LITEN ANNUAL REPORT 2015

TECHNOLOGIES FOR TOMORROW'S ENERGIES

ENERGY STORAGE

HYDROGEN

ENERGY EFFICIENCY

HEATING SYSTEMS

SOLAR ENERGY

MATERIALS

BIOMASS

liten
cea tech

DIRECTOR'S FOREWORD

Liten, leading the way in France's renewable energy landscape

Renewable energy research at Liten is structured to support the French government's energy transition policies, with activities focusing on the following areas:

- Renewable energy, with a specific emphasis on solar and bio-based energy. Research at Liten covers the entire value chain, from component fabrication and integration into basic systems through to integration into energy systems characterized by far greater complexity – microgrids, neighborhood grids, and, in the future, municipal and regional grids – and often including storage capabilities.
- Energy efficiency, with a focus on energy-efficient buildings and industrial processes.
- Reducing greenhouse gas emissions and, in particular, carbon dioxide, through advances in electric mobility and CO_2 recovery using a variety of conversion technologies.
- Finally, our materials efficiency research is playing an increasingly crucial role. Our work includes synthesizing new generations of materials and developing new processes like 2D and 3D printing.

This year's Activity Report highlights the results of our research in these pivotal areas. At end-2015, Liten had achieved some major technological advances in electrical, thermal, and hydrogen energy.

More generally, 2015 was a pivotal year for renewable energy. The French government passed its Energy Transition for Green Growth Act, which sets forth the nation's renewable energy targets. This new piece of legislation will reshape the energy landscape, spurring a shift toward distributed energy production and storage resources. At Liten, we shifted our strategy to align with these emerging challenges several years ago. In 2015 we further sharpened our focus, most notably by leveraging our modelling know-how to develop software platforms to enable the dimensioning and agile management of energy systems.

Florence Lambert,
Director, Liten

Our capacity for innovation was stronger than ever in 2015. We once again filed a significant number of patents, earning CEA Tech the number one slot in the Reuters global innovation ranking. We are also pleased to showcase Liten spinoffs in this report, with startups addressing markets like energy management, hydrogen, and medical systems.

Last but not least, 2015 marked a turning point in Liten's international development, supporting several of our partners' export strategies through projects in Bolivia, Qatar, and the Middle East/North Africa.

CONTENTS

Liten: the driving force behind the sustainable energies of the future

Liten is Europe's largest renewable-energy technology research institute. Based mainly in Grenoble and Chambéry, France, we boast high-quality facilities staffed by world-caliber scientists and engineers prepared to lead the energy transition.

Liten, the Laboratory for Innovation in New Energy Technologies and Nanomaterials – a branch of France's leading research organization, the CEA – is spearheading the EU's efforts to limit dependency on fossil fuels and reduce greenhouse gas emissions. Liten is the only research institute to cover the entire value chain, from the synthesis of materials to the development of complex demonstrator systems. Liten offers its industrial partners personalized technology development services and digital dimensioning tools for energy systems.

400 R&D agreements each year

We are the partner of choice for manufacturers of all sizes, regardless of where they are on the technology value chain. Every year we put in place 400 research contracts and carry out R&D on behalf of industrial partners from a wide range of market segments: energy, transport, construction, civil engineering, environmental, and IT industries, amongst others.

1,300 patents: a robust intellectual property portfolio

Intellectual property forms a major part of our activities. We have a portfolio of more than 1,300 international patents and are one of the CEA's most active generators of intellectual property, filing 235 in 2013, 230 in 2014 and 231 in 2015.

A three-pronged approach to strategic research

Our R&D addresses technological and economic challenges in three main areas:

- Renewable energy, especially solar and biomass.
- Energy efficiency and energy storage, including environmentally-friendly mobility, energy-efficient buildings and building energy management, and power generation systems (from production and storage through to conversion and management of thermal energy, electricity, and gas).
- Materials for energy and new environmental challenges.

Liten, a partner of the Carnot Institute "Energies du Futur"

Liten and ten other Grenoble-based labs are partners in the Carnot Institute "Energies du Futur" initiative, which receives government funding proportionate to the volume of industrial R&D partnerships established. These funds pay for technological innovative research to investigate new topics and proof-of-concept testing of breakthrough technologies and to create demonstrator systems.

INES 2: the INES Energy Transition Institute

Liten, along with its partners at the French Solar Energy Institute (INES), is eligible for government funding as an Energy Transition Institute (a French government initiative). INES 2 was set up to support and accelerate the development of France's solar-energy industry, from PV and solar thermal energy production through to building-integrated systems and grid integration. The funds allocated to this program are helping expand the existing technical facilities and supporting research and training at the international state of the art.

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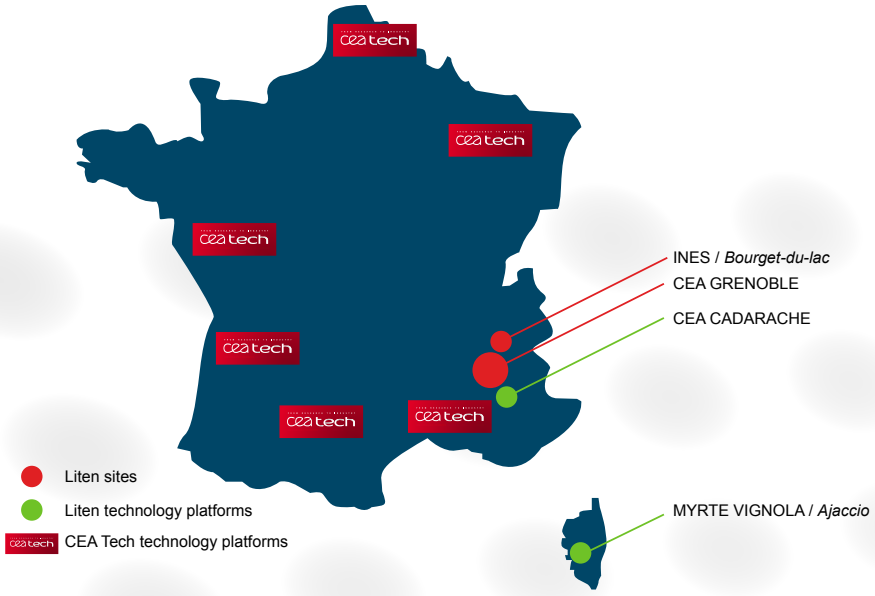


Working with Liten

At Liten, we are poised to meet the needs of businesses of all sizes, from start-ups and SMEs to major multinationals. Our main facilities in Grenoble and Chambéry, France, are supplemented by regional offices in Bordeaux, Metz, Toulouse, Nantes, Cadarache and Lille, and by experimental technology platforms in Cadarache and Corsica. We offer a flexible range of R&D services that can be tailored to our industrial partners' specific innovation strategies. Our turnkey services are designed to boost our partners' competitiveness, with targeted solutions for all stages of technology development, from material characterization and economically-viable components through to complete systems to address the current and future needs of a specific market. Moreover, all our services are provided in an ISO 9001-certified environment with the right systems and resources to ensure confidentiality, cost efficiency, and on-time completion of development projects.

Choose from four types of partnership

- **Industrial research agreement:** covers a given time period and a clearly-identified R&D topic; can be coupled with a collaborative R&D project (like those funded by the French National Research Agency, French Single Interministerial Fund, or EU programs) to secure additional financing and extend a project's reach. Our engineers have proven experience with this type of collaborative project and can provide expert assistance at all stages.

- **Affiliate programs:** multipartner R&D programs with simplified administrative procedures; especially suited to SMEs with little or no in-house R&D capabilities.

- **Joint R&D lab:** we set up a joint research team with our partner under a reciprocal agreement for a period of up to several years. Shared goals, technology milestones, and joint management mechanisms are outlined in the agreement.

- **Technology transfer:** partners can license our technology under certain conditions, and benefit from our technical support to transfer mature, patented technology to industry.

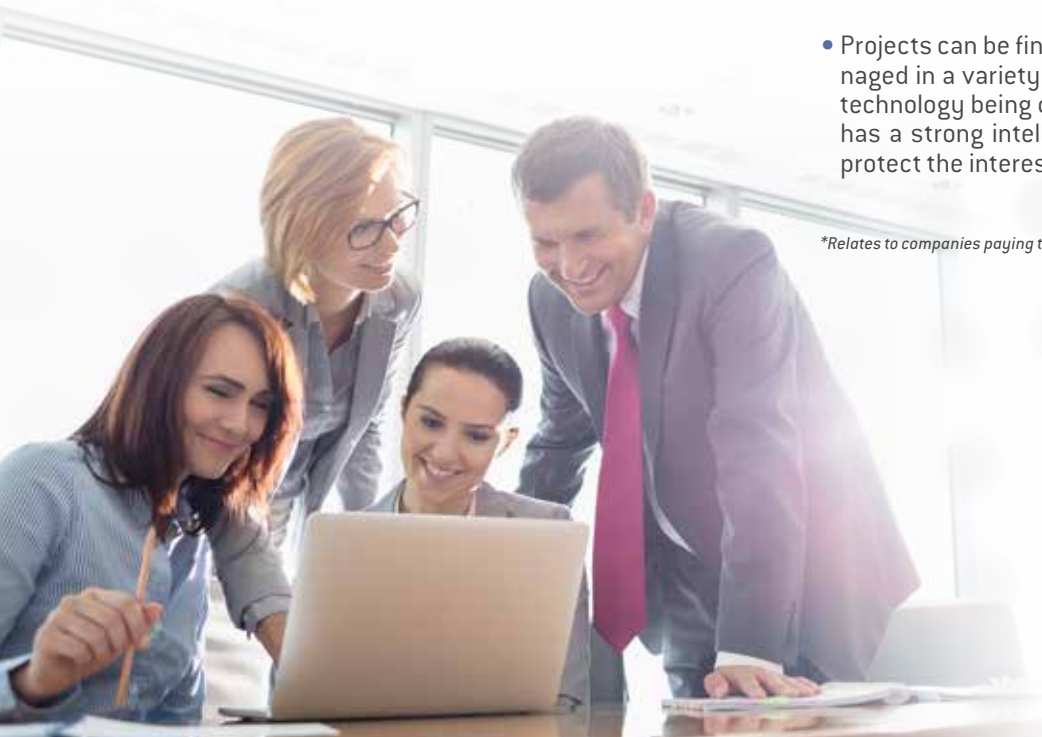
A tailor-made offering

- We tailor the technical resources, number of scientists and engineers, budget, and calendar for each joint development project to meet each partner's unique needs.

- In some cases*, 60% of the R&D costs billed to our partners may be eligible for the French government's Research Tax Credit program.

- Projects can be financed and intellectual property managed in a variety of different ways depending on the technology being developed and its maturity. The CEA has a strong intellectual property policy designed to protect the interests of its partners worldwide.

**Relates to companies paying tax in France.*



From solar to bio-based energy

Our renewable-energy research covers photovoltaic, solar thermal, and bio-based energy and spans the entire value chain, from materials to grid-connected systems. Prototyping at our technology platforms is one of the ways we ensure our work meets manufacturers' real-world needs. Our PV program focuses on premium modules offering very high yields and communications, self-troubleshooting, and other advanced features and on integrated modules designed for specific applications, such as the "solar road". Our solar thermodynamic work supports France-based companies in their efforts to develop solutions for foreign markets. Our bio-based energy research looks at ways to convert liquid and solid waste such as wastewater treatment sludge and solid recovered fuel into energy.

Solar energy

G6 monolike silicon ingots: ECM/CEA CRYSTALMAX process

Our researchers have produced G6 (630 kg to 800 kg) monolike silicon ingots with PV-grade yields evaluated on several thousand wafers. Yields were measured at 18.3% for bricks cut from the center of the ingot, and the bricks offered good stability throughout their height. Bricks cut from the sides of the ingot produced yields of 18.1%. The process has already been transferred to our industrial R&D partner. However, our researchers continue to work on several potential improvements: they are characterizing the material to gain a deeper understanding of the phenomena underlying the appearance of dislocations that lower conversion yields; studying the effects of mechanical stirring of the liquid bath; adjusting the thermal recipe to obtain an optimally-shaped liquid-solid front; and investigating new crucible coatings to limit contamination of the silicon.

A cost-competitive fabrication process for bifacial n-type solar cells

Our researchers have successfully demonstrated on laboratory equipment a fabrication process for bifacial n-type solar cells. The patented process, which leverages PERT technology, produces cells with yields of 19.8%. The number of steps in the process has been reduced to seven, five of which are compatible with today's production lines. A study showed that the production costs (€/Wp) of n-type cells is similar to that of p-type cells produced using aluminum BSF technology. The process could help n-type cells – which offer greater yields and better stability over time – make inroads into a wider market. Our researchers must now validate two remaining steps of the process on industrial-grade equipment. The results of the research have been promoted in several communications campaigns to attract interest from potential industrial partners.

IN BRIEF

- Liten's Oxymap technology now boasts a PV yield degradation prediction module that uses measurements of the interstitial oxygen in monocrystalline silicon. The module has been validated by a manufacturer.

INTERVIEW

Charles Roux,
Head of the Heterojunction LabFab at the French Solar Energy Institute (INES)

Revitalizing Europe's heterojunction cell industry

"Asian manufacturers dominate the low- and mid-range PV cell market. The premium heterojunction cell market represents a substantial opportunity for European manufacturers capable of producing affordable, high-yield cells. We have put together a team of top-notch researchers to tackle this issue and have signed a R&D partnership with Swiss manufacturer Meyer Burger, Europe's leading PV production equipment manufacturer.

We have several objectives, from improving the materials and the cells and pushing yields even higher using a bifacial cell approach through to developing 60-cell modules with minimum power of 300 W and lifespans of 30 years or more. And, of course, we will work to bring costs down.

Our pilot manufacturing line, the Heterojunction LabFab, is unique in Europe. The line can produce test runs of tens of thousands of cells. Meyer Burger has been working on heterojunction cells since 2008 and the CEA has been investigating cells and modules since 2005, with a number of patents on the technologies. This makes the partnership a very well-rounded one."

Colas invents the "solar road"

In a development that has garnered substantial media coverage in France, Colas, the world's largest transportation infrastructure company, has unveiled its new "solar road" concept. The innovation, which is protected by several patents, consists of tiles into which PV cells coated in a multilayer substrate have been incorporated. The tiles are laid on the road's paving material using an adhesive. A kilometer of "solar road" can generate enough power to light up a city of 5,000 inhabitants. The technology, which Colas developed over five years of joint R&D with Liten at the French Solar Energy Institute (INES), was presented at the COP 21 climate conference in Paris in December 2015. The solar tiles are compatible with standard paving materials and can withstand the weight of even heavy trucks. The research is ongoing, with the focus now shifting toward further increasing the tiles' reliability and aging and preparing for industrial scale-up.

Making concentrator PV modules available to the masses

A novel medium-concentration module technology (M-CPV) for III–V PV cells is currently under development at our labs. The technology leverages proven PV-industry assembly processes to drive costs down and bring manufacturers opportunities to diversify. The initial module was built by laminating cells onto an aluminum mirror that plays several roles: mechanical support, optical concentration, and heat dissipation. The module achieved conversion yields of 30.8% indoors and 25% outdoors. Additional improvements are still being made to reduce costs and enhance thermal behavior. These optimizations could push outdoor yields to 35%. In addition, M-CPV can be used in areas with moderate solar irradiance, such as the south of France.

Solar energy

Making PV panels two to three times lighter in weight

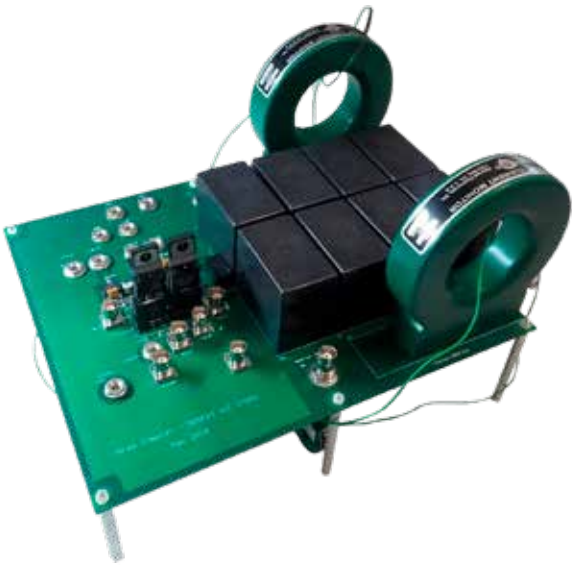
Our researchers have developed PV modules weighing in at just 6 kg/m^2 and 4 kg/m^2, two to three times lighter in weight than standard PV panels. These advances, which were achieved under two separate R&D projects, entailed partially or completely replacing the aluminum frame and glass front-side, which account for 80% of total weight, with innovative composite materials ensuring the module's mechanical rigidity. The first research project is in partnership with a France-based manufacturer. The 6 kg/m^2 were manufactured on the same production line used to make traditional panels and offer similar lifespans. Because of their light weight, however, the new panels could penetrate the huge commercial rooftop PV market. The second research project is in partnership with the French Defense Procurement Agency DGA and a France-based manufacturer. It focuses on 4 kg/m^2 panels light enough to be supported by a tarp. Life-sized prototypes were built and tested in lab conditions.

BIPPP project for powerful, cost-competitive bifacial modules

The BIPPP project, conducted in partnership with ECM Green Tech and backed by funds from the French government, focuses on developing a technology to produce bifacial PV modules on monolike silicon at a cost comparable to standard silicon modules. The initial modules, installed at the CEA and monitored continuously since April 2015, have achieved an average improvement of more than 25% over monofacial modules. The enhanced performance was due to improvements made across the entire material-cell-module-system chain. At the same time, the researchers have been actively involved in the standards organizations creating a new PV standard for bifacial modules.

Liten produces certified PV modules

Our researchers, working in collaboration with Mondragon Assembly, produced 72-cell, 300 Wp PV modules on Liten's industrial-scale fabrication line. The modules were sent to certification organization Certisolis, where they came through IEC 61215 testing with flying colors. The certification confirms the modules' electrical performance and durability. In terms of power, the modules showed low dispersion, with a standard deviation of just 0.6 W. Liten is now one of the only labs in Europe capable of producing small runs of modules that comply with the latest standards, giving manufacturers developing new materials and modules a valuable resource to accelerate their product validation cycles by up to three months.



Characterization bench for hard-switching power inverters

A characterization bench for hard-switching silicon carbide (SiC) inverters has been built to measure the dynamic performance of 1.2kV and 1.7kV switches over a temperature range of -40°C to 200°C. The results of the experiments enabled the researchers to use electrothermal models to scale the static electricity converters used in PV power plants hooked up to the grid at 400VRMS or 690VRMS. An additional characterization bench will be developed by the end of 2016 to assess 10kV caliber SiC switches for medium-voltage PV applications. This type of characterization bench is being used in several ongoing industrial R&D projects in the field of electrical energy conversion.

IN BRIEF

- Vinci Technologies has sold its first high-sensitivity gas permeameters. The instrument was developed in conjunction with Liten to characterize the leak tightness of barrier films for optoelectronic applications like organic photovoltaics.
- The organic PV modules developed and manufactured by France-based Armor earned awards at international trade shows in the United States and in France. Armor worked with Liten under a five-year R&D contract – at INES, France's national solar energy research institute – on module's architectures, processes, and characterization.

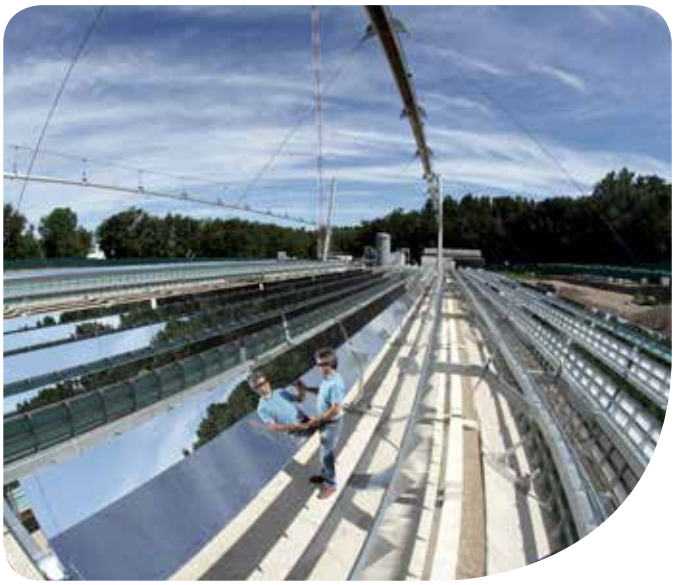
Self-testing modules prevent production shutdowns

Our researchers have developed new self-testing capabilities for photovoltaic modules. The technology can generate the current/voltage characteristic, or I-V curve, for each module in a production chain in less than a thousandth of a second. The I-V characteristic are then analyzed by software developed to detect the electrical signatures characteristic of different types of defects. In the event of an incident, power to the defective module is cut off without disrupting the rest of the system or stopping the supply of energy. The technology comes ahead of future US standards that will require an individual protection system able to cut off power to each module. The system can be retrofitted to existing modules (the unit measures just a few square centimeters) or integrated into new module designs. It has been patented and tested on PV equipment at several locations and has already generated interest from manufacturers.

Solar thermal energy

A pre-design model of multi-thermal solar plants

Our researchers have developed a numerical model to facilitate the pre-design and dimensioning of multi-thermal solar plants up to 1 MW. The model factors in electricity, heating, cooling, and desalinated water requirements, the operating requirements for each component, the technological variants (mirrors, turbines, etc.), and production costs. It also calculates which architecture will best meet the identified needs for a given budget. The model is the only one of its kind in the world, and it meets a major need expressed by manufacturers selling multi-generative solar plants. It was developed under the EU STSmed project, which also included the installation of four demonstrator systems around the Mediterranean. The calculation method used in the model has been widely distributed.



Thermal solar plants and heating networks: a winning combination

The Toulouse-Balma thermal solar plant, the first in France to be hooked up to a heating network, has been in operation for a year now. The plant's 458 sq. m of vacuum tube solar collectors, which are built on a CEA technology, power a 600-household eco-neighborhood. And the solar plant is a productive one at 600 kWh/sq. m, enough to cover an average of 6% of the heating network's needs. In summer, the coverage rate climbs to 38% over the day as a whole, soaring to an impressive 95% for the space of one hour. Our researchers achieved this advance by refining the system's regulation rules for more efficient starts and stops depending on energy-production conditions. They also validated their thermal solar plant numerical model. Since the summer of 2015 they have been monitoring a second demonstrator system in place near Montpellier, in the south of France. This new system boasts 300 sq. m of solar panels and serves 1,000 homes.

IN BRIEF

- Liten has acquired two optical spectroscopy instruments and can now characterize the optical performance of solar absorber materials in real-world temperature conditions and under air atmosphere.

Biomass

Biomass-to-energy: GENEPI platform open

The grinding and torrefaction equipment at the GENEPI technology platform, used to produce biofuel by the gasification of solid bioresources, is 100% operational. Commissioning of the high-pressure (30 bars) gasifier is in progress. GENEPI, which is unique in France, lets industrial R&D professionals and academic research scientists conduct tests from 50 kg/hour to 150 kg/hour and complete technical and economic assessments. Liten is the platform's main operator. Research at the platform will ramp up in 2016, with several projects involving more than ten industrial R&D and academic research partners. The platform will also be used for several training courses on the thermochemical conversion of biomass.

Microalgae: promising hydrothermal liquefaction test results

A Liten-designed continuous hydrothermal liquefaction (HTL) reactor has been used to test the conversion of different microalgae into biocrude. The process, which has been patented, was optimized at 150 bars and 300°C with throughput of 2l/hour. The carbon conversion yield varied between 50% and 60%. The longest test was on 5kg of an algal paste consisting of the microalgae and part of their culture medium. The HTL process used much less energy than a traditional dry-extraction process. The research leading to the development ran until the end of 2015 and was part of a project funded by the French National Research Agency (ANR). The research is continuing in 2016, this time under a project backed by the French Energy Agency (ADEME); this new project is also investigating biocrude refining.

New processes, improved performance

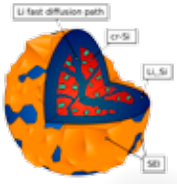
At Liten, we carry out targeted R&D programmes to improve the performance of materials for energy and flexible electronics. Our researchers are coming up with innovative solutions that leverage nanostructuring to exacerbate given material properties, or combine several different materials when no single one can meet an application's specifications. We are also developing alternatives to some current materials – rare-earth elements, indium, gallium, lead, and solvents – that could become difficult to procure or use due to geopolitical, economic, or regulatory transformations. And our materials work doesn't stop there. We are also investigating new processes to achieve three objectives: make more economical use of material, for instance through additive fabrication processes; shrink the environmental footprint of materials and processes (by addressing process energy efficiency and eliminating substances like solvents); and integrate greater proportions of recycled material.

Nanomaterials

Nanostructuring to enhance optical surfaces

Our researchers have helped develop a nanostructuring process for refractory materials with high dimensional precision (30nm to 50nm) under the EU HRC Power project. The advance, which has been patented, has given molybdenum optical surfaces reflectivity with high contrast between visible and infrared light and absorption of up to 99% in the solar spectrum. These advances could be used to enhance selective solar absorbers and selective IR emitters. The process can also be used with other refractory ceramics, such as silicon carbide. Simulation tools are used to determine the size and geometry of the nanostructures to achieve the desired optical properties. The solar absorbers have also been integrated into a hybrid converter that will be heated by both solar concentration and internal thermal combustion.

FIB-ToF-SIMS unlocks secrets of lithiated silicon electrodes



One of the CEA's latest pieces of characterization equipment – a Focused Ion Beam Time-of-Flight Secondary Ion Mass Spectrometer, or FIB-ToF-SIMS – has provided new insights into the mechanisms underlying the insertion of lithium into silicon Li-ion battery electrodes.
The distribution of lithium can be characterized from the surface to the current collector. At the particle core, the lithium accumulates more in certain areas, where it tends to prefer rapid diffusion pathways that occur due to local defects in the material. This new information provides a deeper understanding of electrode degradation after multiple lithium insertion-deinsertion cycles. The researchers are now pursuing their characterization work on other types of materials. FIB-ToF-SIMS can detect all elements in the periodic table to depths in the tens of micrometers.

Advances toward detailed characterization of nanoparticles in liquid

Our researchers can now observe nanoparticles in liquid (water, blood, urine, etc.) at ambient temperature and atmospheric pressure thanks to a new specimen holder for our transmission electron microscope (TEM). The specimen holder also makes it possible to inject reagents during observation to study nanoparticle modification and dissolution in real time. The characterization of gold nanoparticles immersed in water has already been completed, producing excellent information on the particles' size, shape, and agglomeration status. The specimen holder will also help more accurately and realistically describe the interactions between nanoparticles and living organisms, useful in studying the effects of nanodrugs on diseased or target cells.

IN BRIEF

- A best practices guide for preventing nanomaterials-related hazards for construction workers has been published. The guide details nine degrees of risk and recommends the appropriate protective measures for each.
- An electrostatic precipitator has been developed to collect nanoparticles. It is lighter and quieter than commercially-available products, and offers collection efficiency of 94% while limiting ozone production.

Organic electronics

Printed sensors on flexible materials for new monitoring instruments

Our researchers have designed battery and fuel cell monitoring sensors, printed them on flexible substrates, assembled them into networks, and used them to study Li-ion batteries in operation. The resulting measurements (temperature and acoustic emission) align with those taken using traditional sensors. The new sensors can be printed on the system's packaging, regardless of shape, and positioned nearest to where the phenomenon to be observed are occurring. The information obtained will be used to boost system performance and security. For example, battery skin temperature maps can be used to optimize charge-discharge cycles and detect the early warning signs of thermal runaway. The sensors are also cost-effective to manufacture and easy to implant.

IN BRIEF

- Organic photodetectors developed at Liten now offer enhanced reliability and electrical performance; the hole injection layers have been replaced by a doped semiconductor layer.

Printed sensors catching up with sensors produced using conventional techniques

Strain gauges fabricated using screen printing on a flexible plastic substrate have achieved a gauge factor of 10 – the same as conventional sensors – which is a world first. And the technology is compatible with low-cost, volume manufacturing (10,000 sensors can be printed on a single square meter of plastic film for around €10). This printing technique can also be used to make different kinds of components simultaneously (temperature and piezoelectric sensors, transistors, OLEDs, and photodetectors). This means that a personalized layout can be printed on a very large planar or curved surface, with the different sensors placed at will.

Organic photodiodes get more reliable

Startup Isorg is working to develop a process to make millimeter-sized organic photodiodes in research conducted under an agreement with the CEA. Advances in encapsulation have vastly improved the components' reliability – a crucial factor in scaling up the technology for industrial manufacturing. The photodiodes produced have been operating continuously for a year in a protected environment and no degradation has been observed. Aging tests (temperature, moisture, light flux) were used to extrapolate a component lifespan of around ten years, which is compatible with the industrial applications being targeted. Now that this first stage – a single photodiode – has been completed, the researchers are looking at pixel matrices, with the ultimate goal of making networks of several million components integrated with their connectors onto a flexible, large-surface-area sheet.

Recovering and recycling critical materials

Ni-MH batteries: rare-earth element recovery validated on five-liter reactor

Our researchers worked with industrial partner SNAM to develop a hydrometallurgical process for recovering rare-earth elements. The process was scaled up (x100) and validated on a five-liter reactor. The lanthanum and cerium in Ni-MH batteries were recovered with excellent results, both in terms of selective dissolution (100% of rare-earth elements), yields (75% to 90% depending on the type of salts), and savings on reagent consumption (around 80%) compared to total dissolution. The agitation method, process monitoring, and security were all validated, marking a new step forward toward an industrial-scale test reactor. A second reactor, with double the capacity of the one used in these experiments, will soon be set up at SNAM to begin the tech-transfer process. The same equipment could also be used to recover the nickel and cobalt in Li-ion batteries.

INTERVIEW

Étienne Bouyer
Associate Director, New Energy Technology Program, a cross-disciplinary CEA research program

EU projects: materials efficiency garners growing interest

"In 2015 we kicked off or obtained EU certification for eight R&D projects focusing on materials efficiency. In other words, how can we use less of materials whose long-term supplies are uncertain? How can we use these materials more efficiently? How can we recycle them? Can they be replaced by other materials? We are serving as coordinator on the Cabriss project, which focuses on indium, silver, and high-purity silicon for PV materials. The REE4EU project is aimed at developing new techniques for extracting the rare-earth elements in Ni-MH batteries. And we are working with KIC Raw Materials project to evaluate whether the materials offered by our partners can replace cobalt as a Li-ion battery electrode material, for example. In addition to assessing these new materials and processes, we are also analyzing how they affect total energy system performance and costs. The goal is to advance on all fronts and encourage the wider-spread adoption of alternative forms of energy by making them as attractive as possible."

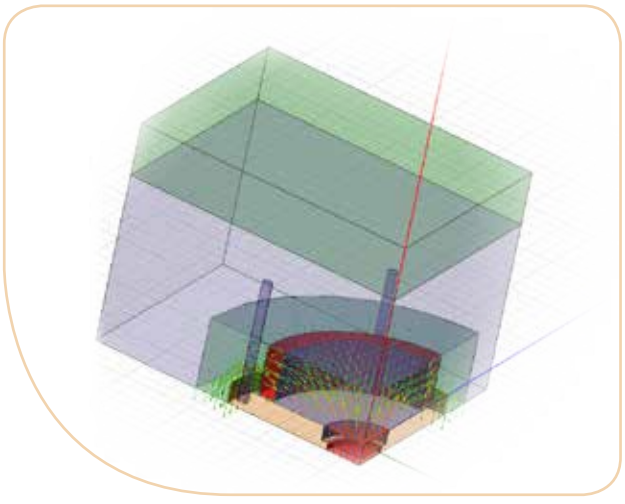
Magnets with 25% recycled material prove effective

Permanent neodymium magnets (also called NdFeB magnets) made from 25% recycled material have been produced and tested, demonstrating magnetic properties comparable to commercially-available magnets made from 100% new powders. Spent magnets are ground into a homogeneous powder with an average grain size of five microns. This powder is blended with new powder under a controlled atmosphere to eliminate the risk of oxidation. Sintering is then used to achieve the desired final density. Our researchers are pursuing their work, with a focus on further increasing the percentage of recycled powder. The overriding objective is to reduce dependency on rare-earth elements like neodymium and dysprosium, sourced mainly from China. The process of implementing the recycled material will also be a source of energy savings.

Materials processing

Welding: assembling incompatible materials

Our researchers have used diffusion welding to assemble parts made of copper and tungsten – two materials that cannot be welded using traditional techniques. Liten has been working on diffusion welding – a method that leverages the diffusion of atoms between two materials to create bonds – for two decades. Diffusion welds are made at high temperature and pressure using a predetermined cycle adjusted to each particular case and validated on a model. The latest assemblies completed are tungsten-copper-stainless steel parts for GANIL (France's heavy ion accelerator in Caen). Other parts have been assembled for the ITER reactor in the south of France. Liten's unique know-how in diffusion welding has numerous applications in industries like aerospace, nuclear, glass, plastics, chemicals, and new energy technologies.



A new generation of ferrite magnet just over the horizon

Our researchers have produced sintered ferrite magnets with an 87% alignment rate using a novel process: injection molding combining the magnetic powder with a polymer blend. The process is better than compacting and densification in that it can produce varied forms and detailed patterns without the need for machining, which helps reduce costs. Our researchers are working on improvements to ultimately create details smaller than a millimeter in size. And for neodymium (NdFeB) magnets, Liten has acquired a semi-industrial strip casting facility, meaning it can now handle the entire manufacturing process in house. The goal is to produce magnets that can withstand the high temperatures of applications like electric vehicles, without using heavy-rare-earth elements.

IN BRIEF

- A new facility has been designed to test the seal of ceramic composite "sandwich" sheathing and other tube-shaped objects at ambient temperature and up to 200 bars of helium.
- A direct metal plate cooler-insulating ceramic substrate assembly has passed tests of 60 heat cycles (-50°C to 250°C). The material will be used in power electronics components.

Toward environmentally-friendly mobility and energy storage

At Liten, our hydrogen-energy R&D mainly focuses on extending the range of clean electric vehicles to encourage their widespread adoption for intercity driving. Specifically, we are looking at ways to bring down fuel cell costs and developing combined battery-fuel cell systems with advanced capabilities like self-regulation. We are also looking at hydrogen as a way of storing energy as an alternative to batteries for making excess renewable energy available when needed. We are developing effective power-to-gas solutions that combine high-temperature, high-yield electrolyzers with ways to use the hydrogen produced, either by adding CO_2 to transform it into methane, or by making it directly available to industrial consumers.

High-temperature electrolysis reversibility demonstrated

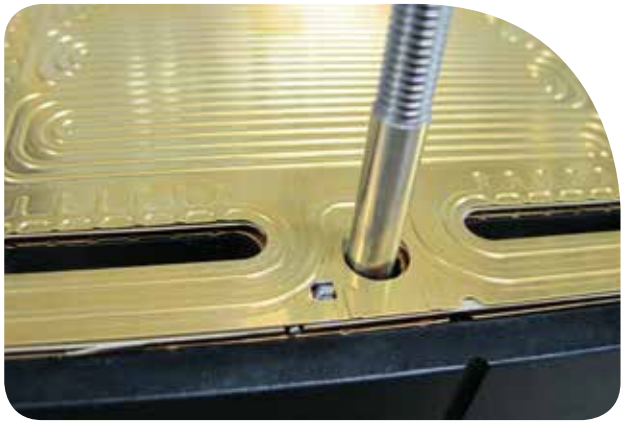
The Sydney high-temperature electrolyzer system (6kW), which offers yields in excess of 90%, was successfully modified to operate in fuel cell mode. The modifications, which have been patented, focused on certain components, such as the one for heat management, which is different in fuel cell mode than in electrolyzer mode. This is the first time that reversibility has been successfully demonstrated on an integrated system, with electricity in the range of a kW generated in fuel cell mode for different fuels (H_2, CH_4). The research is ongoing, with two objectives: first, to obtain optimized yields in both modes; and, second, to scale up to ten times more power. Plans are also on the drawing board to test Sydney outside the lab on actual applications.

Micro fuel cells move closer to commercialization

UK-based Intelligent Energy has been working with Liten since May 2015 to develop a micro fuel cell with its own hydrogen cartridge. The technology, developed over a decade of R&D at Liten, is already protected by 50 patents. The current R&D is focusing on industrial scale-up of the technology. Intelligent Energy is targeting markets like mobile chargers for electronic devices and drones. The company has a subsidiary in Grenoble and has assigned four employees to the project full-time. A total of fifteen Liten researchers and engineers are also working on the project.

IN BRIEF

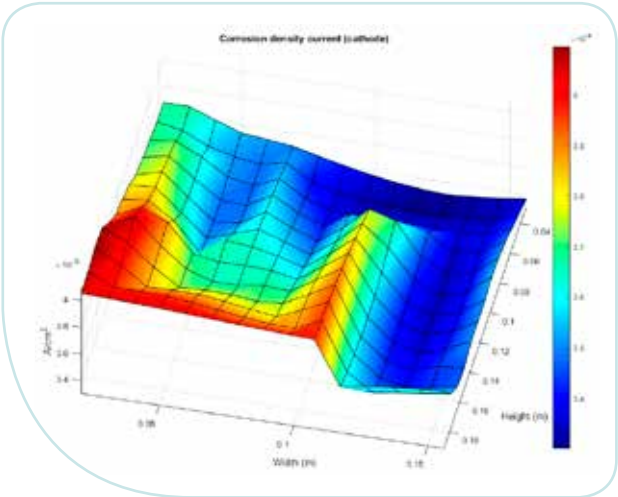
- High-temperature electrochemical converter monitoring is getting better. Our researchers developed a three-electrode (two active, one as a reference) electrochemical measurement system that can measure each electrode's response separately.



Fuel cell bipolar plate successfully instrumented

An electronic voltage-transposition circuit patented by the CEA was integrated between the two bipolar plates of a fuel cell. Despite the very small space – less than a millimeter – between the two plates, our researchers were able to fit the new component into the dead space around an assembly anchor, where it can measure each cell's voltage. These individual measurements are needed to improve yield and prevent degradation. The circuit transmits the data over the impedance signal, eliminating the need for the direct connectors previously required. The circuit, on a flexible substrate, offers low fabrication costs and can be integrated into all current market fuel cell geometries.

Advances in PEMFC lifespan prediction models



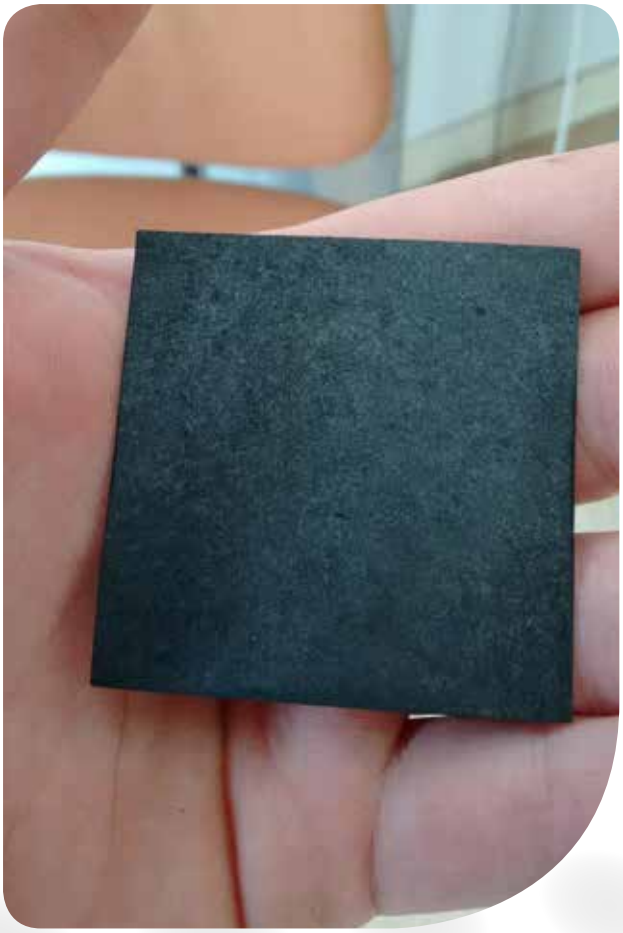
Our researchers made major advances in PEMFC degradation modelling. The initial model described platinum dissolution. It was enriched with the description of Oswald maturation, a phenomenon that modifies platinum particle size. The model was validated in lab conditions under the EU Impact project. When coupled with a cell model, the degradation model can be used to predict PEMFC lifespans and improve platinum loads and particle sizes. Advances were also made on a bipolar plate oxidation model (under the EU project Cobra). This model calculates the corrosion current, potentially helpful in determining use strategies to minimize plate corrosion.

Calculating ROI for a hydrogen chain for mobility applications

Our researchers completed a study for an industrial facility seeking to reduce its environmental impact by implementing a fleet of hydrogen-powered vehicles. The study set out to evaluate the ROI of the planned hydrogen production, storage, and distribution chain for 50 fuel cell-powered utility vehicles. The approach included modelling and dimensioning the technologies and assessing production costs and hydrogen and oxygen sales prices. The study showed that the price of oxygen (produced during electrolysis) is a key factor in overall ROI. The models and management strategies developed will be integrated into Liten's Odyssey numerical simulation platform for energy systems, where they will be used for future studies.

Liten GDL at the state of the art

Membrane-electrode assemblies (MEA) integrating a gas-diffusion layer (GDL) developed at Liten have obtained levels of performance equivalent to the best MEAs integrating commercially-available GDLs for automotive applications. Liten's GDL leverages a new microporous layer and innovative hydrophobic treatment method. The process results in a 3D carbon structure that offers both rigidity and conductivity. Two patents have been filed and a third is pending. At the same time, in other R&D conducted with industrial partners, an optimized GDL led to a total stack cost reduction of around 10%. The slightly higher cost of the improved materials is largely offset by the savings generated throughout the product lifecycle.



PEMFCs achieve 2,000 hours of operation in real-cycle testing

Two PEMFCs (2 kW and 3 kW) designed and built at Liten underwent durability testing in transportation conditions. Both of the fuel cells operated for 2,000 hours in real-cycle testing based on the New European Drive Cycle (NEDC). The results are encouraging for the components currently in development. The electrochemical characterization and post mortem tests completed to determine the aging mechanisms at work quantified the loss of active electrode material and pinpointed areas of degradation on the catalysts and membranes. The researchers now know where to focus their efforts on further extending the PEMFCs' lifespans toward the automotive-industry imperative of 5,000 hours.

IN BRIEF

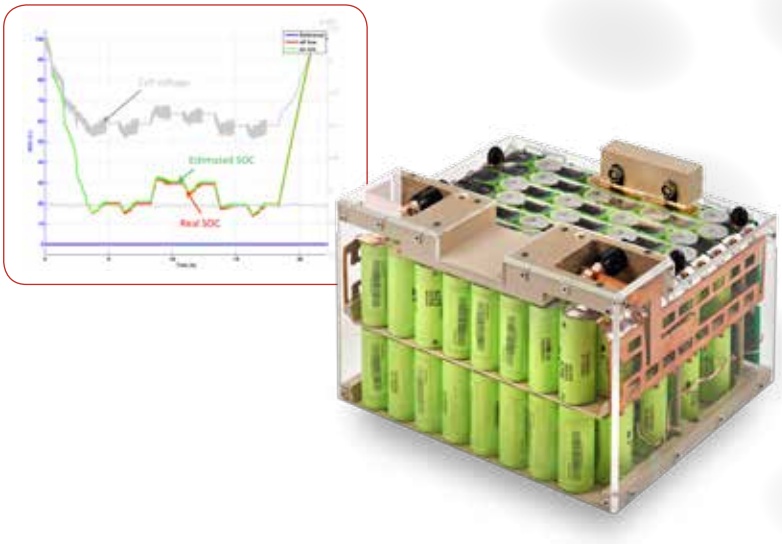
- Michelin technicians and engineers have been attending training at Liten since April 2015 on MEA (membrane-electrode assembly) fabrication under a knowledge-transfer contract between the two partners.
- Liten is a partner in the HyWay experimental hydrogen-powered utility vehicle fleet rollout, providing fuel cell aging and vehicle usage data analysis.

For stationary and embedded applications

Liten's electrochemical energy-storage research focuses on solutions for stationary and embedded applications, from the substantial power required for electric vehicles down to mobile objects like wearable technology and medical devices. Our work looks at technologies such as lithium-ion, which are already available on the market, as well as breakthrough technologies like lithium-sulfur and sodium-ion. With projects targeting materials design, batteries, and battery management and monitoring systems, our work covers the entire energy-storage value chain. We are developing battery instrumentation and supervision systems to track thermal behavior and identify critical thresholds – crucial to improving reliability and lengthening the lifespans of tomorrow's storage systems.

Determining the reliability of charge status algorithms

We now have the capacity to simulate, compare, improve, and validate the battery state-of-charge algorithms developed as part of our industrial R&D projects. A new numerical platform developed using Matlab is able to factor in the type of battery, type of mission, and temperature conditions to determine each algorithm's strengths and weaknesses. The platform also pinpoints where the algorithm actually achieves its accuracy objectives. To date, state-of-charge algorithms generally have margins of error of more than 10% and they can fluctuate wildly depending on use conditions. Validation can only be carried out during actual experimentation, which makes it difficult to optimize the process. The new platform, successfully tested during three industrial R&D projects, identifies areas for improvement.



Sound could be used to help troubleshoot batteries

Acoustic sensors covering the ultrasonic range (100 kHz to 300 kHz) can be fitted to different kinds of batteries to track certain phenomena for troubleshooting purposes. For example, at the end of a charging cycle, nickel batteries produce a degassing phenomenon that has a unique acoustic signature. This type of indicator could be used to make battery management systems (BMS) more reliable. When used on lithium batteries, acoustic sensors can pick up the early warning signs of thermal runaway. For lithium-ion batteries, the sensors can "listen" to the sounds emitted when the passivation layer is formed (during the initial charge) to gain valuable insights into the layer's quality, which has a direct impact on battery lifespan.

Advances in energy density of lithium-sulfur batteries

Our researchers have increased the surface capacity of positive electrodes for lithium-sulfur batteries from 2mAh/cm^2 to more than 4mAh/cm^2. They have implemented two technical innovations to achieve this advance. First, carpets of carbon nanotubes aligned on an aluminum substrate were used to boost the active surface of the positive electrode's current collector, increasing the surface discharge capacity. Second, the sulfur was placed directly in the electrolyte, which substantially lengthened the Li-S batteries' lifespans. This novel architecture results in even better energy density – excellent news for Li-S batteries, which were already considered prime candidates for aerospace and automotive applications. Plus, the architecture did not have any negative impacts on safety or power handling.

A promising sodium-ion battery

A joint CNRS-CEA research team has developed the first sodium-ion battery in standard 18650 (1.8cm diameter, 6.5cm high) cylinder format that can be easily scaled up. The battery charges and delivers its energy rapidly and its lifespan exceeds 2,000 charge-discharge cycles. It offers an energy density of 90Wh/kg, putting it on par with early lithium-ion batteries, also a good sign for the new batteries' potential for performance improvements. Ultimately sodium-ion batteries could compete with Li-ion batteries for stationary applications: sodium is a thousand times more abundant than lithium (23,600ppm and 20ppm in the Earth's crust, respectively) and much less expensive. Another benefit is that the technology can be transferred to production lines originally built for Li-ion batteries. Several patents have been filed, and the new technology has already garnered interest from potential industrial partners, several of which are involved in the EU Naiades project on the same topic.

15 kg of lithium-rich cathode material produced

We have produced fifteen one-kilogram batches of lithium-rich cathode material at our upscaling platform at a rate of one batch per week over several months. The purity of the material, produced on a test reactor using co-precipitation, has been confirmed. And the synthesis process is reproducible and robust at this scale, with less than 5% variation in the material's capacity. Lithium-rich cathode material is currently the best candidate to achieve the energy densities of 250 Wh/kg and more required for electric and hybrid vehicle batteries. The batches of material produced are being used in a variety of characterization experiments on high-energy Li-ion battery prototypes under the EU MAT4BAT project and the LiBOB project, which is funded by the French National Research Agency (ANR).

IN BRIEF

- Liten now possesses the equipment and procedures required to dismantle very-high-capacity (>10Ah) Li-ion batteries safely, a prerequisite to post-mortem analyses.
- Liten has perfected a technique for integrating a reference electrode into a commercial Li-ion battery in a flexible pouch to perform in situ electrochemical measurements without disrupting battery operation.

All-organic battery gets promising results

We have synthesized the organic electrode materials lithium carboxylate and polyimide, tested them in button size batteries against lithium, and assembled them into an all-organic battery that achieved promising levels of performance in terms of specific capacity and lifespan. The battery's energy density still needs to be doubled, an improvement our researchers plan to achieve by adjusting the materials' formulations. The materials have been modified to become insoluble in the electrolytes. The all-organic battery offers a number of benefits: low cost, readily-available materials, no heavy metals, and the option of complexing ions other than lithium. The battery will target emerging applications like smart textiles and smart packaging. Our researchers are continuing to improve the battery's performance as they gain a better understanding of how it works.

IN BRIEF

- A Toyota COMS electric vehicle equipped with a lithium battery pack developed at the CEA has achieved a range of 91 km in road testing. The energy delivered is 50% higher than that of the lead battery packs previously used.
- The Airbus E-Fan electric plane crossed the English Channel in 40 minutes on July 10. Liten dimensioned and validated the battery system, which had to meet stringent weight and volume restrictions.

- Liten has helped develop Iveco's 100% electric Ellisup bus, which can be charged in just a few minutes at an end-of-line charging station. The issue of Li-ion battery pack overheating during fast charging was addressed from the design phase.

Zéro CO_2 sailboat returns to open sea

The Zéro CO_2 sailboat traveled more than 900 nautical miles on the Mediterranean over the summer of 2015, equipped with its new 19kWh lithium-iron-phosphate battery pack, fuel cell, and battery management system (BMS), all of which were designed and built by the CEA. The systems powered the onboard network and auxiliary engine for the duration of the six-week trip. The experimental sailboat, which was launched in 2010, is still the only one of its kind in the world. Real-time measurements were recorded to monitor the functional degradation of the system and its components. The results are currently being analyzed to assess the impact of the charge-discharge cycles on the pack and the effects of saltwater corrosion on the bipolar plates. A new plate coating will be tested during a new trip in 2016 in research conducted under the EU Cobra project.

Recovering, storing, and redistributing energy

Developing effective ways to manage the intermittency of renewable energy will mark a crucial step toward grid integration. Finding solutions for managing the intermittent availability of power generated from renewable sources is critical if they are to be connected. That's why Liten is working on systems to store energy-from several hours to several months-then release it when needed. Our researches focus on three markets: the construction industry, where we are developing models to predict building energy performance according to building components – like walls, glazing, and HVAC – and occupant usage; the manufacturing industries, where we are coming up with solutions to reinject waste heat from various processes or recycle it in other forms; and electricity grids, with simulations to help right-size storage systems and determine optimal management strategies.

INTERVIEW

Etienne Wurtz,
Director of Research, Liten

COMEPOS: very-low-energy-consumption single-family homes

"We have been coordinating the COMEPOS project since 2013. It is France's largest R&D program on very-low-energy-consumption single-family homes. The project counts more than twenty academic research labs, homebuilders, and construction materials manufacturers among its partners. We are now focusing on monitoring 25 occupied and instrumented demonstrator homes equipped with innovative new systems. The objectives are threefold. We want to: make progress toward "active" homes that take full advantage of their environment (temperature, sun exposure, etc.); ensure suitable energy performance; and use renewable energy for near self-powering homes. And, of course, keep costs reasonable.

We have already gained some valuable insights that will contribute to France's upcoming 2020 building thermal performance regulations. For example, in a house that already offers very high energy performance, triple-glazed windows and tighter air sealing are not necessary. The program has also gathered interest from manufacturers, resulting in new R&D contracts to develop innovative systems with us and then test them on demonstrators."

Advances made toward a representative model of building thermal behavior

Improvements to building energy consumption and occupant comfort can be made through effective active-system (HVAC, etc.) management. And predictive management is especially powerful. Integrating building thermal behavior models makes it possible to add new capabilities like optimizing renewable energy usage and boosting solar-energy usage rates. Liten has developed a method to generate a simple model that adjusts to seasonal fluctuations and that can very rapidly perform the many simulations required for predictive management. The algorithms were tested in several experimental implementations in real-world conditions in 2014 and 2015. In 2016 the model will be used to enhance ventilation flows at one of the houses at the INCAS testing facility with the ultimate goal of improving occupant comfort in summer.

IN BRIEF

- A collective solar water heater with individual supplementary capacity has been developed and tested for three years at two demonstrator sites, one in Perpignan in the south of France, and the other near Paris. The water heater is suitable for apartment buildings with 5 to 50 units.

A home that stays cool in summer, air-conditioning free!

Liten has partnered with homebuilder IGC to design a 100% solar house. The institute has patented an air-conditioning-free cooling system that keeps the home comfortable during the warmer months of the year. The system consists of a wall of hollow bricks that communicates with a water tank under the house. At night, the water fills up the brick panel, where it cools off via convection, radiation, and evaporation. During the day, the cool water circulates in the underfloor heating network, transforming it into an underfloor cooling system. The system has been installed at a test site in Bordeaux, and won an award at the COP 21 climate conference. The initial investment is only slightly higher than for the home's original heating system. Software has also been developed to operate the system depending on temperature forecasts.

Grenoble district heat network fine-tunes temperatures

CCIAG, which operates Grenoble's district heat network, is working with Liten to improve its strategy for planning network temperatures. The traditional linear method uses expected and observed outdoor temperatures. A simulator developed by our researchers also takes into account the propagation of heat throughout the network. The new method could make it possible to lower the starting temperature and reduce heat loss in the network by nearly 10% without affecting user comfort. The simulator replicates a representative sample of 26 consumers in a Grenoble neighborhood, with maximum power of 30 MW. The method is now being tested in real-world conditions in several neighborhoods.

IN BRIEF

- Our researchers have produced 3D models of solid-to-liquid phase changes inside a tube heat exchanger used to store heat. The models covered the entire height of the exchanger.

A model for dimensioning desalination plants

Our researchers have developed a technically and economically viable model for dimensioning multiple-effect desalination plants, with or without steam compression. The model makes it possible to couple the future plant with various heat sources and to determine a baseline water-production cost over the equipment's lifetime. It also produces an environmental score based on the carbon footprint, waste production, and potentially-environmentally-hazardous substances present in the waste generated. This is the first model of its kind on the market. It was validated by comparing the data from three systems in operation for capacities ranging from 2 cu. m to 9,000 cu. m per day. The model is particularly robust, which makes it suitable for very large plants (treating up to 30,000 cu. m per day). Liten is currently using the model in four projects (R&D partnerships, EU projects, and audit/consulting contracts).

ENERGY EFFICIENCY

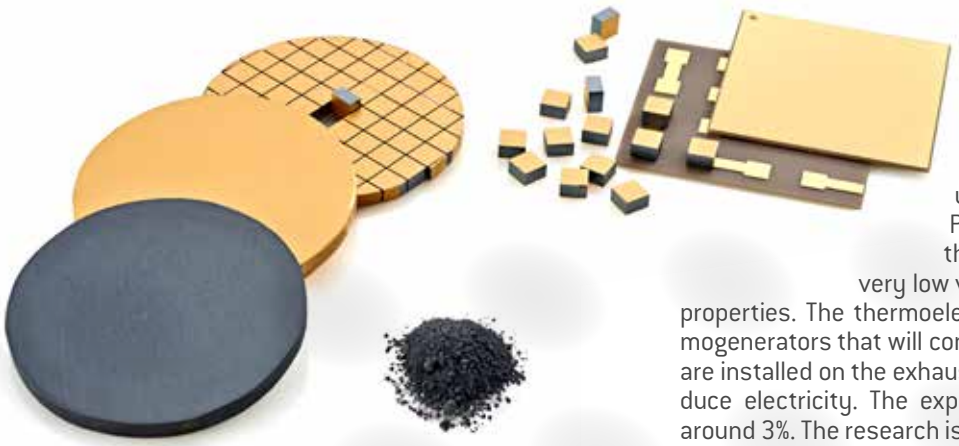
Solar-powered mobility moves toward 100% solar charging thanks to smart management

A single parking station equipped with PV panels (on a solar carport) and a smart energy management system can provide enough energy to power the 15,000 km generally driven per year by the average passenger car. Without the smart energy management system, a solar-equipped parking can only provide 40% of a plug-in electric vehicle's energy needs. The CEA and its partner Corsicasole are developing electric-vehicle charging management and operation programs for installation on the company's Parasol solar carports. These carports are comprehensive systems integrating PV production, storage, and charging stations that can be used with all types of plug-in electric and hybrid vehicles. Local multi-station management and stationary battery storage will ultimately make it possible to achieve 100% solar charging.

PV plus storage: a winning pair

A 190 kWh electrochemical storage system managed by Liten-developed algorithms has been installed at a hospital in Martinique that has its own PV power plant. The system smooths out fluctuations in PV production and prioritizes self-consumption, also helping to regulate the voltage and frequency fluctuations on the island's grid. The use of storage and smart energy management has boosted the renewable-energy penetration rate. In a separate study, also in Martinique, our researchers investigated grid integration of PV and self-consumption. Their research revealed that, if appropriate energy-management strategies are used, PV-plus-storage systems could contribute to penetration rates of 25% and create 200 local, long-lasting jobs in electricity production.

Thermoelectricity for automotive applications ready to roll



We have produced 2,000 thermoelectric legs for use in automotive demonstrator systems from abundantly-available, non-toxic, and low-cost raw materials. The thermoelectric materials were developed using industrial processes like sintering. Performance measurements showed that the production chain is reliable, resulting in very low variability of the materials' thermoelectric properties. The thermoelectric legs will form the core of the thermogenerators that will contribute to tomorrow's efficient cars. They are installed on the exhaust pipe where they use waste heat to produce electricity. The expected energy-efficiency improvement is around 3%. The research is part of the RENOTER 2 project carried out in partnership with automotive component manufacturer Valeo, start-up HotBlock OnBoard, Renault, and Renault Trucks.

e-SIMS: Electricity and energy storage management software

e-SIMS has developed the first software platform that manages intermittent energy sources and electrochemical storage.

The startup's innovative work will enable large-scale integration of intermittent energy sources into the grid. It does this by implementing swarm intelligence and dynamic-service-oriented architecture, which allow fast development of dedicated energy management applications. For solar energy producers in island environments characterized by "weak" grids, the software platform delivers a solution for maximizing production output (25% – 30% reduction of kWh cost of energy stored in batteries). Software developed using the e-SIMS platform leverages high-quality storage modeling and multi-criteria optimization based on technical, economic, and financial criteria. Following seven years of research and demo work, e-SIMS was launched in June 2015. Liten plans to support the startup's technology-transfer phase and business development. The startup will put its technical expertise in the diverse fields of storage, optimization, and software development to work to bring the solution to its first customers.

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SUBLIMED: Transcutaneous electrical nerve stimulation patch

Sublimed gives patients with chronic pain a new chance at life, offering a transcutaneous electrical nerve stimulation patch that is flexible and discreet.

For over 30 years, transcutaneous electrical nerve stimulation has been used treat neuropathic, back, and other chronic pain. However, 20% – 40% of patients suffering from chronic pain eschew the technology because of the bulky impulse generator and inconveniently long electrode wires. Sublimed has replaced these conventional devices with a technology protected by five CEA patents:

- A thin and comfortable electric-impulse generator that can run for 20 hours between charges and that can be placed on any part of the body
- Skin electrodes, attached to just 10cm–15cm of wire
- Electronics that can be controlled from a smartphone; the phone can control two to four electrodes and even send the information to a doctor. The startup hopes that this innovation will increase both patient adoption and treatment efficacy. Partners of the project include pain treatment specialists and the Grenoble University Medical Center Pain Unit.

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SYLFEN: Smart energy hub for ecodistricts and energy-plus buildings

Sylfen offers competitive and flexible energy solutions. The startup's Smart Energy Hub can either produce gas or electricity and heat depending on user needs and utility rates.

Sylfen's Smart Energy Hub, protected by some 20 patents, is the result of ten years of R&D work at Liten. The Smart Energy Hub consists of a hightemperature (700°C – 800°C) electrolyzer that is reversible and, therefore, can be used as a fuel cell. In electrolyzer mode, the equipment converts electricity into hydrogen. In fuel cell mode, it produces electricity and heat. The process boasts unbeatable yields. Available in several versions, starting at several dozen kilowatts and going up to several hundred kilowatts, the technology is particularly well suited to the energy-production needs of energy-plus buildings and ecodistricts. Users can choose the desired mode for their usage, from energy storage and fueling hydrogen vehicles to recharging batteries and providing heating – and more. To support the development of distributed intermittent energy production and to adapt to energy price fluctuations, Sylfen has developed operations and management software for use with its equipment. The Smart Energy Hub gives users the energy they need when they need it.

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MAJOR PROJECTS

Liten shaping the energy transition through multi-partner R&D projects

In 2015 Liten got involved in several flagship energy-transition R&D projects.

• Energy Observer, renewable energy on the open sea

The Energy Observer catamaran will sail the oceans for six years, promoting renewable energy throughout its journey. The vessel's energy system features 130 sq. m of PV panels, fuel cells, Li-ion batteries, hydrogen tanks, and an electrolyzer to produce hydrogen right on board. Liten is designing, developing, and integrating this energy mix and associated management system into the catamaran.

• Jupiter 1000: France's first Power to Gas demonstrator

Liten's advanced knowledge of methanation technology earned the institute a slot among a consortium of industrial partners on France's Power to Gas R&D program. The project aims to convert unused or excess renewably-generated electricity into hydrogen using water electrolysis. Methanation will then be used to combine the hydrogen with CO_2 to produce synthesis methane, which will then be injected into the gas transportation network. A 1 MW demonstrator system will be built as part of the project.

• Liten increasing its international visibility

Liten signed three major international agreements in 2015:
- Support for ECM Green Tech in building a PV-grade wafer line in Qatar.
- Cooperation with ECM Green Tech to build a test reactor to synthesize battery electrode materials in Bolivia.
- Partnership with Morocco's energy agency Masen on a thermodynamic solar concentrator project.

• Experimental smart grid platform

The Smart Grid Campus project submitted by Liten in partnership with French grid operator RTE, French electric utility infrastructure provider ENEDIS (ex ERDF), Grenoble-Alpes University, Grenoble INP, the French National Center for Scientific Research (CNRS), and the Grenoble school district, was selected for certification in July 2015. The program will focus on developing a smart grid technology platform that researchers and SMBs can use for their smart-grid-related R&D and innovation projects.

• Carnot Institute *Energies du Futur* heading new industry-specific initiative Energics

The Energics initiative was selected to receive funding from France's "Investments of the Future" programme. The purpose of the initiative is to boost the impact of the Carnot Institutes' innovation activities on France-based SMBs operating in the eco-industries and renewable energy. The Carnot Institute *Energies du Futur* and four other Carnot Institutes – M.I.N.E.S., BRGM, CSTB, and ICEEL – are involved in the initiative, which will be funded for six years.

Biomass platform

Our biomass platform – unlike any other research facility in France – is exploring ways to achieve high-yield energy production from waste. R&D at the platform covers grinding, torrefaction, pyrolysis, hydrothermal liquefaction, and gasification at a scale that can be extrapolated to industrial processes. The platform works with around fifteen industrial and manufacturing corporations, including ENGIE, CMI, and Michelin.

Smart-grid systems platform

This platform looks at how to scale, operate and optimize energy systems connected to intermittent power sources and electricity storage systems. The platform has all of the necessary equipment to study a variety of grid configurations, manage system components, and determine effective operation strategies. Around 50 industrial partners, including corporations like RTE, Alstom, SRD, SOREA, and Urbasolar, as well as smaller businesses, are conducting R&D with the platform.

Photovoltaic solar platform

This platform was set up to support France's solar-energy industry by conducting R&D on PV materials, processes, and equipment. The platform's signature asset is its Heterojunction LabFab, a pilot production line capable of manufacturing heterojunction PV cells with yields of over 20%. The platform has partnerships with more than 100 companies, from small- and mid-sized businesses Semco, Thermocompact, ARMOR, CNR, ECM, MPO…) to large corporations (EDF, Mersen…).

Thermal technology platform

The thermal technology platform is unique in Europe, in terms of both its size and the scope of its R&D activities, which span technologies to produce thermal energy (concentrated solar power), store it for later use, and use it efficiently for industrial applications like heat pumps, boilers, and thermal exchangers. Around 50 industrial partners, including Total, Saint Gobain, and Engie, are currently engaged in R&D projects with the platform.

Hydrogen production and storage platform

This platform is developing hydrogen production and storage technologies for energy applications. It is one of the world's leading patent filers in the fields of high-temperature electrolysis and solid oxide fuel cells. The platform tests demonstrator systems like storage tanks, for example, and works with around ten industrial partners.

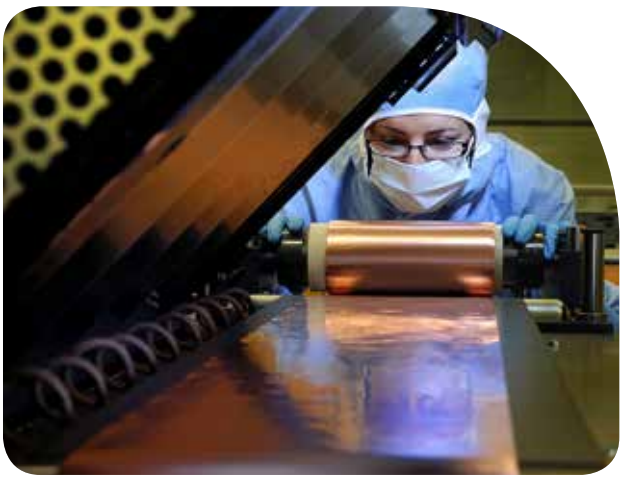
Building energy platform

Our building energy platform is available to homebuilders and building materials manufacturers seeking ways to improve building energy performance and occupant comfort. Focus areas include new construction methods and approaches, opaque and glass wall solutions, materials, insulating coatings, smart windows, innovative ventilation systems, solar sensors, and heat storage. The platform has a staff of 40 people and four instrumented test buildings.

Fuel cell platform

This platform conducts research to improve PEMFC performance and lifespans while reducing costs. The platform's integrated approach covers materials, membrane-electrode assemblies, stacks, and testing in real-world conditions. The R&D conducted at the platform is at the international state of the art and results in between 10 and 20 patents filed each year. Around ten industrial partners, including Symbio FCell and Areva Stockage d'Energie, conduct R&D at the platform.

Battery platform

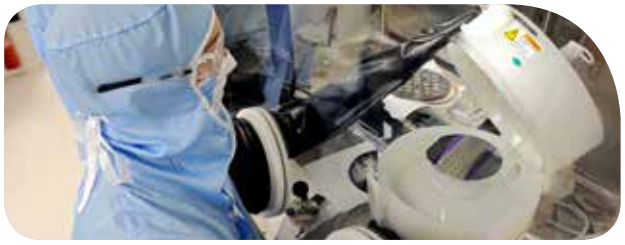


The battery platform develops and manufactures small series of lithium-ion batteries, covering the entire value chain from materials and components through to pack assembly, integration into systems, and testing. The platform's work targets applications ranging from hearing-aid to electric buses. The platform is the largest and most technologically-advanced battery R&D center in Europe. More than 30 industrial partners are using the platform, from small businesses to corporations like Renault, Umicore, and Solvay.

Electric mobility platform

Our electric mobility platform integrates battery and fuel cell prototypes developed by the CEA into land, air, and sea vehicles and vessels and tests them in real-world conditions. The tests, conducted either at a closed site or in the open, provide valuable feedback on battery and fuel cell performance, cycling, and aging. Around ten industrial partners – battery, fuel cell, and combustion-powered or electric vehicle manufacturers – use the platform.

Micro-energy-source platform



This platform is developing micro fuel cells to power mobile devices like smart cards, sensors, and laptop computers. The platform possesses equipment for industrial process scale-up and focuses on optimizing materials, using techniques like screen printing and PVD-CVD (physical/chemical vapor deposition). The platform's main industrial partners are Intelligent Energy and Hotblock OnBoard, a startup spun off from the CEA.

Large-surface printing platform

The Pictic large-surface printing platform enhances plastic, paper, and textile substrates by enabling them with electronics like sensors, optics, logic circuits, and display systems. The applications for these flexible circuits include human-machine interfaces, smart lighting, interactive displays, and environmental monitoring. The platform has partnerships with several companies based in France and further afield, including startup Isorg, chemical corporation Arkema, and paper manufacturer Arjowiggins.

Poudr'Innov 2.0 Powder metallurgy platform

The Poudr'innov 2.0 platform develops and produces high-added-value components from metal, ceramic, semiconductor, and magnetic powders whose properties have been enhanced – in some cases surpassing the properties of the traditional material. The platform's work targets the energy, power electronic, healthcare, finechemicals, and other markets. The platform is staffed by around 50 people.

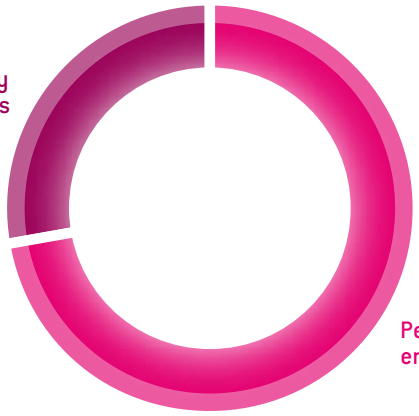
Nanocharacterization platform

The development of nanomaterials and components requires in-depth knowledge of the underlying morphology and chemical and physical properties. The nanocharacterization platform provides these insights through around 40 research equipments capable of generating 2D and 3D images approaching the atomic scale. Some of the equipment is only available at a handful of other facilities worldwide. The platform works with around 20 characterization equipment manufacturers and industrial partners.

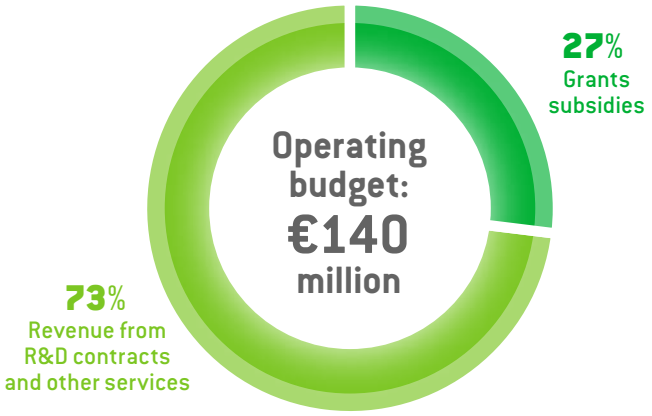
Nanosafety platform

The nanosafety platform investigates protection, health, and security issues related to the handling and the use of nanomaterials. The platform conducts R&D and can take on operational assignments such as on-site measurement campaigns, audits, emergency response personnel, and training. No other facility in France – or probably Europe – offers such a broad range of services.

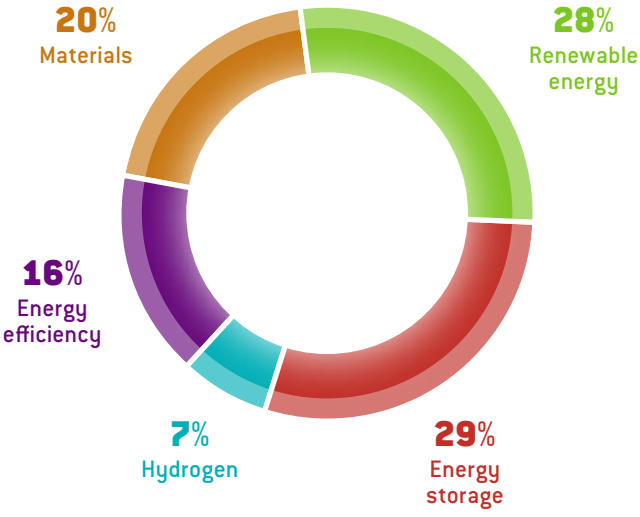
Total staff



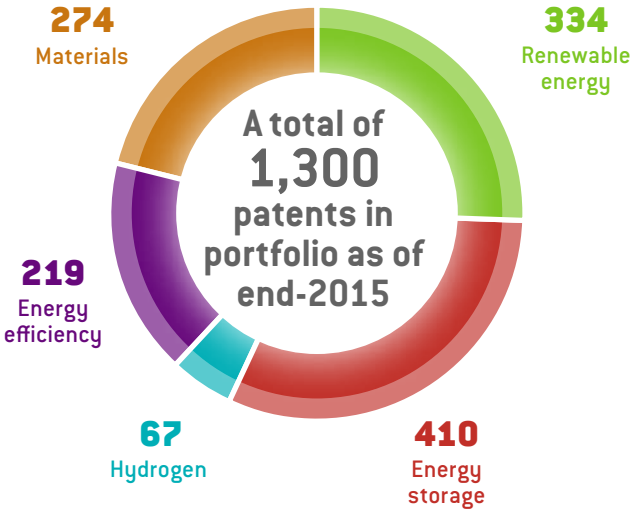
Budget



R&D staff by program



Breakdown of intellectual property



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