly and individually each partner alone. Dissemination was performed at a number of levels (see also Layman's Report) including

- Immediate - User(s) & supplier chains and networks involving the two members of the consortium
- Industry wide– to potential users and other relevant audiences in the Electronics industry sectors
- European – to potential users and other relevant audiences across Europe

6. PROGRESS, RESULTS

6.1. Task overview

Table with task overview see chapter 4 above.

6.2. Description of State of Play

Task A:	Foreseen	Achieved
Demonstration Fabline Set-Up	Provide an electronics assembly line suitable for demonstration of environment-friendly production of RoHS compliant electronic products. The assembly line shall match future requirements on process control, traceability and documentation to allow rapid set-up and transfer of RoHS material compliant process parameters to client owned assembly lines. The assembly line shall be suitable for training as well as experimental production to be performed by external clients' personnel. **1 Procurement** **2 installation,** **3 ISO certification audit**	Task successfully completed. 1. Technical specifications had been compiled and offers acquired. 2. By Dec. 2005 most of the equipment of the fab line has been purchased and set up: a Juki placement system at the beginning of the line and different soldering ovens (convection, vapour phase): a) SMT-Line: solder paste, resp. adhesive printing, placement & reflow soldering by hot gas b) Wave soldering (with a pot of molten solder, the bottom side of the PCB (printed circuit board) is wetted by wave) and selective wave soldering (dto. but "wave" is only about 5mm in diameter) c) Vapour phase reflow soldering (defined heat with a vapour of fluoric hydrocarbons) The end of the line is an AOI = Automatic Optical Inspection system, and finally several different rework stations. d) Two automated point solder systems (to complement the selective wave solder system with laser, induction, and iron soldering. This larger variation of selective soldering technologies, a more sophisticated cleaning equipment, and automated optical inspection could be added to the original equipment plan at no extra costs due to better than foreseeable cooperation on the side of the equipment manufacturers. 3. Fab line was integrated into the ISO 9001 certification of the site by May 2006. Especially important is a control program to avoid disturbance of the neighbouring semiconductor fabrication by the high numbers of visitors. ISO 14001 plus EMAS is being internally prepared without external certification.
Comments:		

Task B:	Foreseen	Achieved
Data Mining for Environment-Friendly Production Parameters	Collect information regarding electronics design and production and make it available to SME clients. Make use of this information in the equipment selection as well as in the integrated operation scheme for the fabrication training line. Demonstrate advantages of holistic equipment and process specification (EU ecological goals). **4 Structuring** **5 collection and** **6 edition of relevant information**	Task successfully completed. 4) Structuring (material flow model on umberto software for the LEADFREE demonstration vehicle) has been finished. (sent 03/2007) 5) Collection continued until Dec. 2006, because much more information (especially in the Internet) has become available than foreseen. 6) Edition of e.g. a link-list with regard to information in the Internet (e.g. tables of RoHS conform components of suppliers, as from www.weichloeten.de). Also from time to time articles for a handbook (loose-leaf-collection, Forum Verlag) are published in cooperation with other than the LIFE projects. Concerning the EUP directive (energy using products) of Sept. 2005 a review of the information collection will be compiled in a later stage of the project.

Task C:	Foreseen	Achieved
Demonstration and Training Preparation	Prepare training modules in theory and practice for different levels of personnel, integrating a) a decade of experience in industry personnel training in soldering and related electronics assembly production steps: b) innovative approaches for electronics production c) respect the new WEEE and RoHS legislation. Contents: • Management level: product/marketing, procurement, materials, production and quality, EMAS certification • Engineering level: design, production and quality • Worker/specialist level: reflow, wave & manual soldering; rework, repair; inspection. **7 Training modules description with experts consultation,** **8 creation of manuals** **9 test vehicle production**	7) Modules and discussion for workshop material was finished (Dec. 2006), see also ISIT Seminar schedule 2006 and 2007. 8) a) Material for participants is available for all seminars, the one for "Power Electronics" also in English language. b) The cooperation with external know-how pools is broadened to incorporate available process knowledge provided by the machine manufacturer; c) "Actual design for excellence" took place 15.03.2006 and end of Nov. 2006. This is an EMAS and environmental soldering workshop held with external experts (PE Europe, later substituted by Lüneburg University, and HEPP). 9) "electronic SMT clock" and "Testboard leadfree 3" plus other boards (e.g. wind tester).
The production of the test vehicle "electronic SMT clock" was the Go/NoGo milestone, set out in the proposal. It was fully reached in February 2006. A detailed description was integrated in the Interim Report in January 2007.		

Task D:	Foreseen	Achieved
Hands-on Demonstration and Training on the Demonstration Fabline	Organise training and exercise sessions for efficient assembly fab line utilisation: a) “public” training with participants from several different companies b) exercise sessions for companies exercising on their internal own products c) Teaching of personnel, junior staff and apprentices and dissemination of holistic approach to electronics design and assembly. Participation in the LEADFREE training sessions is free of charge, as it is covered by the project cost plan. **10 Scheduling** **11 preparation and** **12 execution**	11) The ISIT seminar team dynamically updates of the training contents (e.g. enhanced process optimisation and practice parts in each course), manages external speakers, auditorium and catering . 10 + 12) the goal of 300 participants is far exceeded at the end of the project: a) As of December 2007/ In 2007, the LEADFREE competence centre trained 295 participants from 178 different electronics manufacturing companies in nine demonstration and training events. Additional to these soldering seminars, the beneficiary organised several free-of-charge LEADFREE training demonstration sessions with about 100 participants from about 60 companies (01.03., 27.06. and 31.10.2006). In 2008, a number of 203 participants took part in the solder seminars, including the event in Timisoara, Romania b) The "private" tests of clients' internal products was used by 20 clients in 2006. The Internet calendar is set up and allows registered members to view the allocation schedule of the fab-line resources in order to plan own tests. In 2008, 50 uses of the LEADFREE training line were counted of company or product specific applications for process test or user training until October 14 (end of project). c) The teaching started with the addition of the “practical day” to the ISIT leadfree soldering seminar. Eleven demonstration and training events have taken place, serving a total of 202 participants from 136 different electronics manufacturing companies.
Comments: Some sessions were booked out from the start, others needed extra marketing, sometimes just a name change ("soldering technology II" instead of "Leadfree"). A large demand of companies for in-house soldering and quality awareness is noted. This means going into the companies to reach a larger circle of recipients. The advantage is very effective on-site knowledge transfer, the disadvantage is that ISIT personnel is less available for LEADFREE training line related projects.		

Task E:	Foreseen	Achieved
Acquisition and Dissemination	Achieve maximum publicity and awareness: • Enroll small and medium sized electronics enterprises from all over Europe. • Knowledge sharing and creating awareness, and impact toward the scientific and industrial community, multipliers, civil society, regulatory authorities and environmental policy stakeholders. • ensure the sustainability after project lifetime • publication of best practice (reports), • publication of collection of case studies of successful transformation to RoHS conformity (success stories), • presenting papers and presentations on documented experimentally derived process parameters and patterns, • showcasing samples of RoHS conform products, • presenting papers on LEADFREE certified training curriculum, • presenting papers and talks on LEADFREE ISO 9001 certified demonstration line. • Wide mix of instruments: electronic / online publications, printed flyers, brochures, reports, presentations of papers and participation at industry events/conferences/trade fairs, two LEADFREE dissemination conferences to stakeholders, press & media relations. **13 Partners basic**	The beneficiary employed a wide range of dissemination vehicles as set out in the proposal: 13) Acquisition of partners and participants: • multiplicators: cooperation with equipment manufacturers • joint marketing with FED (Fachverband Elektronik-Design, Berlin) with regard to RoHS compliant design and production seminars (see web pages www.fed.de) • Expert meetings, seminars and technology days: I. enhancement of soldering seminar by practical day, implementation of a new topic seminar ("actual design for excellence") II. FED Conf., 21.-23.09.06, Kassel III. Process Simulation 27.-28.02.2007, Essen IV. 49th Meeting of SAET (Sächsischer AK Elektroniktechnologie) 14.03.07, Dresden V. 10. Europäisches Elektroniktechnologie-Kolleg 22.-23.03.07 in Mallorca VI. Technology and Logistics of RoHS Transformation of Electronics Assembly, 17.04.07, Hamburger Lötzirkel Meeting at ISIT, Itzehoe VII. 4th Annual DEKnology Day: Effect of Voids on CSP Reliability 31.05.07, Sibiu, Romania VIII. FED-Conference Seminar assembly manufacturing, 13.09.2007, Bremen IX. Technologieseminar Herausforderung Speziallöttechnik, 26.09.2007, Freudenstadt X. 6. Technologietag KSG Leiterplatten, 27.09.07, Chemnitz· XI. 1. Balver Zinn & Cobar Herbstseminar on 12.10.07, Eisborn XII. Weichlöten – die wichtigste Verbindungstechnologie in der Elektronik, 17./18.10.2007, Regensburg XIII. 1. Technologietag, 30.11.2007, Friedrichshafen at inovel • participation in trade fairs: XIV. IPC/Soldertec Global 4th Int. Electronics Conf. and Exhib., 25-27.04.06, Malmo, Sweden, XV. productronica 14.-18.11.2005, SMT&Hybrid 30.05. – 01.06.2006 • Awareness events: XVI. LEADFREE inauguration event, 05.-06.05 XVII. Regional demonstration event, 01.03.06 XVIII. Leadfree and Leadout project-meeting (see taks F, under 18) XIX. See also under task F/19: practical training seminar at Timisoara, Romania. 14) Strategy: the essential base is paper mail, followed up by e-mail reminders; information material prepared and ready assists client care activities on trade fairs and during personal contacts; this material is available for the multiplicators, mainly the equipment suppliers. 15) publications in journals and newspapers: I. PLUS 2 (Feb.2006), pp. 279-283, international conferences / proceedings: Presentation of the LEADFREE training line in cooperation with ELFNET at SEMI in April 06; II. "Zuverlässigkeitsrisiken Whisker" in RoHS-Handbuch für Hersteller und Zulieferer, Kapitel 8.5.1; Schruttke/Andreae; Forum Verlag Herkert GmbH,

	acquisition **14 compilation of strategies** **15 papers** **16 web site publications** **17 EU-wide invitation & enrolment**	Sommer 2007 III. "Via-in-Pad, Poren, und Zuverlässigkeit bleifreier CSP-Lötverbindungen" in Schweißen und Schneiden 59 (2007) Heft 7-8 IV. Articles on tin whiskers and effects of voids in the DVS-journal "Welding and Cutting (Schweißen und Schneiden)", in the "RoHS-Handbook" (Forum Verlag), and in the DVS "Annals of Micro-Joining Technology (Jahrbuch Mikroverbindungstechnik) 16) After relaunch in summer 2007 the website is now very good. Next to information about the project set up it contains the actual programme and user registration support. 17) European-wide E-mail marketing by ECPE (European Center for Power Electronics) for English speaking soldering seminar in September 2006 and June 2007 and 2008 (see also 15). Cooperation with FED Fachverband Elektronik-Design, for marketing & presentation of ISIT Seminars on RoHS compliant lead-free electronics design and manufacturing. additional: Training video on lead-free hand soldering, (initiated by FED, produced by ISIT) • 27.-29. January 2008, Electronic/EP, Stockholm:European Electronic Summit • 12. February 2008 Product design: Design for Excellence Seminar for environment- friendly development, layout and technology / German language • 13. February 2008 Assembly production with focus soldering process Lead-free seminar together with FED (Fachverband Elektronik-Design) / English language on demand • 26.-29. February 2008 Lead-free solder process in the electronic manufacturing industry Seminar in theory and praxis / German language • 11.-13. March 2008 Lead-free hand-soldering, practice-orientated training / German language • 11. - 13. March 2008 lead- free SMT-rework - practical training / German language • 07. - 11. April 2008 Soldering process II - practice training "LEADFREE specialist" at the ISIT-LEADFREE training line / German language • 18. - 19. June 2008 Tutorial and Training "Reliable Soldering for Power Electronics Manufacturing" Basics in theory and hands-on experience; a Joint programme with ECPE / English language • 7. – 18. July 2008 LEADFREE STEW Solder Training and Exhibition Weeks in Timisoara, Romania in co operation with the Timisoara Chamber of Commerce and Agriculture and the Universitatea Politehnica din Timisoara, Faculty of Electronics and Telecommunication; this event was run over two weeks. The first week provided theory seminars, namely two days focusing on development, one day exhibition, followed by two days with focus on assembly. The second week was a five day assembly practice session. • 7.-8.07.08: Design Optimisation - DfX, Verification, Pad Shapes, Lead- Free, Materials • 9.07.08: Life LEADFREE Training Line: Equipment & Materials Exhibition • 10.-11.07.08: PCB Assembly - Holistic View on Materials, Process and Solder Joint Quality • 14.-18.07.08: Assembly Specialist II - Complex Practice Training on Industry Scale Equipment • 25. - 27. September 2008, 16. FED- Konferenz, Bamberg:

		Elektronik- Design - Leiterplatten – Baugruppen: „Neue Fachkräfte braucht das Land – Weichlöten in der Elektronikfertigung“ • 7. - 10. October 2008 Lead free solder process in the electronic manufacturing industry Seminar in theory and practice / German language

Comments:
Special events also took place:

- "Juki meets friends": Supplier "Juki" and other suppliers organised a Leadfree meeting on the beneficiary's premises in 2007 and 2008, where 4 suppliers presented their solutions (in 2006, this event was preceded by “Rehm Day”).
- "Hamburger Lötzirkel" uses the facilities for dissemination events.
- A film produced by the FED (Fachverband Elektronik-Design) is running well (150 DVDs were sold by FED at 200 € each). The film was taken at the LEADFREE line, costs were covered by FED.

Task F:	Foreseen	Achieved
Reproduction, Transfer and Exploitation	This task is performed jointly by beneficiary ISIT (major project outputs) and partner IZET (entrepreneurship and technology transfer support) and will follow market demands. Generate a number of case outputs, such as • demonstration fab-line set up according to target specifications, • contents and methodologies for lecture and hands-on training courses, • best practice and success story collections, • new networks and expanded potential client contact bases, • information collections , and more. There are three possible avenues of business opportunities for transfer, reproduction, and exploitation: 1. leasing out the demonstration fab line to third parties or projects (specified amounts of time, based on joint usage of the line for R&D or production purposes) 2. continuing the operation of the demonstration fab line for external product development assistance and training purposes 3. marketing and licensing the intellectual LEADFREE project outputs (curricula and teaching materials, best practice knowledge; maintained in English and German language). **18 exploitation plan (IZET) and later concrete business plans** **19 Continued execution and evaluation of questionnaire survey** **20 Summary paper on Socio-economic and**	18) The conclusion from the experiences in trainings and events was to intensify practice training in several certified steps and special topics (such as rework) on the LEADFREE training line after the end of the project in compliance with the industrial requirements. Details: <u>a) Educational courses for soldering:</u> Following the end of the project, the members of the working group have opted to negotiate with DVS (who also certifies trainers for soldering and is member of the European Welding Association) to jointly enter the market with this education. Using DVS as a certifying organisation yields the chance to disseminate the LIFE output not only European-wide but also to the USA and other countries, who accept the TGA certificates. Suggested are three levels: "Lötpraktiker" (1 week course), "Lötfachkraft" (3 weeks), "Lötfachingenieur" (2 months). <u>b) Industry guidelines:</u> The beneficiary has developed a starter set of 4 industry guidelines (DVS 2620, 2621, 2623 and 2624) on education for soldering in electronics production including a certification schedule for trainers, training sites, and training contents. The guidelines will be part of the education guidelines of DVS (Deutscher Verband für Schweißen und verwandte Verfahren e.V.). The response from electronics manufacturers is very positive. Drafts of 5 guidelines have been discussed with DVS end of 2007. Meanwhile in November 2008, the first 4 guidelines passed the DVS education and examination committee. It is planned to forward the guidelines to the EWF (European Welding Federation) to lift he guidelines onto a European level. <u>c) A Training DVD</u> about lead free hand soldering was produced in cooperation with FED and is also applicable for the training program to be established in the course of the DVS guidelines. <u>d) Cooperation with ELFNET</u> (European Lead-Free Network): The beneficiary explored possible support from ELFNET, which combines typical stakeholders. However, ELFNET does not plan follow-up projects. e) Cooperation with project LEADOUT (see details below in the "Comment line"): LEADOUT is a more information-focussed project and not allowed to purchase hardware. It has compiled an extensive information programme on soldering (however maybe addressing a too low level of know-how). Therefore there may be good chances for cooperation. A joint inter project meeting on 05.06.07 with the project LEADOUT about RoHS compliance, solutions for SMEs and success stories, was the kickoff for the guideline development mentioned, see under a) above. (This meeting was originally planned as a public seminar, but interest was too low despite strong marketing.) <u>f) Board repairing:</u> Know-how was acquired by repairing single damaged or faulty expensive boards of clients. This is also a type of use of the training line. 19) A first marketing study showed that lead-free process evaluation was performed mostly in-house; interest in technology is focused on in-house workshops and external seminars.

	environmental impacts of LEADFREE **21 international LEADFREE midterm stakeholder event**	A practical course in Timisoara, Romania, was performed from 07. to 18.07.2008. The suppliers agreed to send and install their equipment on-site in the CCIAT exhibition hall in Timisoara This “Solder Training and Exhibition Weeks” (LEADFREE STEW) in Romania served two functions: a) it was a successful reproduction trial of the LEADFREE idea; b) it contained an international stakeholder event. 20) Summary paper on Socio-economic and environmental impacts of LEADFREE: “Position Paper” was ready 14.07.2008. 21) The “Solder Training and Exhibition Weeks” (see also under 19) in Romania has also the function of an international stakeholder event (on the exhibition day) with information about EuP ("Energy using Products" directive) and its effects on electronics development and production.

Comments:

Additional details on the LEADOUT project:

Details about EU project LEADOUT: (COLL-CT-2004-500454 www.leadoutproject.com and http://www.dvs-ev.de/fv/neu/?Navigation=Leadout)

LEADOUT, Low-cost Lead-Free Soldering Technology to Improve the Competitiveness of European SMEs, is a three year project and started 2004. The consortium comprises 31 partners from 10 European Countries, (11 Industrial Associations, 16 SME’s and 4 Research Institutes).

The main objective of the project is to provide technical support to a wide range of SMEs spread all over Europe in the development of technological solutions for the problems resulting from the replacement of tin-lead solders in the electronics industry. The project also covers environmental impact and life cycle evaluation as well as lead free process benchmarking. A range of dissemination activities such as e-learning packages, seminars and industrial-association events are planned.

TECHNICAL APPROACH: The Leadout project has three primary approaches to assist SMEs make the transition to lead-free soldering:

Process management. The identification and implementation of process best practice within the production chain. This will be supported by benchmarking of process yields of SME project partners through the PPM (parts per million) survey.

Joint reliability. Assessment of the suitability of low cost soldering systems and qualification of processes using appropriate accelerated reliability regimes.

Environmental assessment. Workplace and environmental impact aspects of lead-free soldering technology will be determined together with a full industrial Life Cycle Analysis. For the LCA (Life Cycle Analysis) the software "umberto" was used. However it turned out to be not really suitable for the enormous variety of electronic components. Therefore the beneficiary is testing another software (GABI).

Task G:	Foreseen	Achieved
Project Management	• routine coordination, monitoring and controlling • periodic technical and financial reporting • consortium meetings followed-up with minutes • ISIT: technical coordination, progress monitoring and control of timeliness and quality of technical output. • IZET: administrative project secretariat and coordination of reporting. • IZET is also responsible for the internet project presentation, participant registration and training line booking and usage • project management board of senior representatives of ISIT and IZET • technical board of work package managers • coordination by Dr. Ahrens **22-24 Time and activity supervision;** **25 reporting**	The project management is running as a routine task. Responsibilities have been distributed (see list of equipment responsibilities; organigramme has been updated due to changes at IZET) and a partner agreement has been compiled and signed. Partner meetings took place in 2006 on 21.03. 24.04., 03.05. (senior board meeting), 08.05. and 29.05.2006, in 2007 on 09.02., 12.04., 23.04., 14.06., 15./16.08., 10.09., 29.10., 05.11., 07.11., 13.11. (visit of DO), 21.11.2007 in 2008 on 28.04., 09.06., 24.06., 03.07., 23.07., 12.08., 21.08., 03.09., 04.09., 30.09., 01.10.2008 The topics were 5 times about the position paper on socio-economic impact of LEADFREE, and 6 times on the business plan. Included were management issues on project prolongation, closure, and final report A project prolongation of 6 months was requested and granted by the EC.
Comments: Due to the sudden death of the founder and managing director of IZET, Dr. Ingo Hussla, a major personnel shift at IZET occured and the idea of extending some of the LEADFREE Training contents into “e-learning” had to be abandoned.		

6.3. List of Deliverables:

Deliverable	Foreseen due date	Transmission date	Transmission details
Task A			
Compatibility checklist	30.04.2005	30.04.2005	First floor plan, equipment list in PR2
Summary on line integration suitability	30.04.2005	31.05.2005	Finalized floor plan, equipment alternatives (ISIT), PR2
Response from data conversion experiments	30.04.2005	30.06.2005	Decision for placement system made (ISIT)
List of equipment to be purchased	07.05.2005	07.10.2005	Procurement forms, priority reasoning, material orders placed
Example of lead free assembly (test board)	15.12.2005	24.02.2006	Retardation due to late delivery of components (5 months!) (ISIT)
Result from ISO certification audit	31.01.2006	31.05.2006	
Task B			
Process and machine specifications	31.07.2005	31.07.2005	Internally ISIT
Information guides on environmental legislation and available materials	31.08.2005	06.12.2005	EU regulation EuP late Nov. 2005; delivery with presentations on inauguration event
FAQ catalogues applicable for RoHS compliant assembly personnel	15.09.2005	15.09.2005	Mind Map "RoHS-Conversion" Internally ISIT, to clients
Summary on up-to-date workmanship standards	30.09.2005	15.30.2005	Presentation "TA leadfree" & "Design for Manufacturing"
RoHS compliant environment friendly test vehicle design "Green Life LEADFREE Product"	31.10.2005	31.10.2005	Test boards are the "SMT Clock" and "leadfree 3.2"
Task C			
Curriculum proposal on RoHS compatible assembly line operation training	15.09.2005	05.12.2005	Presentation with exhibitors and machine suppliers
Sample report on seminar handouts	15.11.2005	20.02.2006	Solder seminar handout, "Was wird anders durch bleifreies Löten"
Sample assembly	15.12.2005	24.02.2006	"SMT Clock" processed
GO/NOGO report	15.12.2005	23.03.2006	The Go/Nogo report is part of the Progress Report 2. The concerned fab line has been visited already in December 2005 by the MoT.
Task D			
Invitation for public seminars in fall 2005	15.10.2005	15.12.2005	Seminar mailing, repeated in Feb 2006
Filled matrix allocation plan for different clients and different parts of the fabline	15.12.2005	04.03.2006	See www.life-leadfree.de
Feedback from the first sessions of assembly line operation training	15.03.2006	24.02.2006	First ten participants in practical one-day demonstration class
First class of candidates certified for environment-friendly high tech manufacturing Biannually Continued certification	30.06.2006	16.06.2006	7 candidates certified as LEADFREE Specialists in 06/2007, 5 in 11/2006, 15 in 05/2007, 8 in 11/2007.

Deliverable	Foreseen due date	Transmission date	Transmission details
Biannually Report on usage by single clients for environmental friendly manufacturing exercises	30.06.2006	12/2006	Biannually report: by Dec. 2006 19 clients have used the training line for parameter optimisation or verification
Task E			
Preliminary dissemination strategy and activities reports, including an assessment and statistics depicting the dissemination impact.	15.06.2005	15.06.2005	Internally with IZET
LEADFREE web site up and running to be constantly maintained up to date	15.09.2005	15.09.2005	Refined and updated in 03/2006 and greatly enhanced in 08/2007 www.life-leadfree.de
Demonstration Fab line capability specifications to be made public	15.10.2005	15.09.2005	see web-site
Proceedings of first LEADFREE dissemination event for stakeholders at project outset	15.11.2005	06.12.2005	LEADFREE inauguration event
Two scientific papers per previous year, which were made public and/or presented	15.02.2006	08.-09.06.2006 22.-24.09.2006 06.-10.11.2006	IPC/Soldertec, Barcelona; FED Conference, Fulda; ISTFA, San Jose, USA;
Intermediate dissemination strategy update and activities reports, including as assessment and statistics depicting dissemination impact	15.02.2006	04.03.2006	Update seen on web pages; companies want RoHS production evaluation also on in-house processes; number of inquiries increase from various paths
Two scientific papers per previous year which were made public and/or presented	15.02.2007	Feb.2006 Apr.2006 April-Mai 2006 Sept.2006 Sept. 2006 Oct.2006	PLUS 2 (Feb.2006), pp. 279-283; IPC/Soldertec Umweltmagazin April-Mai; FED Conf., Kassel Sept. 21-23; Metallographietagung, Leoben, Austria; ESREF, Wuppertal Oct. 3-6
Preliminary collection of success stories / case studies to be made public	15.02.2007	05.06.2007	LEADFREE success stories “Seminar on RoHS Transformation Experiences” on 5th of June 2007 → joint LEADOUT/LEADFREE meeting with DVS
Preliminary show casing of RoHS conform products	15.01.2007	done Oct 2007, not submitted (confidential)	A modified leadfree-3 testboard was tested by an avionics manufacturer with tin-lead and leadfree from 10/2007 to 03/2008. Due to confidentiality reasons further information is available upon request and only for internal documentation
Best practice reporting to be made public	15.06.2007	31.01.2008	Best practice reported in Seminar „Baugruppenfertigung“ disseminated in FED education program, see e.g. Sept 13, FED conference, Bremen Also 4 articles.
Two scientific papers per final year to be made public and/or presented	15.12.2007	15.12.2007	4 papers on avoiding tin whiskers on tin platings and effect of voids in lead-free CSP solder joints
Final showcasing of RoHS conform products	15.12.2007	15.06.2008	Testboards dedicated in their development for evaluating and training RoHS compliant production processes are “hand-solder“, “binary clock”, „bleifrei3.2”, “analog SMT-clock”, and “Rework”; for further description see appendix

Deliverable	Foreseen due date	Transmission date	Transmission details
Proceedings of second LEADFREE dissemination event for stakeholders at project conclusion	15.06.2008 (orig. 15.02.2008)	05/2009 (with FR)	"Solder Training and Exhibition Weeks" (LEADFREE STEW) 07.-18.07.2008 in Timisoara, Romania. Seminar contents in english language on CD-ROM appended.
Final dissemination strategy update and activities reports, including as assessment and statistics depicting dissemination impact	15.08.2008 (orig. 15.02.2008)	Nov. 08 (done) Nov./Dec.08 (done)	Clear professional training guidelines with DVS committee for education and examination (Guideline drafts see appendix) Perform pilot training for manual soldering (1 week) and for solder specialist (3 weeks)
Task F			
Preliminary results reproduction, transfer and exploitation plan	15.05.2006	05/2009 (with FR)	See Business Plan in Appendix.
Summary of first marketing study from questionnaire responses by current and potential customers	30.06.2006	05/2009 (with FR)	See Business Plan in Appendix.
Finished business plan and license calculation	15.09.2008 (orig. 15.04.2007)	05/2009 (with FR)	See Business Plan in Appendix
Report on networking and cooperation with industry associations and societies as future client base for self financing lead free soldering fab line operation or licensing of LEADFREE concept	14.10.2008 (orig. 15.04.2008)	05/2009 (with FR)	• Operating Networks include Hamburger Lötzirkel → published in www.weichloeten.de; • FED Berlin → joint seminars on environment-friendly assembly; • DVS Düsseldorf → Working Group AG V 6.3 for Education on Soldering in Electronics; • Distribution network of equipment manufacturers → supply of equipment, and organisation of customer events at the LEADFREE training line premises; • Education Network for Solder Training (see Flyer in Appendix)
Position paper on socio-economic and environmental impact of LEADFREE project results	14.07.2008 (orig. 15.04.2008)	05/2009 (with FR)	See position paper in appendix
Task G			
Six month activity report	15.09.2005	16.03.2006	= PR1
12 month management report and costs statements and annual audit result	15.04.2006	16.03.2006	= PR1
12 month quality control report	15.04.2006	16.03.2006	= PR1
18 month activity report	15.09.2006	29.03.2007	= IR
24 month management report and costs statements and annual audit result	15.04.2007	29.03.2007	= IR
24 month quality control report	15.04.2007	29.03.2007	= IR
30 month activity report	15.09.2007	29.10.2007	Just informal, official PR2 was changed to 34 months activity report (agreed by EC)
34 month activity report	15.01.2008	30.04.2008	= PR2
36 month final report and costs statements and annual audit results	14.01.2009 (orig. 14.04.2008)	30.03.2009	Final report completed
36 month quality control report	14.01.2009 (orig. 14.04.2008)	30.03.2009	dto.

7. DISSEMINATION ACTIVITIES AND DELIVERABLES

Dissemination Plan (summary)

- LEADFREE addressed other scientific communities, regulatory authorities, multipliers and environmental policy stakeholders by involving them into the programme activities or by actively engage co operations, for example with the Universitatea Politehnica din Timisoara, Faculty of Electronics and Telecommunication in Romania and the Timisoara Chamber of Commerce. This yielded in the organisation and presentation of the LEADFREE STEW in Timisoara, Romania in July 2008. The idea is to turn this into a regular event.

- Building on professional associations: One of the most important organisation and multiplier that could be acquired is the DVS - Deutscher Verband für Schweißen und verwandte Verfahren e.V. Duesseldorf, because of it amount of members, namely 18,000 institutions form the industrial and private- individuals sector. As the certifier for the professional LEADFREE training concept of the ISIT the DVS enjoys high acceptance in the industrial community. Another important partner in terms of a multiplier function is the FED – Fachverband Eletronik Design e.V. in Berlin with 550 members including the entrepreneurial segment and private individuals. The emphasis of support is put on precise marketing activities in close synergetic cooperation. In addition, the LEADFREE professional training programme was presented by ISIT in a presentation during the 16th FED-conference on September 26th, 2008 in Bamberg, Bavaria.

- Internationally, the European Centre for Power Electronics (ECPE) crystallized itself as a reliable and effective partner for LEADFREE. ECPE and ISIT are in close collaboration, which lead to a concept which is now implemented. On an annually basis a seminars is given at the Fraunhofer Institute ISIT in Itzehoe called: “Soldering for reliable power electronics” with a European-wide target group.

- Further, active marketing is performed by placing notes and information on the seminar program via web pages into internet and into journals, by presentations in national and international conferences (see the list of event participation in 2008), by networking with equipment manufacturers and material suppliers, and, last not least, by active marketing through the new founded company trainalytics as a training service provider, and the group of training centers established in the follow-up of the LEADFREE project, based on the new education in electronics soldering guidelines.

- For a detailled list of dissemination activities see chapter 6.2 “State of play” for task E and F.

- The list of dissemination deliverables is included in chapter 6.3 “Deliverables” above.

- The final seminar and training contents are included in submitted deliverables, which are a CD-ROM with the contents of the repated LEADFREE Seminars

performed in 2008 plus the CD-ROM content of the Reliability Quartett from July 2008, a CD-ROM with the contents from LEADFREE STEW, July 2008, and a CD-ROM with the DVS Guidelines about the new training.

8. EVALUATION AND CONCLUSIONS

Project implementation

a. The process
This project was implemented on the background of lack of professional education in electronics assembly. There are an estimated 80.000 people in Germany alone – about three times as many are estimated in Europe – working in the eleconics assembly industry, by far most of them unskilled or with professional education in a completely different field. All these are directly impacted by the environmental legislation, especially the restriction of hazardous substances (RoHS), which directly leads to new solder process. This leads to smaller process windows, different materials to design, procure, join, and inspect.
Working closely with many assembly companies in direct consulting, research partnership, interaction in discussion forums etc., it was found that knowledge transfer by intensified practical training was best to assist especially SME to accept and implement European environmental policies in electronics production. On the background of the experience with theoretic solder seminars and with microtechnology apprentices, and the analysis and evaluation of electronics products and processes, the LEADFREE project was proposed to train European SMEs in the new environment compliant electronics assembly.

b. The project management, the problems encountered, the partnerships and their added value
The project was laid out between only two partners, namely Fraunhofer ISIT and IZET Innovationszentrum. The partnership concentrated the technology at the Institute reknowned for its competency in applied research in electronics assembly, having participated partly in leading roles in respective projects in national and international cooperations (e.g. EUREKA LEADFREE), and the management at the institution matchmaking technology partnerships on a European Scale, and assisting start-up companies with administration and office infrastructure (for the project management organigramm, please see chapter 4). Due to the slow start of the project there was a delay, as the project began officially in April 2005, but funding was granted late in fall 2005, so the orders for equipment could not start before the end of 2005. Thus the task “Line Set-Up” started half a year later than proposed. This delay however was later met by project prolongation of six months. Management encountered problems due to the sudden death of the director of IZET, which led to rapid changes of personnel at the partner. During this phase, reporting fell on the technical partner who was at that time mostly engaged in data collection and seminar preparation. After a new director was established at IZET, the partnership went again smoothly, so towards the end of the project, the highlights such as training in industry consensus, number of stakeholders reached, and transfer to a European level were completed successfully. Even the background was laid for the LEADFREE training going into commercialisation.

c. Technical and commercial application (reproducibility, economic feasibility, limiting factors)
In the meantime, the LEADFREE training line is applied generally in consulting questions with regard to environment-friendly electronics production. The LEADFREE technical manager (H. Schimanski) is engaged in a recently founded ZVEI (Zentralverband Elektrotechnik und Elektronikindustrie e.V.) working group concerned with repair of complex electronic assemblies; two projects of applied research have started to illucidate and match special requirements of high heat demand due to multilayer PCB with regard to rework and selective soldering; clients are making use of manufacturing and repair equipment in combination with the expertise in production technology and analysis of the LEADFREE training personnel. In this way, production and integrity testing is a combination SMEs are making use of, without the need of investing in own equipment. Up to now, however, European clients had inquired but not yet made use of the LEADFREE line, even though repeated seminars brought participants from various European countries to Itzehoe, and Seminars were held in different countries (e.g. Sweden – Stockholm, January 2008, Timisoara, July 2008). The limiting factor in making use of the LEADFREE Training Line seems to be the need for travel, preparing all necessary material and logistics like placement programs for production beforehand. Coming for training alone hoewever, by application of the material and course structure developed during the LEADFREE project is well accepted. In this way, the new training philosophy and thus the collected know-how on environment-friendly electronics production has found its way into the companies.

d. Comparison against the project-objectives
The line set-up and work was implemented as planned, up to ISO certification. While the line itself was not certified for EMAS, the seminar contents could relay the actions necessary for environmental certification on a design and management level. (FED/ISIT Seminar “Gestaltung”). During the course of the project, different testboard assemblies were generated suited for different levels of practice training. These were found very effective to demonstrate needs of tools and process parameters to match new demands of environment-friendly electronic products. One of the project goals was geatly exceeded, namely to reach 300 stakeholders during the course of the project. Overall, more than 600 companies were participating in LEADFREE seminar activities and making use of the LEADFREE Training Line demonstration capabilities.

e. Effectiveness of dissemination activities
The number of companies mentioned above making use of the technology offers shows the effectiveness of dissemination. Further, the program established with DVS has after the completion of the project lead to the formation of an education network established by four companies which engage now in lead-free solder training for electronics assembly.

f. The future: continuation of the project + remaining threats
The LEADFREE training line continues operation at the Fraunhofer ISIT laboratory, serving clients in the way as developed during the project. The original project manager has founded a new company for training and analysis. This step has put the new company as another training line site into operation in a place 350 km south from Itzehoe. The idea is to serve different regions, and continue cooperation between the two sites. The networking with companies

around the Hamburger Lötzirkel (Hamburg Solder Circle) continues to generate requests for usage of the LEADFREE Line at ISIT; marketing is assisted by salespeople representing equipment present in the line. The developed training scope is twofold, namely to combine technology training and information about environmental legislation and the consequences with regard to material choice and process parameters. The interesting focus for participating clients who send their personnel for training however lies in the fact that the new training in industry consensus are in-depth measures including theory and practice parts, and that certification will only be granted after passing a demanding examination. After the end of the LEADFREE project, no more sponsoring of materials or training personnel is available, so that training costs may lead to diminuishing interest on part of potential clients. In addition, with the current decline of the economy, external costs have to be reduced in every company, which also may lead to decreasing registrations.

Analysis of long-term benefits (please see also the Position paper on Socio-Economic and Environmental Impact of LEADFREE Project Results)

a. Environmental benefits

1. Direct / quantitative environmental benefits (e.g. reductions of emissions, energy or resource savings)
   By conforming to the RoHS legislation, for the dedicated product categories the hazardous substances are significantly reduced. As long as consumers comply to the WEEE part so as to return used EEE products to collection sites, deposition of the declared hazardous substances on waste dumps can be reduced to almost zero. Speaking of the effect of better manufacturing control by better educated personnel, the effect is seen in reduced production defect rates. Following are reduced need for rework / repair, saving material, personnel and energy cost.

2. Relevance for environmentally significant issues or policy areas (e.g. industries/sectors with significant environmental impact, consistency with 6EAP or important environmental principles, relevance to the EU legislative framework (directives, policy development, etc.)

b. Long-term sustainability

1. Long-term / qualitative environmental benefits:
   LEADFREE addressed other scientific communities, regulatory authorities, multipliers and environmental policy stakeholders by involving them into the programme activities or by actively engage co operations. The following groups have been reached by the training concept: Electronics manufacturers, OEM or contract manufacturers; companies from plant engineering with in-house production, prototypes or other trials; employees from production, operation planning and technology, who want to experience the special boundary conditions of RoHS-compatible manufacture, and test the process ability of specific designs. As the training was developed specifically to support SMEs in in their efforts to maintain and extend their position in the global market, the measures support socioeconomic development within the European Union, whilst promoting the environmental benefits associated with RoHS-compliance.

2. Long-term / qualitative economic benefits
   Due to the complex nature of the solder processes involved, graduate and master-level engineers in large companies are often responsible for overseeing and trouble-shooting the processes. The key advantage of the changeover to lead-free processes is found in the opportunity presented as an advantage especially to SMEs, namely to offer key non-graduate personnel a level of expert training in the specific area of solder process theory and practice. This results in three significant benefits: Reduction in personnel costs associated with overseeing and trouble-shooting the soldering processes, increased expertise through high-level practical training in the state-of-the-art, release of graduate-level creative capacity in the organisation for other tasks.

3. Long-term / qualitative social benefits
   The increased expertise of production personnel is especially essential as the European industry needs to improve its anticipation preparation for the challenges of adjustment. The objective set by the E.U. at the Barcelona European Council is to raise the level of R&D investment up to 3% of GDP by 2010 and to invest in intangible assets and human capital in order to make the most efficient use of knowledge and maximize its diffusion. Due to the lack of qualified employees even non-graduate personnel and unqualified people receive an opportunity to be introduced to hand work and fabrication within the LEADFREE professional training. Qualified employees with no relation to the electronics field also receive the chance to become soldering specialist within a reasonable period of time. Elderly workers who do not have an option to return into their former employment position, but who still have an interest to bring in their work force can also be qualified with the LEADFREE professional training by the LEADFREE training concept. In conclusion, a huge potential of qualification can be mobilized through LEADFREE. This is of special interest regarding the fact that every 6th company in Germany is not able to fill in the positions they offer due to the absence of qualified staff, matching their specific needs.

c. Replicability, demonstration, transferability, cooperation

1. Transferability & Potential for Commercialisation, including cost-effectiveness compared to other solutions, benefits for users
   All following parties are involved in the electronics products supply chain: Product development and manufacturing, equipment, materials and component supplier, recycling companies and communal waste management. All steps of development, choice of technology, materials and process specifications, procurements, assembly, inspection, and rework of RoHS compatible products have to be established from basics, revisiting all issues, even for running products. The costs associated with RoHS-compliance are especially harsh for SME assembly houses, as customers expect no extra charge for implementation. Hence, the changeover to RoHS-compliant lead-free production processes represents a technical and economic challenge. However, there is an advantage to be gained which is of particular significance to the flexibility-orientated small series manufacturer, and hence to its partners in the value chain. Once the new production process is implemented, a sustainable and long living competitiveness is almost guaranteed.

LEADFREE addressed other scientific communities, regulatory authorities, multipliers and environmental policy stakeholders by involving them into the programme activities or by actively engage co operations, for example with the Universitatea Politehnica din Timisoara, Faculty of Electronics and Telecommunication in Romania and the Timisoara Chamber of Commerce.
One of the most important organisations and multipliers is the DVS - Deutscher Verband für Schweißen und verwandte Verfahren e.V. Duesseldorf, with its 18,000 personal and company members. DVS certifies the professional LEADFREE training concept; the association enjoys high acceptance in the industrial community for education, applied research, and standardisation activies. Another important partner in terms of a multiplier function is the FED – Fachverband Eletronik Design e.V. in Berlin with 550 members. The emphasis of support is put on precise marketing activities in close synergetic cooperation. In addition, the LEADFREE professional training programme was presented by the ISIT in a seminar contribution during the 16th FED-conference on September 26th, 2008 in Bamberg, Bavaria.
Internationally, the European Centre for Power Electronics (ECPE) crystallized itself as a reliable and effective partner for LEADFREE. On an annually basis a seminar is given at the Fraunhofer Institute ISIT in Itzehoe called: “Soldering for reliable power electronics” with a European-wide target group.

d. Innovation

1. Level of innovation on (inter)national level (including technology, processes, methods & tools, organisational & co-operational aspects)
The main competence of the LEADFREE training center is attributed to the combination of production and analysis. Training participants are going in three levels, starting with manual assembly to learn about materials behaviour and get practice in craftsmanship, followed by an intermission on the automatic assembly to practice process control and process optimization, finalized by evaluation of the manufacturing quality and defect localisation of microelectronic assemblies and modules, to find root causes for defects including the as-delivered quality of components and circuit boards. Methods are destructive metallographic principles and Non destructive (e.g. x-ray) principles. For optimization of manufacturing processes the institute mediates process models and fabrication of samples on in-line equipment including mass production as well as rework systems. So the participants learn process measurement in combination with process simulation and analysis, gettting a holistic view on the production process. This gives them more confidence in their own work and enables them to more responsibility.

9. AFTER-LIFE COMMUNICATION PLAN

Following the project, the LEADFREE project manager founded the company Trainalytics GmbH, which has then taken on organisation and marketing of the DVS guideline training programs. Trainalytics is based in Lippstadt, and offers execution of the solder training curricula in Lippstadt as well as in Itzehoe in cooperation with the LEADFREE beneficiary Fraunhofer ISIT. Trainalytics and ISIT both keep on mailing invitations to the solder training, and both keep their websites updated with upcoming events. Both institutions keep the training line concept in their portfolio,

promoting training and application usage for customer-specific production trials in trade fair and seminar-style events. Examples are

- Meetings of the Hamburg Solder Circle, which are documented on the web page www.weichloeten.de administered by Trainalytics

- Technology days such as “JUKI meets friends” to take place annually at Trainalytics premises in spring, and at ISIT premises in autumn

- SMT trade fair in spring, FED conference in autums, also annual events

- LEADFREE STEW to be repeated as a European wide event in summer 2009, and from then on biannually.

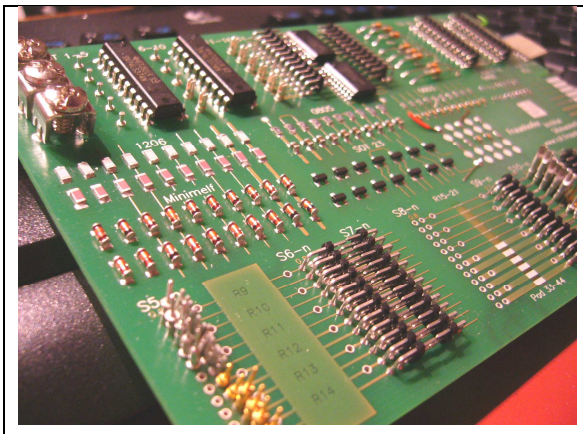
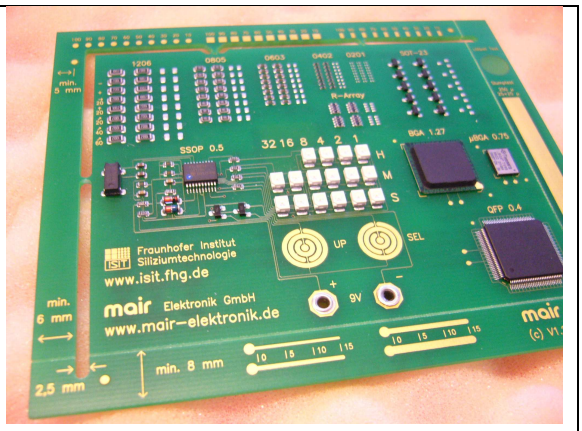
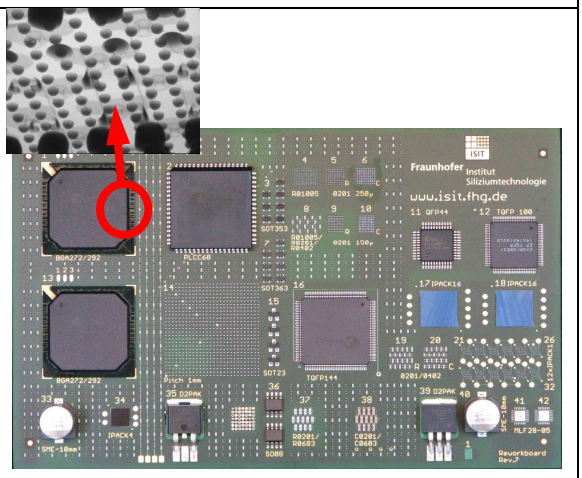
- Technology committee “FA7 Löten” at DVS, where companies and institutes meet to propose applied research projects for innovations in mechanical and electronics assembly processes by soldering.

A special task force with own interest has formed itself from the DVS working group AG V 6.3, to offer solder training as developed for the education guidelines as the main output of the LEADFREE hand and machine soldering seminar trials. This group has multiplied the idea in the sense of reproduction, as they head for commercialisation of the training concept. This in its own is the best result in terms of industry approval. 2.000 Flyers have been printed and are under industry-wide distribution via the customers relations of each individual partner in the association.

The LEADFREE STEW event will take place in English language, and will be advertised Europe-wide by English language journals. It would certainly be helpful to place the information on the seminar, workshop and exhibition on appropriate LIFE dissemination channels.

10. APPENDICES TO TECHNICAL REPORT

Testboards dedicated in their development for evaluating and training RoHS compliant production processes are “hand-solder“, “binary clock”, „bleifrei3.2”, “analog SMT-clock”, and “Rework”; for further description see appendix.

	
“hand-solder”, a sample workpiece for practice training and examination for LEADFREE manual soldering with regard to DVS 2620	“binary clock”, sample workpiece for manual SMD assembly and materials behaviour with regard to DVS 2621 Module 1
	
Sample PCB workpiece “Bleifrei 3.2” with four layers and a larger size to teach systematics of solder profiling; shown are the thin thermocouples on the PCB to measure temperature vs. time during soldering regarding DVS 2621 Module 2	“Rework” is a sample complex multilayer double-sided PCB assembly with built-in defect sites for defect localisation and cause analysis with regard to DVS 2621 Module 3

- Included are CD-ROMs with the presentations of key seminars on LEADFREE technology and reliability training during the final year, plus the contents from the LEADFREE STEW & stakeholder event in Timisoara, summer 2008.

- Partner's data: the only partner was IZET Innovationszentrum Itzehoe. IZET's main part was management; the main remaining contribution is installment and maintaining the LEADFREE website, collection and writing of the position paper, and the business plan. Position paper and business plan are found in the appendix.

11. OTHER ANNEXES

Key output of the training dissemination and transfer is the formulation of DVS solder education guidelines. These guidelines are to be published in spring 2009. They are

DVS Richtlinie 2620 "Handlöt-Arbeitskraft / Elektronikfertigung"

DVS Richtlinie 2621 „Lötfachkraft / Elektronikfertigung"

DVS Richtlinie 2623 „DVS®-Bildungseinrichtungen auf dem Gebiet der Löttechnik / Elektronik -- Zulassung - Schulung – Überwachung"

DVS Richtlinie 2624 „Planung und Einrichtung von DVS®-Kursstätten für die Löttechnik / Elektronik"

DVS Richtlinie 2622 „DVS®-Lehrgang European Soldering Engineer – ESE"

The appendix contains the final drafts (except 2622 which is only an outline yet) on paper and on CD-ROM.

12. LAYMAN'S REPORT

See Appended Layman's Report

13. REPORT OF FINANCIAL AUDITOR

a) name, address, tel/fax, contact person and registration number of the auditor:

Oskar Walter
Wirtschaftsprüfer, Steuerberater
SüdTreu Süddeutsche Treuhand AG
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Registration number 150825900

b) the Auditor's Report / Declaration

The auditor's report already was sent to the EC by our central accounting department in Munich.

14. FINANCIAL REPORT

14.1. Financial Overview

The budget figures "Payments made by project in €" are as of 14.10.2008

Categories of expenditures	Provisional budget €		Payments made by project in €		Difference eligible costs in €	% of the eligible costs
	Real costs	Eligible costs	Real costs	Eligible costs		
1. Personnel	1.833.871	1.833.871	2.261.451	2.261.451	-427.580	123,3%
2. Travel	50.000	50.000	39.231	39.231	10.769	78,5%
3. External assistance	270.000	270.000	235.021	235.021	34.979	87,0%
4. Durable goods:						
Infrastructure	428.000	107.000	0	0	107.000	0,0%
Equipment	1.208.500	604.250	1.367.800	599.688	4.562	99,2%
Prototype	0	0	0	0	0	0,0%
Sub total	1.636.500	711.250	1.367.800	599.688	111.562	84,3%
5. Consumables	235.000	235.000	190.665	190.665	44.335	81,1%
6. Other costs	6.000	6.000	50.270	50.270	-44.270	837,8%
7. Overheads	217.428	217.428	236.343	236.343	-18.915	108,7%
TOTAL	4.248.799	3.323.549	4.380.782	3.612.670	-289.121	108,7%

14.2. Comments on Financial Report

The total amount used for the project did overshoot the original plan because of a higher effort to prepare for the seminars to prepare the training material for the demanding practice training on industry relevant work pieces. Marketing was another issue which was underestimated in the beginning. Later there were more requests for presentations on technology days in various companies, which mostly meant almost two days travel for only few hours of presentation. The proposed budget for infrastructure could not be used due to the fact that the Fraunhofer Building management decided to start this work as the project had officially started, but before the grant from EU was approved, as this was a prerequisit before beginning of machine set-up and installation. As for the lower figure in travel this was because a visit for the presentation in the USA was not applied for in time, and could not be brought into account due to the time lag of late request to the EU.

Best match was the equipment which could be planned and procured with long view beforehand.

The high amount of "Other costs" was due to the fact that with the practice training on the machines, trainer competency with a lot of experience from field activities was needed. The only chance to get the special know-how ready in time for the participants during the project runtime was with external assistance from application engineering, namely from the equipment trainers. This was booked in the Extra categorie, as this was not expected during the writing of the proposal. However, this way to proceed was a good advantage, as the equipment manufacturers had the opportunity to enhance networking with their customers.

14.3. Detailed Financial Report

The detailed financial report already was sent to the EC by our central accounting department in Munich.

The cover paper for that report is available on the following page.

LIFE Project Number

LIFE05 ENV/DE/197

FINANCIAL FINAL REPORT

Reporting Date

24/02/2009

LIFE PROJECT NAME

LEADFREE

Data Project

Project location	Itzehoe
Project start date:	15/04/2005
Project end date:	14/04/2008 **Extension date:** 14/10/2008
Total Project duration (in months)	42 months **Extension months** 06 months
Total budget	total € 4.248.800,00 (eligible: 3.323.550,00)
EC contribution:	€ 1.661.775,00
(%) of total costs	39,1 %
(%) of eligible costs	50 %

Data Beneficiary

Name Beneficiary	Fraunhofer Institut für Siliziumtechnologie (ISIT)
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Project Website	www.life-leadfree.de