LEE BED

Unified value-chain of the European nanomaterials and LE (Lightweight Embedded) Electronics

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INTRODUCTION

In 2022, the world revolves around electronics from its use in business, industry and in personal lives. But what is an electronic device?

An electronic device is composed of 3 types of materials: conductor, insulator, and semiconductor.

What defines printed electronics (or printable electronics) is when a solution (ink) is developed with these materials as well as the use of organic and inorganic materials each providing a set of advantages such as high conductivity.

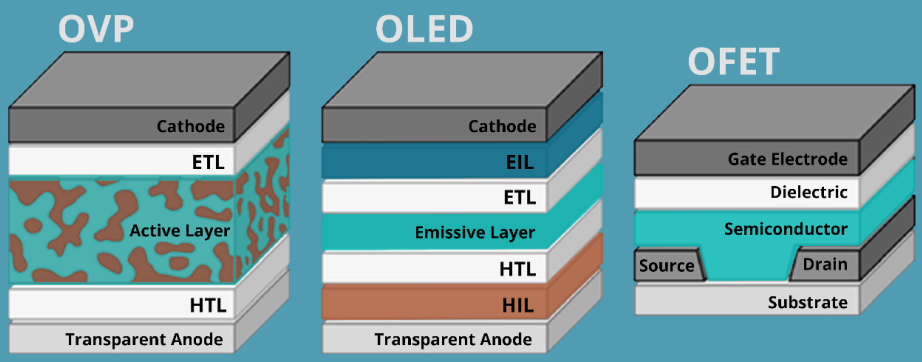


Figure 1: *Diagrams showing organic electronic device structures (Wade, Hollis, & Wood, 2018), adapted by Sustainable Innovations*

Recently, research has been focusing on organic and hybrid semiconductors. They are a true innovation as for the longest time, electronics relied on inorganic semiconductors such as silicon. Even if printed electronics are already an installed commercial technology, research is still undergoing to understand how chemical structure and deposition conditions impact electronic performance. This leaves room for the development of new techniques and the use of nanoparticles made from metals or ceramics already demonstrated its importance for more efficient and low-cost electronics. (Shanker, Hussain, & Rani, 2021)

As further improvements in manufacturing and performance are expected, the printed electronics market is estimated to reach $73 billion by 2027. Its market is soaring rapidly, and the technology is used in more and more products such as displays, photovoltaic cells, radio-frequency identification tags (RFID), lighting, sensors, batteries, and more. (Wade, Hollis, & Wood, 2018)

The field of printed electronics is very competitive globally and various territories already entered a race to develop innovative technologies and manufacturing capacity. Europe's strong position in research and development of printed electronics helps to position its territory in a leading place, as it is capable of manufacturing in low/medium volume segments with added value thanks to its cutting-edge equipment. But it is a joint and coordinated effort that helps the European Union strives as a competitive territory. (European Commission, 2018). LEE-BED is the perfect example of such coordination.

LEE-BED's ambition

LEE-BED is an H2020-funded project that qualifies as an Open Innovation Test Bed with the ambition to eliminate the barriers for European stakeholders penetrating the embedded/printed electronics industry. The goal is to offer the European industry a full-service minimising concept to prototype to below six months. As such, LEE-BED upgrades and goes beyond the state-of-the-art within the development and pilot production of nanomaterials, nanomaterial-based formulations and digital-based embedded component production.

Figure 2: *LEE-BED concept and value chain*

LEE-BED is set to be a springboard for Europe production industry through the following objectives:

1. Be an affordable and independent entity

The LEE-BED project has been created and funded to ensure an affordable and independent entity that can sustain itself financially through cost optimization as well as bring innovation to a greater number of stakeholders with an emphasis on SMEs.

2. Provide European users full techno/economic assessment services

The ecosystem has been built to offer a variety of services that will facilitate the development of the users' ideas and innovation. Thanks to the expertise of LEE-BED partners, various aspects will be covered, from technical assessment to economical ones, always bearing in mind sustainability and feasibility.

3. Provide LEE-BED users upgrade pilot lines across the entire value chain

LEE-BED includes partners who are leaders in their areas and own the infrastructure to support the ecosystem as well as the knowledge and know-how to guide users into the realization of their innovation. Indeed, these partners are specialized in nanomaterials, inks, adhesives, composites, and printed electronics divided in 3 pilot lines (nanomaterial , formulation , component).

4. Provide LEE-BED users post Project support

Finally, LEE-BED is aiming at offering an entry to the market for its users through personalized support that ranges between patenting, safety and investment. By doing so, users will get a complete groundwork and pathway through a concrete development of their innovative idea to a promising business.

The project LEE-BED stands for Innovation test bed for the development and production of nanomaterials for lightweight embedded electronics. In recent years, LEE-BED has made efforts creating a bridge between European Research and Technology Organisations (RTOs) to foster the development and manufacturing of functional nanomaterials and printed components through a cost-effective and sustainable infrastructure. Thus, giving access to companies of any size a well-designed combination of pilot production of nanomaterial, inks, adhesives and composites as well as digital-based pilot production technical, business, patent mapping, safety, life-cycle analysis modelling and funding services.

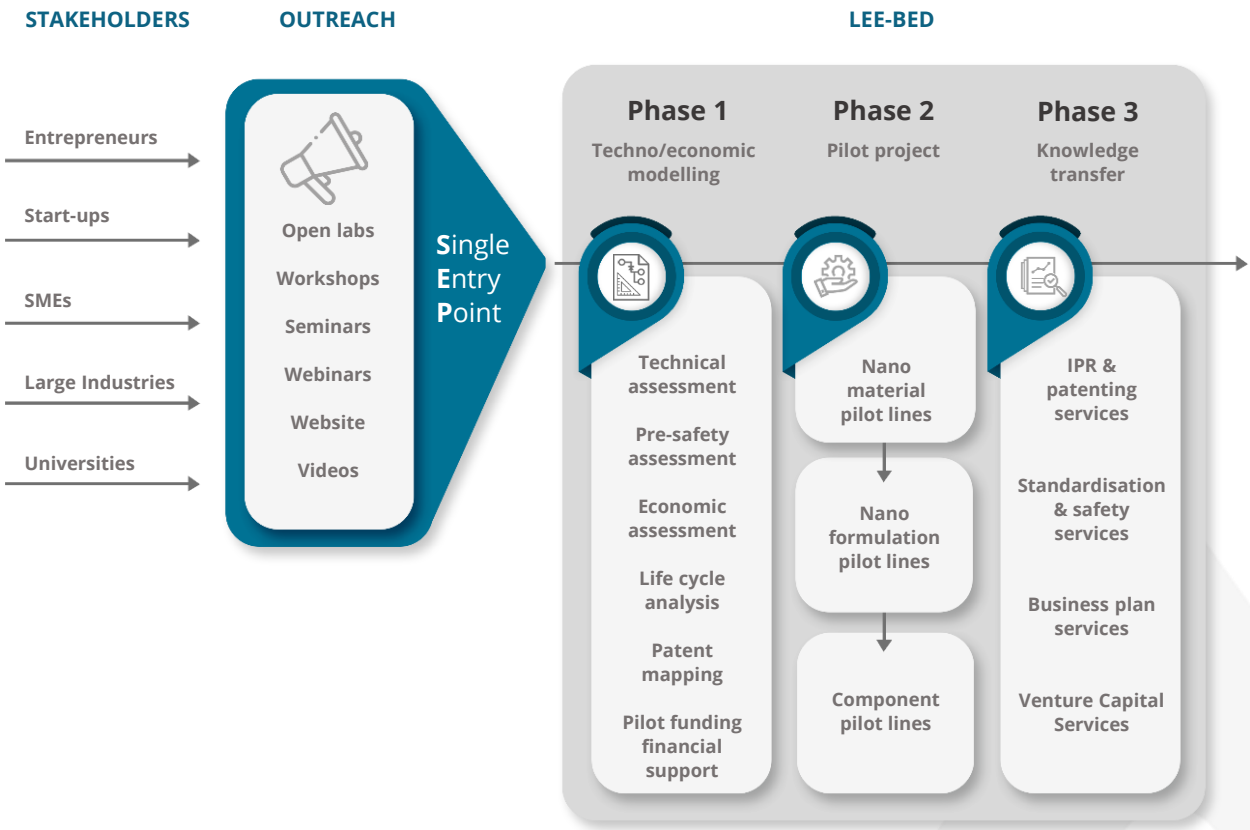


Figure 3: LEE-BED ecosystem

The main value proposition of LEE-BED lies on its main characteristic, being a web-based Single-Entry Point (SEP). It is a functioning and independent entity that overlooks the ecosystem created by the LEE-BED service providers. It is the main contact between the clients and the service providers. Different protocols called Phase have been created to ensure the best user experience and efficiency. It has been designed to cover the current unfulfilled demands of a fast-growing market by putting together a set of high-quality services into a single stop-shop solution.

PHASE 1: Techno/economic assessment

This phase includes 6 services, each offered by a partner expert in the field:

Technical assessment: This service quantifies the technical feasibility meeting LEE-BED user specifications through electromechanical and production design and modelling. This assessment will provide detailed information about nanomaterials, formulation and component pilot lines needed to perform the pilot project in phase 2.

Pre-safety assessment: Safety and regulatory issues for both material and processes, based on the technical assessment, will be reviewed to determine any potential barriers that need to be addressed within the technical solutions presented.

Life cycle assessment: LCA will be used to predict the environmental impact of the materials used and processed for each end-user case. LCA will consider recyclability and sustainability issues as well as support specific industrial cases, focused on the specific products and circumstances.

Economic assessment: A business model canvas will be developed using the information provided through the technical assessment. The model will be used to ascertain the cost of the pilot project and to make a preliminary plan for the return of investment (ROI) and investment requirements for both the pilot project and the transfer of knowledge and technologies.

Patent mapping: To ascertain the state-of-the-art (SoA) within a field, patent mapping tools will be used, which can produce patent statistics based on geography, timing, etc. Main players, competing technologies and IP barriers will be the output of this mapping

Pilot project financial support: Based on the previous assessments, the price estimation for phase 2 pilot projects will be calculated. A dedicated service will provide options for regional funding, crowd funding and access to private investors for users with limited financial capabilities, such as start-ups and SMEs

PHASE 2: Pilot projects, Access to pilot lines

This phase goes from proof of concept, prototyping to pilot production. There are 3 types of pilot lines within LEE-BED:

Nanomaterials

Nano-enabled formulations

Printed & embedded components

Nanomaterial services: This service allows the development of four types of nanomaterials:

- AgNPs for ink-jet, valve-jet and lift printing
- AgNWs for transparent and low loading conductive screen printinks
- Copper micro and nanoparticles for cost effective ink-jet, screenprint, flexo inks and resin infusion
- BaTiO3 for resin infusion and ink-jet high dielectric inks

It also holds a Gas phase pilot line that produce small amounts of multiple pure materials and have the capability to directly write simple components. It enables rapid material screening

PHASE 2: Pilot projects, Access to pilot lines

This phase goes from proof of concept, prototyping to pilot production. There are 3 types of pilot lines within LEE-BED:

Formulation services: This service optimised nanomaterial dispersions from the nanomaterial pilot lines,using solvents systems compatible with the formulation lines. There are 2 types of formulation lines:

- Copper based inkjet
- Zn based inkjet
- Colour changing inks.

These services use Nano-ink, Nano-adhesives and Nanocomposites to provide the most adapted result.

Component services: These services offer a long list of facilities and component pilot lines for use by industry and other stakeholders allowing prototyping and production - 4 pilot plants located across Europe (Netherlands, Denmark, UK and Spain):

- 3D multi-material pilot line
- Ink-jet pilot line
- IoT pilot line
- Packaging pilot line

Characterization services: It is based on non-destructive testing (NDT) and includes X-ray scattering, dynamic light scattering, X-ray fluorescence (XRF) and micro and nano CT technologies. The aim is to provide fast and non-destructive feedback to the development and production of nanomaterials, formulations and components, in order to decrease development times and reduce production wastes.

PHASE 3: Knowledge Transfer Services

The third phase is handed over to the selected partner to create a sustainable project that is feasible and attractive. It is composed of 4 services listed below:

IPR and patent mapping (AXIA): Review of IP gained during the pilot projects and all patenting needs determined. As the starting point of the service, IP rights is being agreed upon individually, on a case-by-case basis.

Standardization/safety services (ITENE): This service reviews the phase 1 regulations and safety standards that are relevant. Extra safety services include exposure assessment and toxicological profiling studies if needed.

Business plan services (SIE): Reviewing the preliminary economic feasibility plan is performed to determine the exact need for further economic support for technology transfer and upscaling to commercial levels, based on pilot project findings.

Investor capital Services (SDP): LEE-BED users have the option of procuring capital through access to private investor companies, based on the final business plans.

After the completion of phase 3, the client's technology should be ready to enter a selected market.

This structure of the development support services will ease the procedure for the development of new products for the benefit of both large companies and SMEs & start-ups companies, offering an integrated set of results in a short period of time.

LEE-BED protocols

This is a detailed description of the protocols followed during the introduction of clients in the LEE-BED Open Innovation Test Bed (OITB), through the specially designed online platform, as well as the organisation of actions between the OITB members and their relevant interactions with the Single Entry Point (SEP).

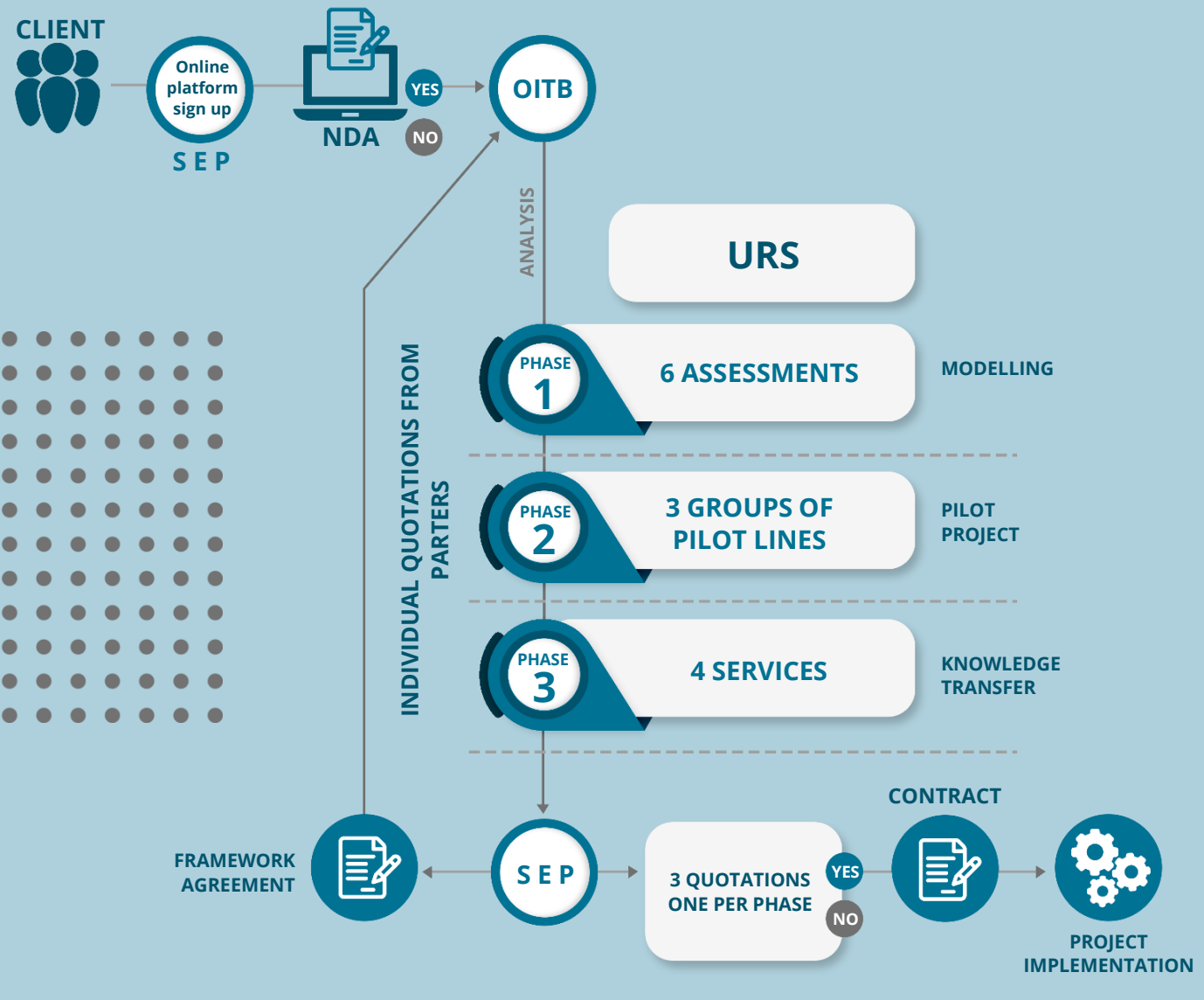


***Figure 4**: LEE-BED client OITB roadmap*

Phase 0: Technical and Eligibility check

On our website, clients can sign-up to gain access to its services.

1. The client fills out a registration form where it includes its idea, needs, specifications and requirements.
2. Confidentiality is at the centre of the process as a Non-Disclosure Agreement (NDA) will be signed directly between the client and the SEP. (if asked)
3. A questionnaire called User Requirements Specification (URS) is then sent out to the client to collect more input on the developed product.

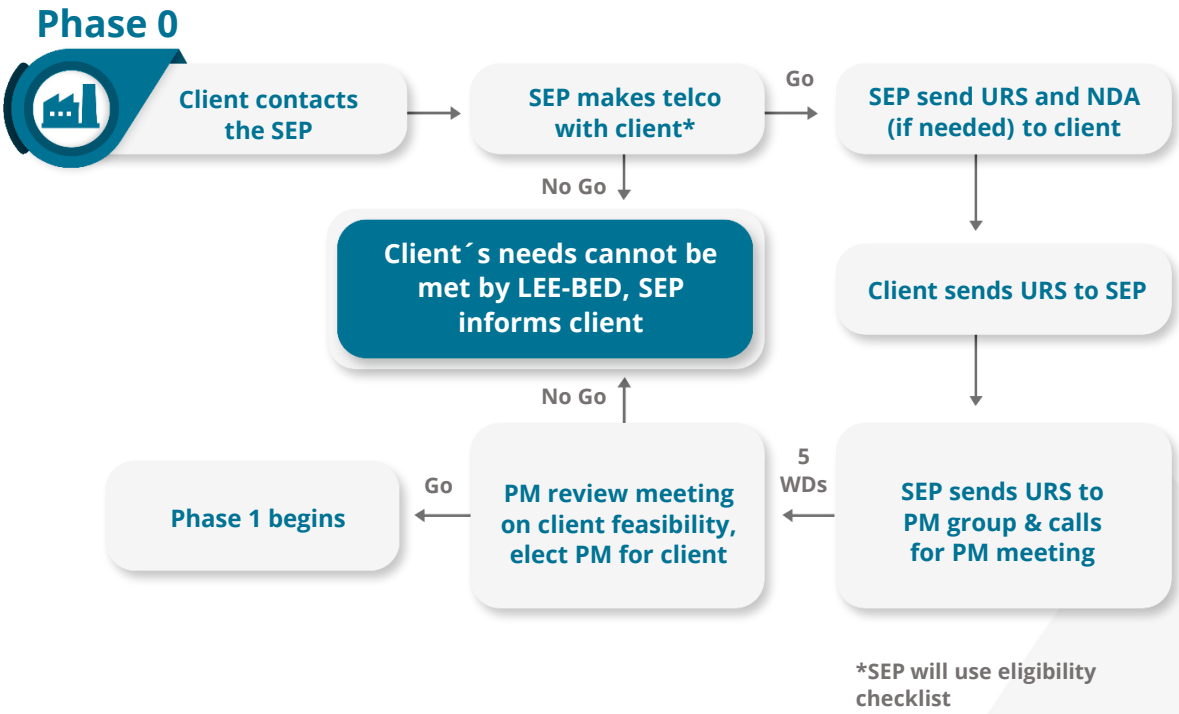


Figure 5: *Phase 0 diagram*

Therefore, the workflow diagram above indicates how the client access the OITB and all the necessary steps until the initiation of activities is presented.

The SEP prepares a quotation with all the phase 1 services, clients will be able to clearly identify the services provided and their costs, this quotation will be adapted to the characteristics and requirements of each project.

LEE-BED Platform

The LEE-BED website allows interested stakeholders to apply using the "Register and gain access to the services and pilot lines" function. The following figure presents the 5 steps that the client is invited to follow to provide key information on the developed product/process.

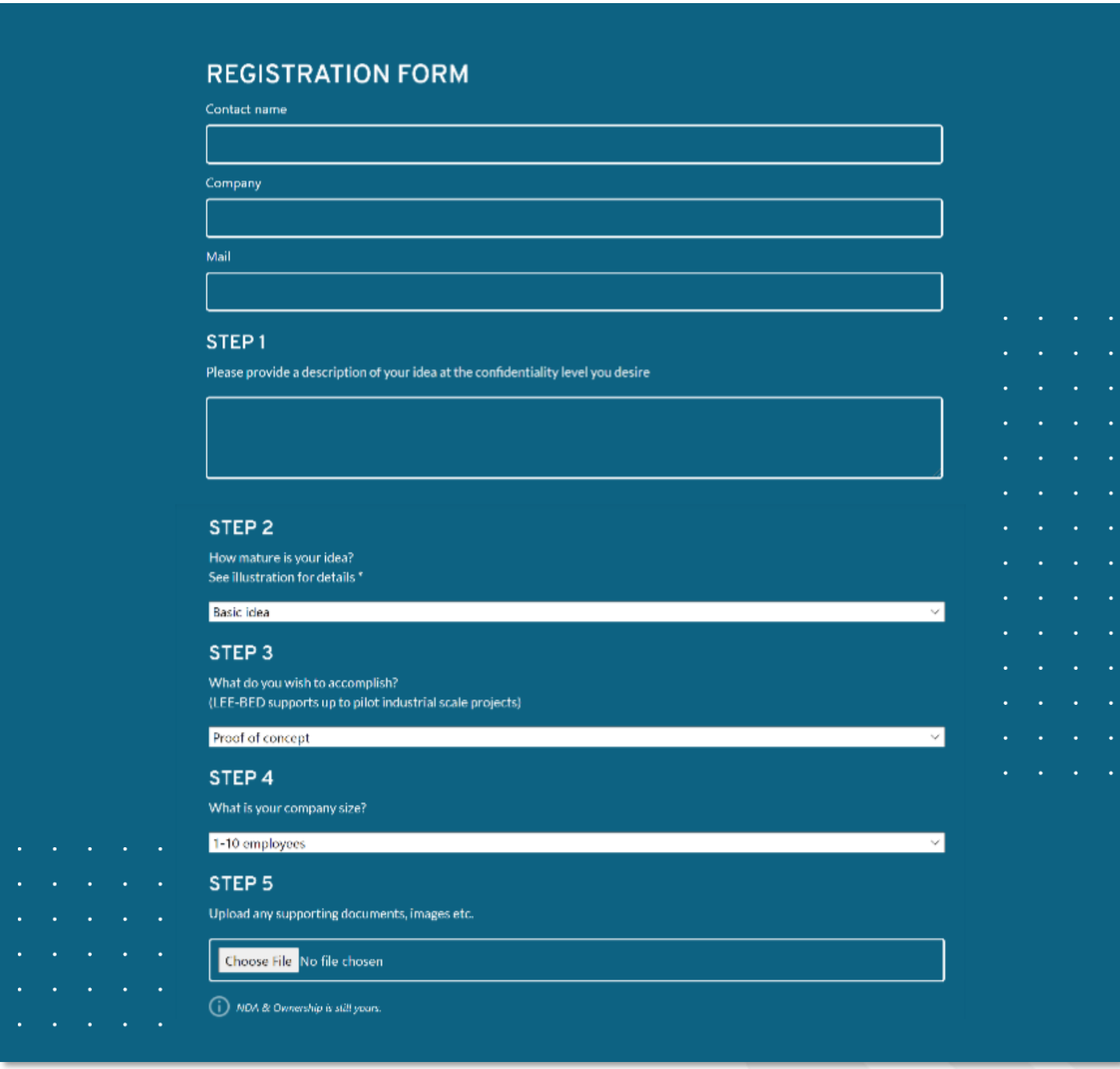


Figure 6: *LEE-BED website platform sign up*

Amongst LEEBED clients there are entrepreneurs, start-ups, SMEs, large industries or universities. They should provide information on the company name and size. Clients can also provide information at their desired level of confidentiality aiming to describe the concept of the project they want to implement through accessing the LEE-BED OITB. They will indicate what they want to accomplish, as well as the level of maturity of the idea they are bringing into the ecosystem, by using a simple drop-down menu (basic idea, proof of concept, laboratory scale). They can also upload documents or pictures that they will act as additional documents presenting their idea.

NDA between Members of the OITB and the Clients

The Non-Disclosure Agreement, which is going to be signed by the client before providing confidential information, has been developed through mutual agreements with all partners.

The NDA defines the parties involved and the terms related to the SEP, the confidential information, Project – Phase 1, effective date, as well as the Disclosing Party and the Receiving Party (i.e. the "client" & the "LEE-BED SEP").

The purpose for which the Confidential Information is disclosed by the Disclosing Party to the Receiving Party will also be defined, establishing the rights and obligations of both parties.

Obligation on behalf of the receiving party, non-obligations, storage of information, copies, advance notice, exploitation of the information, and confidentiality terms and conditions are also described in detail within the NDA.

It is important to note that the NDA is signed only if it is requested by the client. If the client agrees to sign it they will be asked to provide initial input through the questionnaire on the developed product(s) (functionalities, usability, aesthetics etc.), the clients, the business case and Safety, Health & Environmental aspects.

Finally, both parties will also agree on the terms for potential termination of the agreement and destruction of confidential information and the relevant remedies. In case of non-agreement to sign the NDA by either of the parties the project will terminate at this stage.

User Requirements Specification (URS) Report

The User Requirement Specification (URS) report is a dedicated questionnaire that will be filled in after the signature of the NDA (if an NDA is requested). This questionnaire's goal is to collect more detailed information related to the idea, including the overall concept, the purpose of the product development, along with some functionalities, dimensions, aesthetics and usabilities that are required, directly for the client.

Moreover, some information related to the market will also be obtained, such as Client value proposition, Target client group, Pricing, market access and Market position. Additionally, regulatory, safety and environmental aspects will be described, where clients will specify the requirements /procedures regarding EU, US and other national regulations, as well as possible compliance to international product standards (ISO, IEC, etc.).

The URS report will be shared among the service providers, being the first document, along with the information derived from the platform sign-up, that will act as a dialogue among the clients and LEE-BED. The URS includes all the information, the idea, the vision and the expectations that the clients want to be met when accessing LEE-BED.

Additionally, this report will help in the evaluation of the client's idea, based on its relevance to the services offered by the LEE-BED, its feasibility and the TRL level of the technology already owned by the client.

Phases roadmap

The URS report will then be evaluated by the LEE-BED OITB and the relevant pilot line owners and service providers.

The collection of the information from the URS report will allow performing a further analysis in order to provide quotations for the 3 individual LEE-BED Phases to be accessed.

Phase 1: Each client can receive one or more of the services, facilitating the development of their project. An additional URS meeting will be organised among the SEP, the Project Managers the Phase 1 service providers and the client to further elaborate on the project to be implemented. The following Figure summarises the procedures under Phase 1.

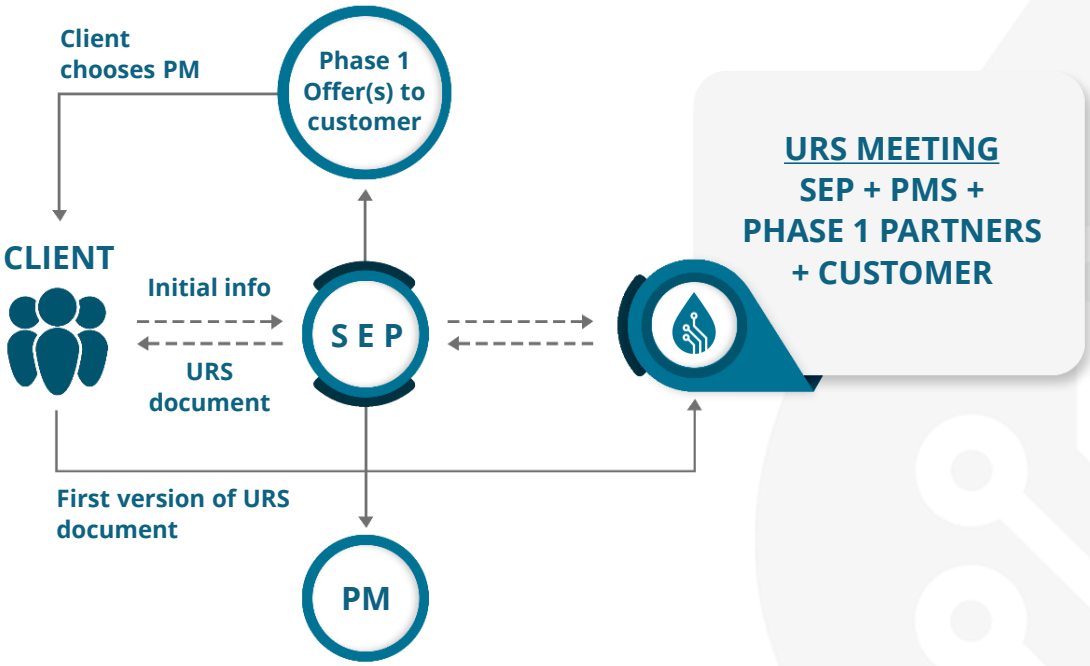


Figure 7: *Phase 1 procedure*

SEP will make the initial phase 1 offer, using SEP's standard terms and conditions with all services are of course standardized in time and fixed cost. If the PM Partner has referred the client to the SEP, this PM Partner has first rights to PM. Main pilot line service providers will have first rights as PM. If more than one pilot line provider can provide the main service and the PM Partners cannot reach a consensus, more than one PM offer will be provided to the client.

The SEP then makes a combined offer and sends it to the client under these rules. The offer can have more than one suggestion for the Project Manager (PM). If there is more than one offer for PM, the client decides which PM offer they will take. The clients can select the service(s) among the 5 assessments that are offered by LEE-BED. The Phase 1 detailed flow chart can be presented here.

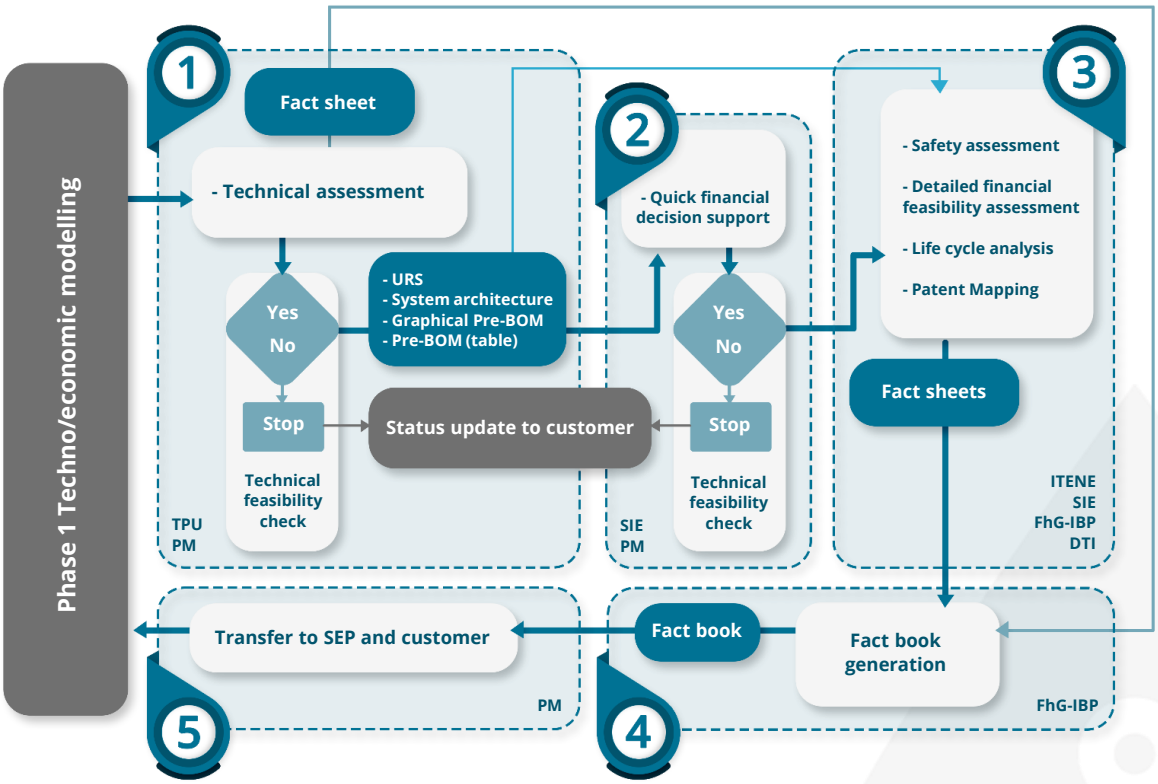


Figure 8: *Phase 1 detailed flow chart*

The end result will be a full techno/economic assessment which will be used for implementing pilot projects in phase 2 and performing final knowledge transfer assessments in phase 3 (if the client agrees on following all the LEE-BED phases). It will be created in unison with the Project Manager, and the involved service partners. Additionally, the outcomes will be transferred to the clients to inform them of the evaluation results, in a form of a Factbook. Finally, the PM takes over the client for Phase 2.

Phase 2: This phase includes the implementation of the pilot projects. Based on the phase 1 assessments, pilot projects will be further developed and executed. In this phase, the PM that the client has selected takes over the process and interfaces with the client, using PMs' standard terms and conditions. Other LEE-BED partners can be involved in the development of the project upon request, based on the specific requirements of the client. However, the final results of the pilot project will go to the SEP and will be communicated to the client. The following Figure summarises the procedures under Phase 2.

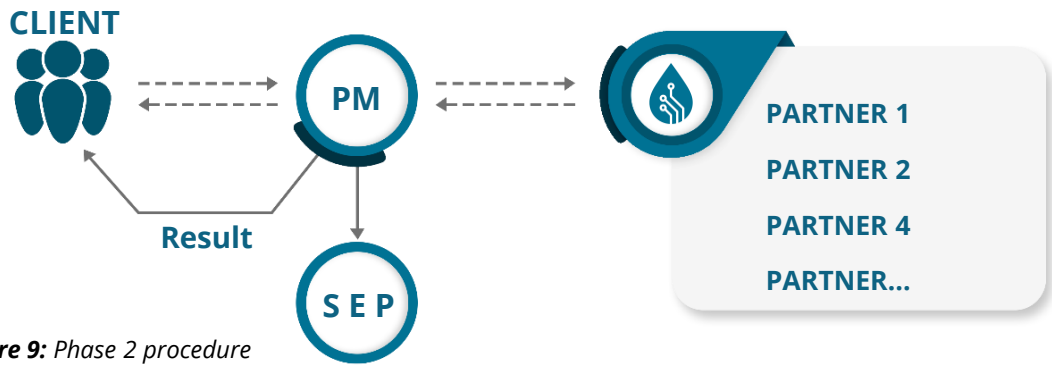


Figure 9: *Phase 2 procedure*

Phase 3: After a successful pilot project, the knowledge transfer services will be applied to each case. The client can choose one or several services depending on its need, it is not mandatory to go through all of them. The idea is to adapt the LEE-BED ecosystem to its client, for them to have a more personalized user experience (UX).

The SEP transfers phase 2 results to phase 3 partners, which then evaluate the client's request and make offers. SEP combines and sends the offer to the client, using SEP's standard terms and conditions. In this phase as in Phase 1, all services are standardized (fixed cost). The following Figure summarises the procedures under Phase 3. A full knowledge transfer report will be delivered to each internal end-user, also as a Factbook for Phase 3.

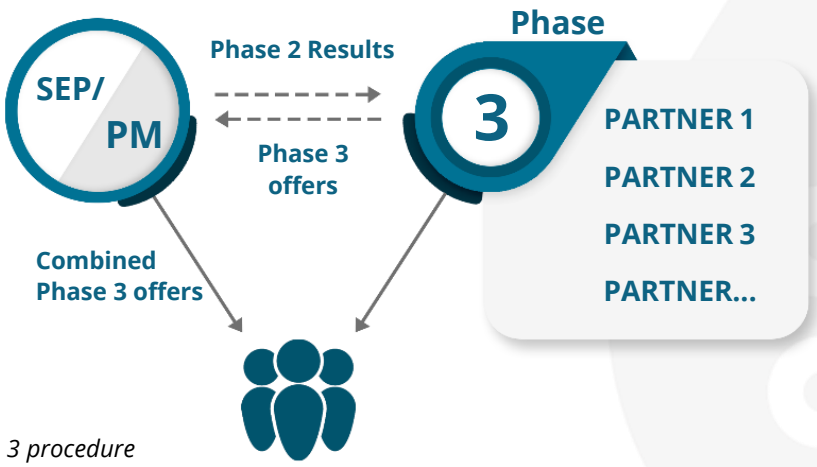
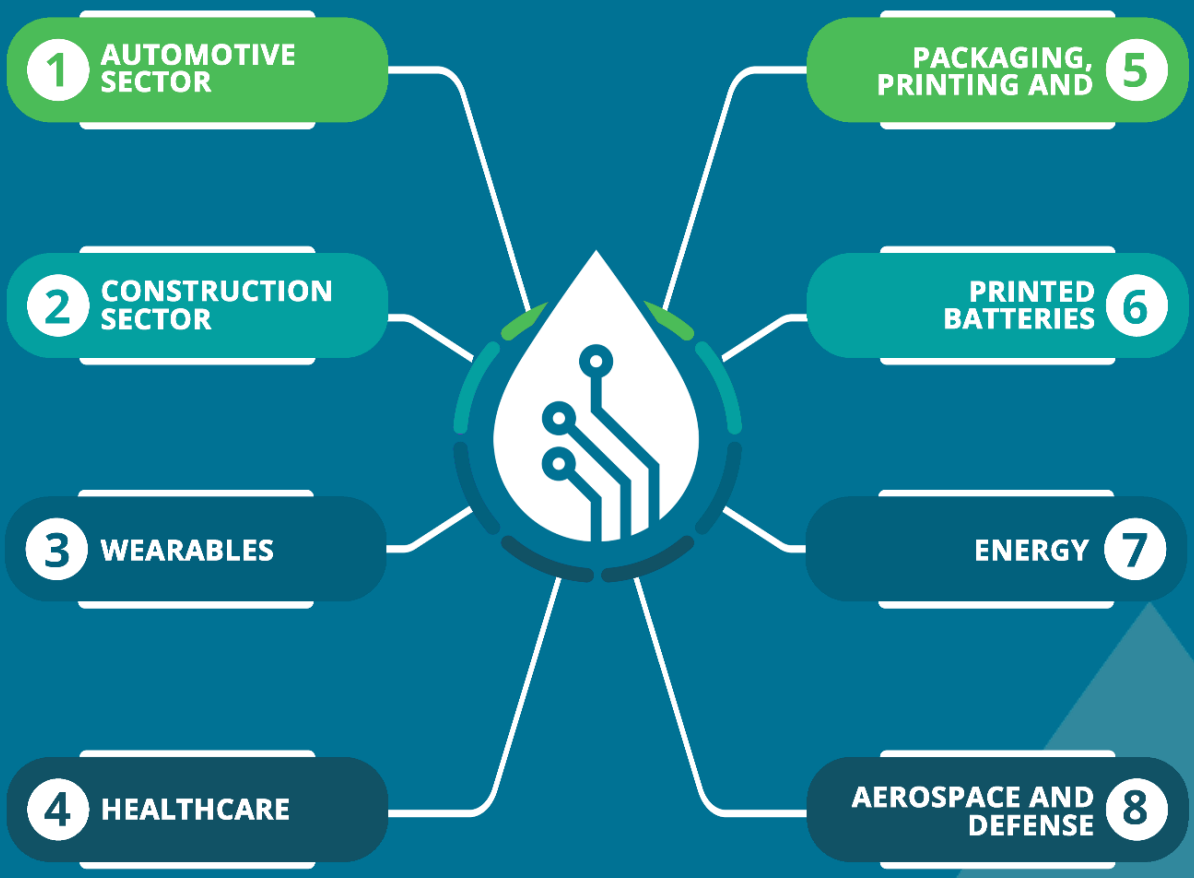


Figure 10: *Phase 3 procedure*

LEE-BED's clients



Automotive sector

Printed electronics have a variety of applications in the automotive sector. With the introduction of electric vehicles (Evs), the possibilities have widened and are projected to improve even more in the coming year. So far, Printed Electronics' use in the automotive sector is divided into two categories of car: electrical and gas propelled.

***Figure 11**: PE applications in a car, MAIER Product portfolio*

LEE-BED developed with its partner MAIER a functional automotive dashboard that includes electronic functionalities such as touch sensing and LED lighting, providing a high added aesthetical value to these components.

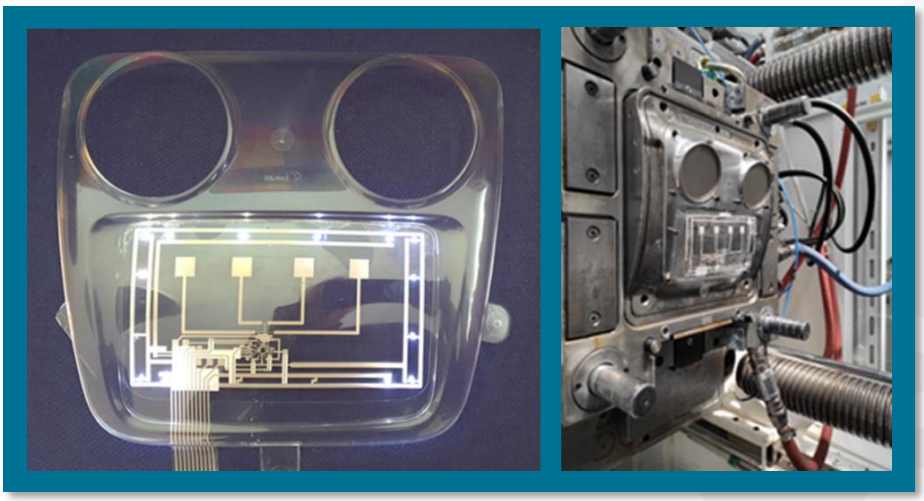


***Figure 12**: Functional automotive dashboard*

Construction sector

In the **construction sector**, the applications of PE can vary between lighting and insulation, from housing to industrial infrastructure.

LEE-BED developed with its partner ACCIONA an autonomous structural monitoring system in order to reduce maintenance costs and increase safety. Electronic functionalities include sensing, wireless data transfer and energy harvesting.

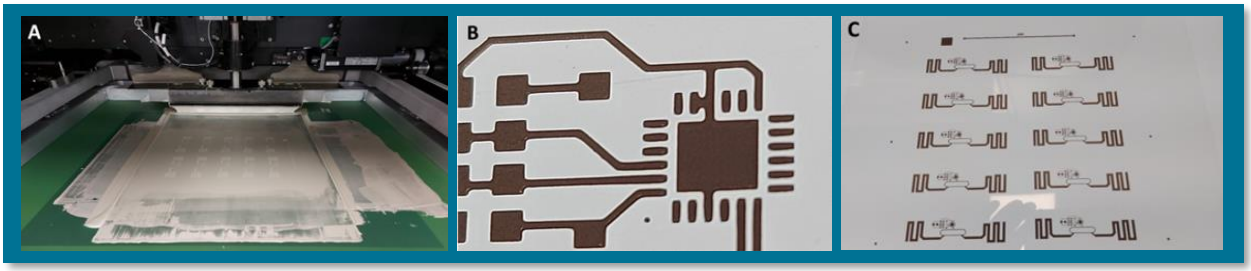


***Figure 13**: Autonomous structural monitoring system*

Wearables refer to the use of sensors that can take measurements from individuals and their environment. The wearable electronic devices market has soared in the past few years. There is an increasing demand for wearable electronics from industries such as:

- Medical and healthcare monitoring and diagnostics.
- Sportswear and fitness monitoring.
- Consumer electronics such as smartwatches and smart glasses
- Defense
- E-textiles and footwear in fashion and sport.
- Workplace safety and manufacturing.

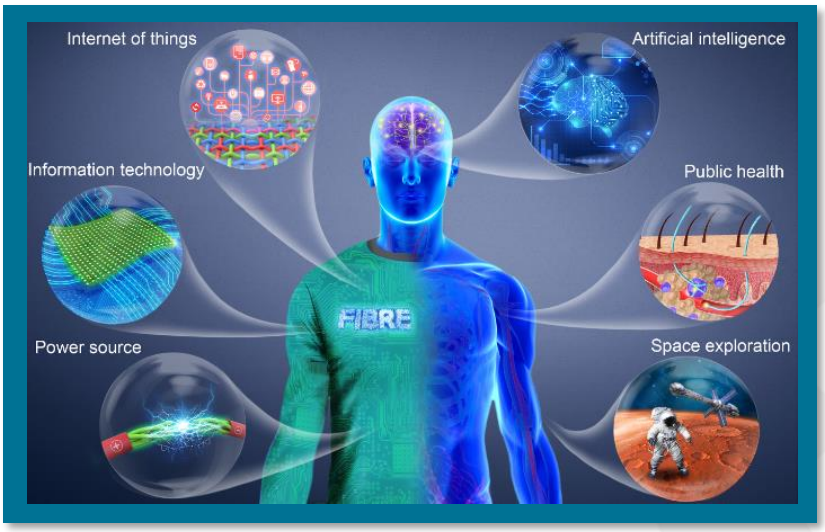


***Figure 14**: E-textiles use (Xu, Xie, Zhang, & Peng, 2019)*

LEE-BED developed with its partner SWAROVSKI several lightweight beauty & fashion accessories with embedded electronic systems. It is a multi-usage concept for the integration of crystal elements into a decorative/functional surface, which can be used for several product lines. Electronic functionalities include sensing, wireless data transfer, lighting and energy harvesting.

***Figure 15**: 3D printed ring developed with SWAROVSKI*

Healthcare

Printed electronics in **healthcare** go from skin monitoring to biosensors as well as hygiene.

Packaging, Printing and graphic arts

New market opportunities open in the **packaging and marketing sector**. Indeed, the R2R gravure printing system proves its efficiency as a cost-controlled technique to print magazines and packaging.

LEE-BED developed with its partner GRAFIETIC an intelligent anti-counterfeiting labelling to explore possibilities such as printed displays to indicate the best before date, printed RFID antenna, inform about temperature and possibly electroluminescent displays.

***Figure 14**: E-textiles use (Xu, Xie, Zhang, & Peng, 2019)*

Printed Batteries

As we are seeing the limits of regular **batteries**, printed batteries are increangly perceived as alternative according to the growing number of applications in the electronics market. Cells using printing technologies, provide low cost, higher flexibility of form factor, and ease in production compared to traditional batteries. Also, integration of PE batteries in electronic devices is easier which drives the market for printed batteries. The producers of printed batteries deal with an enormous challenge in finding suitable packaging material for sealing these cells. (Persistence Market Research, 2017)

Different market segments have emerged based on potential applications of printed batteries:

CONSUMER ELECTRONICS

WEARABLE DEVICES

PHARMACEUTICALS AND HEALTHCARE

Energy

Organic and printed photovoltaics (OPV) contribute to energy generation. They are extremely thin and highly flexible small-format solar cell films that can cover almost all the interfaces of a building or the roof of a vehicle. Therefore, they can produce significant amounts of energy and contribute to the emission-free energy generation of the future.

Aerospace and Defense

The demand for printed electronics in the **aerospace and military sector** is continuously increasing as the printing of electronic circuits on 3D surfaces permits the development of advanced materials for missiles, aircraft wings, rockets, and other defense equipment. Civil aeronautics is also benefiting from the advancements made for its own purpose. (Persistence Market Research, 2017)

LEE-BED Services

LEE-BED is a sustainable model that allows even SMEs to access the latest innovation.

Phase 1		
Service		**Description**
Technical assessment		Quantify the technical feasibility meeting the user specifications through electromechanical and production design and modelling.
Economic Assessment	Quick economic assessment	Preliminary determines if the product or technology will be economically feasible by comparing the expected costs and the forecasted income of the said product or technology.
	In-depth economic Assessment	It aims to determine the economic success of the idea, by developing a business canvas of the idea and company and introducing some aspects concerning the microenvironment. Afterwards, a set of economic analysis are carried out, including the cash and investment needs, the return on investment (ROI), the net present value and the internal rate on returns, which will provide a clear image to the customer on the profitability of the investment in the project.
Pre-safety assessment		Preliminary analyses potential safety and regulatory issues that need to be considered when at all states of the product life cycle, from production to end-of-life.
Life cycle analysis		It predicts the environmental impact of the materials used and processed for each customer. The service also considers recyclability and sustainability issues.
Patent mapping	Simple Mapping	The overall aim of patent mapping is to map technology trends, technology solutions, and relevant competitors, thus providing the clients with strategic knowledge enabling them to further assessment of the possibilities for initiating technological development and commercialisation of the development project.
	Extended Mapping	
	Customized Mapping	
Pilot project financial support		It provides clients with a variety of possible funding mechanism, which will allow them to procure support funding for projects.

Table 1. LEE-BED Phase 1 Services.

Phase 2

- Nanomaterial Line Services
- Formulation Line Services
- Component Line Services
- In-line Characterization Services

LEE-BED Ecosystem Facilities

3D multi material

S2S inkjet

TNO innovation for life

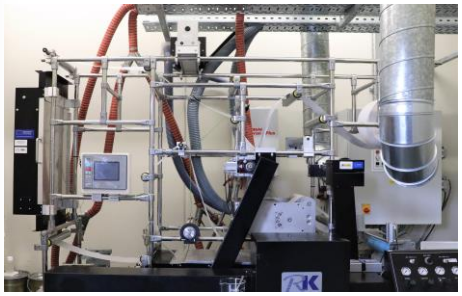
TU/e Technische Universiteit Eindhoven University of Technology

DANISH TECHNOLOGICAL INSTITUTE

RI. SE

- Sheet to sheet
- Multimaterial 3D printing

Packaging



RESEARCH CENTER ITENE BUSINESS, SCIENCE & INNOVATION

IoT

cpi

Large format Inkjet

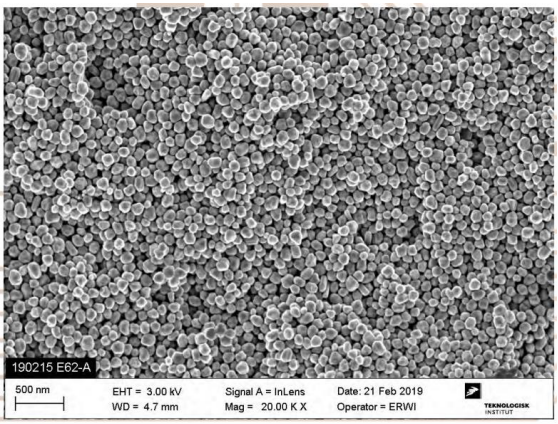
RI. SE

- Roll to Roll

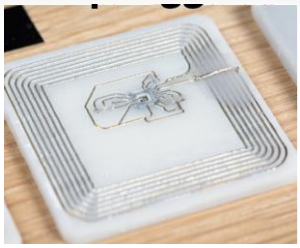
Examples of solutions provided by LEE-BED

Some nanomaterials solutions provided by LEE-BED

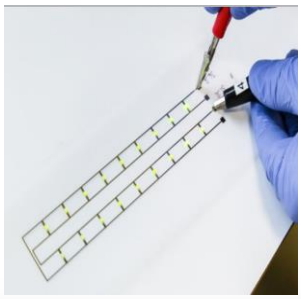
AgNPs for ink-jet, valvejet and lift printing



Some components solutions provided by LEE-BED

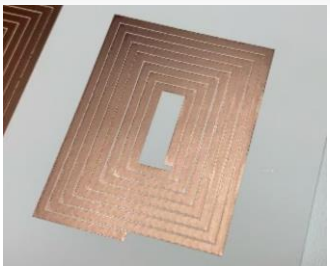


3D printed NFC passive temp logger

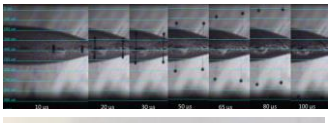


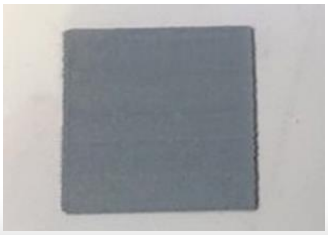
LED lighting

Some formulations solutions provided by LEE-BED



Copper based ink jet formulation

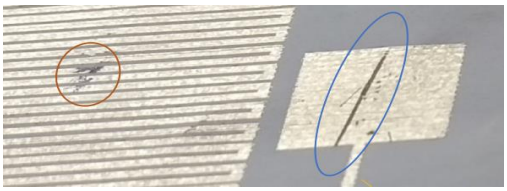


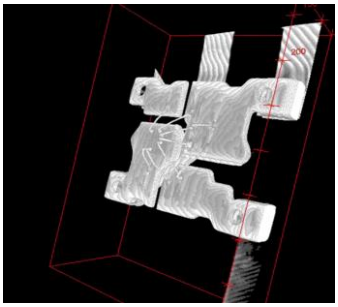


Zn based ink jet formulation

Some characterization solutions provided by LEE-BED

Radiographic QC





Micro and Nano CT QC

Phase 3		
Service		**Details and Advantages**
IPR and Patent	IPR seminars	IPR and patenting review service (IP gained during service & patenting needs determination).
	Additional consulting on patenting and licensing services	
Standardisation and Safety	Standardization consultancy	The service provides a detailed review on regulations and safety standards that are relevant for clients. Extra safety services includes toxicological profiling and studies.
	Occupational exposure assessment: < 3 process	
	Occupational exposure assessment: > 3 process	
	Toxicity assessment screening: cytotoxicity and genotoxicity	
	Toxicity assessment screening: inflammation studies	
	Ecotoxicity assessment: bioassays on aquatic organisms	
	Complete REACH registration management for nanomaterials	
	Compliance with CLP regulation (documentary)	
	Compliance with CLP regulation (experimental)	
Business Plan	Value proposition & external environment definition	The services determine the exact need for further economic support for technology transfer and up scaling to commercial levels, based on the previous phases finding.
	Business Plan development, with 5-years financial projections	
	SWOT & strategic positioning	
	Key stakeholders' identification & engagement	
Venture Capital	Business plan analysis: structured finance	Clients have the option of procuring capital through access to private investor companies, based on the final business plans.
	Start up valuation	
	Term sheet advising	
	Action plan with potential investors (identification, negotiation & closing)	

Table 2. LEE-BED Phase 3 Services.

Strategic partners

ACCIONA Construction is part of ACCIONA group and covers the whole range of construction, from engineering to the performance of works and their later maintenance, and also the management of public works concessions, particularly in the field of transport and social infrastructures. Its objective within LEE-BED was to demonstrate the ecosystem through a project.

Spain

AXIA Innovation offers high added value services specialized in accompanying and supporting companies in all phases of business development and product's commercialization. AXIA Innovation is built from the synergy between four main service lines: project management, innovation management, knowledge transfer, and communication and design. AXIA leads knowledge management and IPR strategy, patent mapping and communication in the LEE-BED ecosystem.

Germany

The French Alternative Energies and Atomic Energy Commission (CEA) is a public body established in October 1945 by General de Gaulle. A leader in research, development and innovation, the CEA is active in four main areas: low-carbon energies, defence and security, information technologies and health technologies. Within LEE-BED, CEA lead non-destructive evaluation in order to organise and develop the support for characterisation and monitoring of new nano-enabled inks and printed materials and structures.

France

Acting as an RTO, the Centre for Process Innovation is a UK based, not for profit SME, a technology innovation centre and the process arm of the High Value Manufacturing Catapult. Operating across a broad range of technologies, they support their partners at every step of the way; from concept to market; business support to technology development; from scale up to supply chain intervention.

United Kingdom

DANISH TECHNOLOGICAL INSTITUTE

DTI is the largest technological service provider in Denmark and one of the biggest in northern Europe. Founded over 100 years ago, the institute's core business lies in providing technological services to industry, especially SMEs. DTI is the coordinating organization of LEE-BED, with the technical, administrative and financial responsibilities but also takes part in technical and business services.

Denmark

Fraunhofer

Two institutes of the Fraunhofer Society participates in LEE-BED: FHG-IIS and the department Life Cycle Engineering (GaBi). FHG-IIS coordinate and carry out the characterization services and FHG Gabi is in charge of life cycle assessment.services.

Germany

grafietic
identificación y sistemas

Grafietic S.L. is a Valencian enterprise with almost 30 years in the market. Its main activity is design, manufacturing and distributing labels in national market and in some cases to international customers. The objective of GRAFIETIC within LEE-BED was to demonstrate the ecosystem through a project.

Spain

RESEARCH CENTER ITENE

ITENE is the specialist Technological Centre in R&D in packaging, logistics, transport and mobility. Its mission is to generate scientific and technological knowledge and adding value to companies through the implementation of R+D+I in these areas. ITENE deployed and exploits of the smart packaging pilot line and associated activities, as well as the regulation and safety assessment of the entire test bed.

Spain

MAIER is one of the leading decorated plastic component supplier with up to 3,000 employees in 8 countries being part of the biggest co-operative group in the world. It manufactures components for the automotive industry. Its objective within LEE-BED was to demonstrate the ecosystem through a project.

Spain

RISE is a non-profit research organization owned by the Swedish government. It offers innovative and value-adding ICT solutions – from idea to prototype – for sustainable

growth in industry and society. RISE core strength is in the area of hardware being able to provide cutting edge resources and technological solution within Digital Communication, Life Science, Clean Technologies and Industrial Production. RISE developed S2S and R2R pilot lines to enable deposition of alternative to Ag metal- based inks, significantly reducing the material costs and an environmental impact.

Sweden

SD Partners is a financial consulting firm and M&A boutique based in Madrid (Spain) and specialized in attracting private capital for Start Ups with a technological base. Within LEE-BED, it ensure funding and venture capital opportunities.

Spain

Sustainable Innovations is a Spanish consultancy firm that provides a wide range of innovative services to a broad range of sectors across Europe: bio-based industry, renewable energy, advanced materials, among others.

The core competencies offered by SUSTAINABLE INNOVATIONS are structured in three main pillars which bridge the gap between ideas to market: Innovation Management, SMEs and start-up services, and Capacity Building.

SUSTAINABLE INNOVATIONS leads the economic sustainability of LEE- BED with the support of all consortium partners to ensure the success of the project from an economic and legal perspective.

Spain

SWAROVSKI

Swarovski is the world leading manufacturer of premium crystal components, providing finest crystals since 1895. Research, Development and Innovation forms the constitutive basis for future growth of the Swarovski Group covering a wide range of R&D topics from glass engineering, over light & optical engineering, glass cutting and polishing to refinement technologies (such as PVD, CVD, PECVD, sputtering, wet chemical coating, lacquering) as well as electronics development. Its objective within LEE-BED was to demonstrate the ecosystem through a project.

Austria

TNO innovation for life

TNO is one of the major contract research organisations in Europe. TNO functions as an intermediary between basic research organisations and industry. Their expertise covers the whole process from basic (material) research, design and engineering to manufacturing and testing of products and systems. The focus is on innovation in the areas of high- tech systems and materials, manufacturing, the sustainable chemical industry and space applications

The Netherlands

tpu

TPU was established in 1990 and focus on product development for its customers, in regard to manufacturing equipment. TPU collaborates in the definition of development methods within LEE-BED.

Denmark

TU/e Technische Universiteit Eindhoven University of Technology

(TU/e) is a research university specializing in engineering science & technology. Its education, research and knowledge valorisation contribute to science for society, science for industry and science for science. Within LEE-BED, TU/e upgraded the component pilot lines, focused on realisation of the integrated LEPUS and LIFT machine from a process control and modelling point of view.

The Netherlands

VSPARTICLE

Based on decades of fundamental aerosol research at the Delft University of Technology, VSPARTICLE was founded in 2014 to bring the spark discharge technology to create nanomaterials onto the market. VSPARTICLE focuses on gas phase direct writing and uses its expertise in product development to support the customer from the initial product concept, market research, prototyping process to a scalable product

The Netherlands

Conclusions

The LEE-BED value chain offers a unique collaboration between expert players in nanomaterials and inkjet printing in the European Union to foster the current production industry, bringing innovation to the business world and supporting small and medium enterprises mainly. This special ecosystem strives for accessibility, knowledge, and most recent equipment.

LEE-BED managed to speed up the development of nanomaterials and lightweight printed electronics through its newly created one-stop shop. This OITB is conducive to the growth of innovation and cost-efficiency and provides a holistic solution to the end-users. Automotive, transportation, construction, wearables, packaging, and energy are market segments where printed electronics (PE) can play an important role and represent vital sectors of the European economy.

Printed electronics' use, in current years, has exploded and can be found in a wide variety of products, invading the industry and the consumer's life.

Its application makes it a fast-paced and essential technology that is set to establish in the near future.

In summary, the benefits of the usage of printed electronics are:

- Low-cost production
- Flexible reformation factor
- Easy to produce
- Easy to embed
- Enable the development of non-conventional functional electronic devices including flexible displays, smart labels, animated posters, active clothing, and more. (MarketsandMarkets, 2021) (Markets, 2020)

This introduction to the thriving market of nanomaterials and PE shows in so-little words the wide variety of possibilities it offers, reasons why the LEE-BED project is focused on targeting the field on a tangible approach, as research is constantly improving and the PE potential is almost immense.

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