liten ANNUAL REPORT 2013

DE LA RECHERCHE À L'INDUSTRIE

cea

Director's foreword

A JOINT APPROACH WITH INDUSTRY THAT ADDRESSES THE DEMANDS OF RENEWABLE ENERGY MARKETS

Renewable energy is more than just a trend. Spurred by the urgent need to develop solutions for the challenges plaguing our economy and society, the energy transition is an undisputed reality. And, like all industrial technologies, new energy systems must prove their performance and cost-competitiveness if they are to carve out a position in the marketplace.

At Liten, we help our industrial partners gain competitive advantage in areas crucial to sustainable energy markets, like energy efficiency, energy harvesting, new-material development, and recycling. Furthermore, our 2013 research results prove that our strategy can effectively help companies penetrate and firmly anchor positions in those markets.

In 2013, researchers at the INES pre-industrial high-output PV cell line stabilized its industrial processes resulting in yields of 20%. Our hydrogen-related and fuel-cell-related R&D made steady progress throughout the year. We achieved notable fuel-cell performance improvements (2.5 kW/L) while cutting system costs. We built a pilot fuel-cell manufacturing line, developed a 25-cell stack for high-temperature electrolysis, and made technical advances with the integration of fuel cells into vehicles (up to 300 kW per prototype).

We expanded our biomass R&D to encompass new resources like waste, potentially opening up new opportunities within this industry. Energy storage remains a major challenge, and over the course of the year we successfully promoted bespoke electric, thermal, and hydrogen-based solutions for a variety of applications.

Our relationships with industrial partners remain strong and focused on long-term benefits. Their demands and the technological obstacles they communicate to us are what spark our researchers' creativity, allowing them to drive innovation even further whilst remaining in step with market needs.

In 2013 we were pleased to renew several multi-year partnership agreements with automotive, aerospace, and defense industry leaders. At the same time, we ramped up support for SMEs through affiliate agreements and the launch of three new CEA Tech regional offices (in Nantes, Bordeaux, and Toulouse).

2013 was also a milestone year for Liten in intellectual property terms. Our portfolio passed 1,000 patents for the first time; tangible proof of our ability to constantly innovate.

Last, but by no means least, at year end we secured the INES2 project, with €39 million of government funding – confirming our position as an international center of excellence in solar energy and a pillar of France's burgeoning solar-energy industry.

Florence Lambert
Director, Liten

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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 is Europe's only research center to cover the entire renewable-energy value chain.

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. Unlike any other sustainable energy research institute, our activities cover the entire value chain from the synthesis of materials to the development of complex demonstrators.

Our industrial partners benefit from personalized R&D support that speeds the transfer of innovations from lab to market – and boosts their competitive advantage.

400 R&D AGREEMENTS EVERY YEAR

We are the partner of choice for manufacturers of all sizes, regardless of where they are on the technology value chain. Our expertise covers all aspects of technology, including materials, processes, components, systems integration, and demonstrators. 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, land transportation, aerospace, construction, civil engineering, environmental, and IT industries, amongst others.

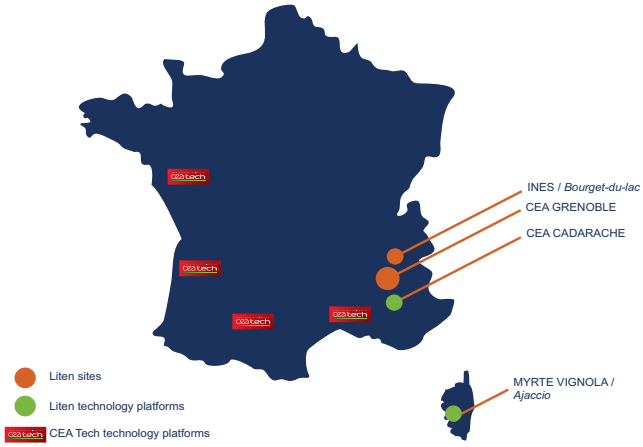
1,000 PATENTS A ROBUST INTELLECTUAL PROPERTY PORTFOLIO

Intellectual property forms a major part of our activities. We have a portfolio of 1,000 international patents and are one of the CEA's most active generators of intellectual property, filing 185 patents in 2011, 200 in 2012, and 235 in 2013.

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 electric vehicle technologies (like batteries and fuel cells), energy-efficient buildings, and power generation systems (from production and storage through to conversion and smart management of thermal energy, electricity, and gas – especially hydrogen).
- Materials for energy, with a particular focus on nanomaterials and micro energy sources.



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 Le Bourget-du-Lac (near Chambéry), France, are supplemented by regional offices in Bordeaux, Metz, Toulouse, Nantes, and Cadarache, 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:** Multi-partner 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 BESPOKE OFFERING

- We tailor the technical resources, number of scientists and engineers, budget, and calendar for each joint development project to meet our partner's unique needs – such as time to market for example.
- 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.

MORE THAN 250 AFFILIATE PARTNERS

In 2013 the French Energy Regulatory Commission issued a call for tender to manage the country's solar energy plants. In order to be eligible, bidders had to agree to participate in a collaborative R&D project – a challenge for SMEs and other companies with limited in-house R&D resources. We responded by creating an affiliate program, open to a broad range of partners, with extremely simplified administrative procedures. Since the affiliate program launch, more than 250 businesses have signed up with research topics including performance optimization, grid integration, and high-voltage power plants.

Materials & processes

DEVELOPING INNOVATIVE SOLUTIONS AND ENHANCING PERFORMANCE

At Liten, we conduct targeted R&D to improve the performance of materials used in energy and organic electronics applications. Our researchers come up with novel solutions when no standard materials are available for a particular need, or to mitigate future supply issues – such as cost concerns, geopolitical instability, or regulatory changes – that are plaguing materials like rare earth minerals, indium, gallium, lead, and solvents.
We leverage multi-material systems capable of meeting complex specifications, along with nanostructuring techniques able to significantly change a material's properties like its melting point and the nature and kinetics of associated chemical reactions. Such breakthroughs allow us to develop less-costly, more durable, and lighter-weight materials.

THE NANOID NANOSAFETY PLATFORM

The €6.2-million NanoID nanosafety platform, created with funding from the French government's economic stimulus package, possesses five state-of-the-art facilities that include a cryo-electron holography microscope and an X-ray fluorescence imager. The equipment can detect and characterize nanoparticles in complex solid, liquid, and gaseous matrices such as those found in the ground, plants, human tissue and biological fluids, food, and air. The platform's work targets applications in toxicology, occupational and consumer health, and environmental monitoring.

NANOMATERIALS

NEW APPLICATIONS FOR CARBON NANOTUBES

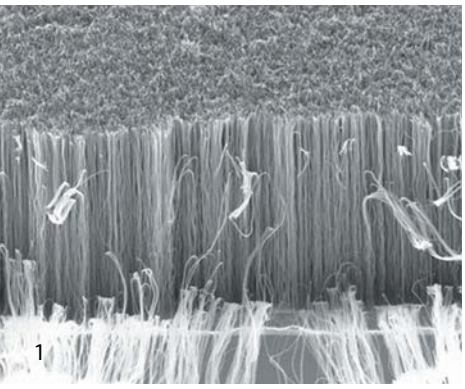
In research co-financed by Intel Corporation, we achieved record conductivity levels for 95-nm-diameter carbon-nanotube interconnect lines. The research aimed to assess the nanotubes' potential as a replacement for copper in integrated circuits within the next few years. We also made another leap forward in nanotubes, developing a hybrid 3D nanostructured material comprised of a "forest" of carbon nanotubes on graphene. The new material targets applications in microelectronics and as an electrode material for batteries in energy storage systems. 1

MULTILAYER AND COTECH PROJECTS TO PROMOTE EU HORIZON 2020 PROGRAM

We are a key participant in two EU FP7 projects selected to promote the EU Horizon 2020 program. The first is the Multilayer project, where we play a key role as project coordinator; it aims to develop a ceramic microcomponent fabrication process using a brazeless technology. Two demonstrators have already been completed: a thermoelectric power source for an electrical switch; and a LED package. The second is the Cotech project, where we developed injection-molded nanocomposites that can improve the heat exchange performance of microcoolers used in IGBT power converters.

COBALT-FREE, HIGH-LITHIUM-CONTENT LAYERED OXIDE FOR LI-ION BATTERIES

Using a coprecipitation process, our researchers were able to synthesize a cobalt-free, Li-rich layered oxide offering high density, good electrochemical performance, specific capacity in excess of 250 mAh/g, and excellent stability during cycling. The new material is among the top candidates for electric-vehicle-type applications. And, because in-lab performance levels were maintained even at pilot-manufacturing scale, the material is also shaping up to be a good choice for mobile electronics. 2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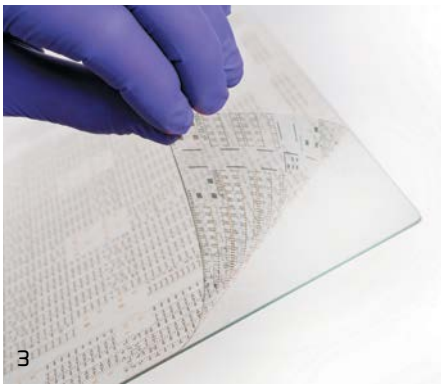
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ORGANIC ELECTRONICS

FIRST-EVER PRINTED ORGANIC ELECTRONICS-BASED ANALOG-TO-DIGITAL CONVERTER

The first ever analog-to-digital converter screen-printed on plastic was unveiled at the ISSCC 2013 trade show. The latest version of our system, which includes both a signal sensor and converter, operates at 20 volts with a resolution of 6 bits and a speed of 2 Hz. Potential applications could include printing the system on plastic food packaging to detect and transmit product freshness data by RFID.

PRINTED FERROELECTRIC MEMORY AND SENSORS

Our joint R&D lab with chemicals company Arkema has made two advances in printed electronics. We used Arkema's ferroelectric polymer inks to print two innovative new components: a non-volatile memory with endurance in excess of 106 cycles at 60% of initial polarization at 25 volts; and a polymer pressure sensor with sensitivity levels of 60 pC/N – superior to the current state of the art. In other news, an Arkema-developed ferroelectric ink was validated for commercialization and is now available on the market. 3

BARRIER PROPERTIES CAN NOW BE MEASURED ACCURATELY AND COST-EFFECTIVELY

Through a joint venture with Vinci-Meca 2000, we developed and patented a permeameter and the associated analysis software to measure encapsulation materials' barrier properties. The measurement device uses stable-isotope mass spectrometry, while the software reduces usual measurement times by up to 75%. Together, the device and software can be used to take barrier-property measurements to the exacting standards of applications like organic electronics – at a lower cost than competing measurement solutions. The technology is currently being transferred to industry. 4

A MAJOR ADVANCE IN ORGANIC PHOTODIODES

"Our Pictic platform is one of Europe's top R&D centers for printed electronics, offering some of the most advanced capabilities in organic photodiodes anywhere. For instance, Pictic and Liten spinoff Isorg worked together to develop the world's first all-plastic image sensor. This technological breakthrough in the design and fabrication of large-surface-area sensors lays the foundations for a host of new digital image sensor applications, from image sensors for medical equipment, connected objects, advanced manufacturing, and logistics through to sensors for consumer HMIs with 3D interactivity. Pictic provided Isorg with crucial support for anchoring its technology, manufacturing prototype pre-series, and determining what equipment would be needed for the company's pilot manufacturing line. In parallel, the Liten-Isorg joint R&D lab is working to improve the reliability and robustness of Isorg's components and processes and to develop sensors with near-infrared capabilities."

Isabelle Chartier,
Head of Printed Electronics Research, CEA-Liten

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MICRO ENERGY SOURCES

CZTS A CANDIDATE FOR THIN-FILM SOLAR CELLS

Copper zinc tin sulfide (CZTS) is gearing up to be a good candidate to replace the CIGS and CdTe currently used in thin-film solar cells – and relieve the pressure caused by the increasing scarcity of tellurium and indium. Yields of 7% have been demonstrated for CZTS cells processed by PVD. Current research is looking at ways to engineer energy bands in the absorber material to push yields over the 10% bar. 1

SYSTEM-ON-FOIL WITH INTEGRATED LITHIUM BATTERY MODULES

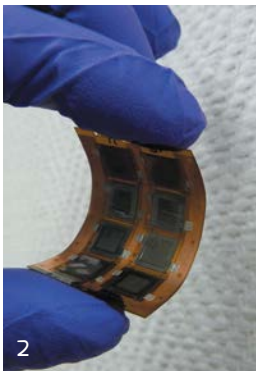
As part of the EU FP7 Interflex project, we developed an assembly process to integrate microbatteries into a complete system – offering energy harvesting, a CO_2 sensor, and power management – on a flexible substrate. Batteries connected in series/parallel reach output voltages of nearly 5 volts and can withstand the 140°C temperatures to which they are exposed during high-pressure annealing. We manufactured around 300 of the microbatteries for the final project demonstrator presented in late 2013. 2

ALD GIVES BARRIER LAYERS THE ULTIMATE IN PERFORMANCE

Our researchers used alumina deposited via ALD to create high-performance barrier layers with exceptional water permeability properties. The barrier layers can be used to encapsulate lithium batteries, photodiodes, OLEDs, and other components, and can be deposited directly on the components or on flexible substrates, like polymers, whose inherent barrier properties are insufficient. ALD offers precise thickness control (under 50 nm) and excellent uniformity. 3

THERMOELEMENT PILOT PRODUCTION LINE

Liten is home to France's only R&D facility capable of manufacturing thermoelectric materials at volumes of up to 3 kg/week. Our pilot production line's capabilities include powder synthesis, SPS, and double-sided rectification of 60 mm wafers. Improvements to the facility's high-temperature thermoelement process route have brought variability below the 7% mark. Additional developments are underway in areas like powder synthesis, with work on mechanical alloying and atomization, and for a second generation of thermoelectric materials that can operate at intermediate temperatures. The research is being carried out in conjunction with start-up HotBlock OnBoard.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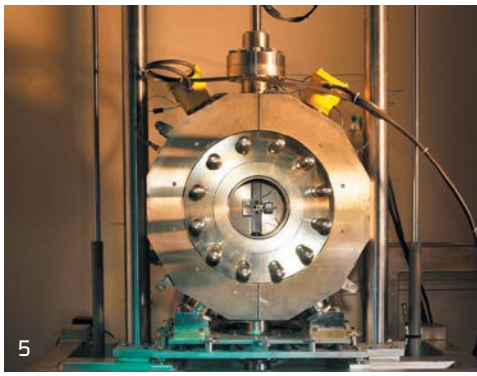
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MATERIALS PROCESSING

COLD PLASMA TO TREAT POLLUTION IN CONFINED ENVIRONMENTS

An air-treatment process using cold plasma to convert VOCs without generating harmful by-products is currently under development. The air is preheated before entering the plasma reactor, and a catalyst is used to increase the VOC-conversion rate to well above that of other processes for equivalent energy consumption. We intend to fine-tune the process even further until it meets industrial specifications.

POUDR'INNOV MAKES FIRST PERMANENT MAGNET

Our powder metallurgy platform, Poudr'Innov, produced its first neodymium-iron-boron permanent magnet using a 0.5%-dysprosium-doped alloy. Characterization demonstrated energy of 40 MGOe, and performance should improve as control of the microstructure gets better. The development is part of a project to revive France's permanent magnet manufacturing industry. In 2014 Poudr'Innov will acquire a strip casting machine to make the initial alloy, enabling the platform to cover the entire manufacturing cycle. 4

USING PRESSURIZED HYDROGEN TO UNDERSTAND STEEL STRENGTH

We have developed a new method for characterizing steel's behavior when subjected to pressurized hydrogen (up to 1,000 bar). Now our institute – which already possesses internationally-recognized capabilities in this field – can investigate steel's mechanical behavior under traction, fatigue, fracture toughness, and crack propagation. The research will be used to establish appropriate safety standards for pressurized hydrogen storage tanks and piping. 5

LITEN'S BRAZING KNOW-HOW RECOGNIZED BY AEROSPACE INDUSTRY

"To make telescope mirrors for aerospace optics, manufacturers must produce increasingly large, increasingly complex silicon carbide (SiC) structures. We at Liten have developed a targeted process for assembling these structures using brazing: the BraSiC® process based on BraSiC® silicon-based brazing alloys. Unlike most commercial brazing alloys, BraSiC® alloys do not react with silicon carbides and can be used at temperatures ranging from 1,100°C to 2,000°C. Airbus Defence and Space (formerly Astrium, an EADS company) recently licensed the technology for its Herschel and Gaia telescopes. And France's space agency, CNES, is also working with us to develop the telescopes of tomorrow. The latest research in this field is focusing on a multi-step brazing technique, which opens the door to even more complex assemblies. Safran similarly drew on our know-how for CMC (ceramic matrix composite) part assembly for its aircraft engine parts. We are working closely with Safran to develop brazing technologies to assemble CMC parts for its aircraft engine exhaust systems – with the ultimate goal of reducing weight to save on fuel."

Philippe Bucci, expert in assembly technologies, and **Valérie Chaumat,** brazing expert, CEA-Liten

Valérie Chaumat, Mathieu Monteremand, Olivier Mailliart, Valérie Merveilleau

Renewable energy

FROM SOLAR POWER TO BIOMASS

Our renewable energy R&D portfolio focuses on PV, solar thermal, hydrogen, biofuels, and biomass, covering the entire value chain for each type of energy – from advanced materials through to grid-connected systems. And, equipped with prototyping capabilities and pilot manufacturing lines, we are ideally positioned to meet the specific needs of manufacturers, designing powerful systems suited to a broad range of applications – often crossing traditional industrial boundaries. Our cross-disciplinary research approach combines photovoltaics and electrolysis; uses liquid, steam, and phase-change energy-storage systems together in unique new ways; and is driving crucial advances in power-to-gas.

A WORLD FIRST IN MONO-LIKE SILICON

"Our team is looking at mono-like silicon, a technology that combines the quality of monocrystalline silicon with the low production cost of the material's multicrystalline variety. Working in conjunction with ECM Technologies, in early 2013 we successfully produced a 450-kilogram ingot with a monocrystalline area covering 98% of the usable material. This world-first was made possible by our expertise in silicon seed particle forming processes and ECM's thermal furnace capabilities. Heterojunction cells were made from the resulting substrate. We further reduced production costs by using copper rather than silver metallization. The cells obtained have conversion yields of an impressive 21.6% – evidence of the intrinsic quality of the monocrystalline silicon produced by Liten and ECM. Our partnership is far from over: the next step will be to produce an 800-kilogram ingot." 1

Anis Jouini, Head of CEA-Liten's Solar Technology Department

SOLAR ENERGY

FASTER PURIFICATION OF SOLAR-GRADE SILICON

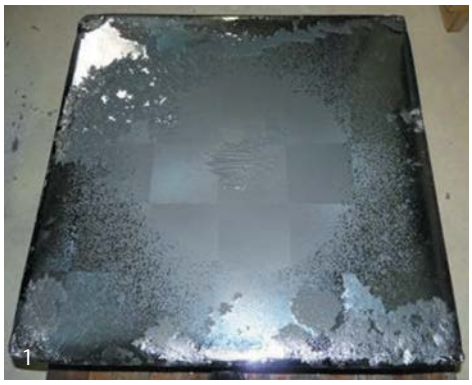
In association with ECM Technologies, we have developed a fast-segregation process for purifying solar-grade silicon, with solidification speeds of 3 cm per hour. Our process uses mechanical mixing rather than natural thermal convection to prevent impurities from building up. Aluminum segregation is maintained at up to 70% or more of the solidified height at the center of the ingot. The process, which is also more cost-effective than those currently available on the market, now needs to be validated on industrial-sized (450 kilogram) ingots.

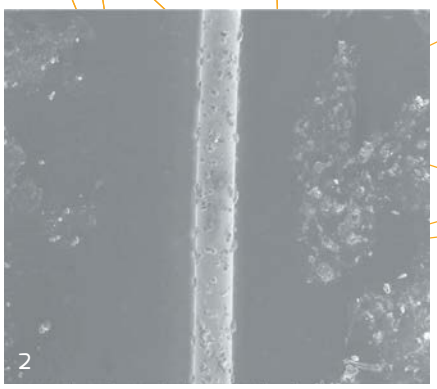
DIAMOND-WIRE WAFER SAW: IMMINENT TRANSFER TO INDUSTRY

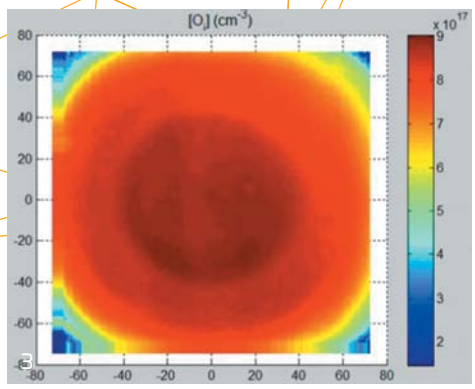
A project using diamonds to cut silicon wafers is moving forward to a production phase in collaboration with Applied Materials and Thermocompact. The project's objective is to understand the physics underlying the cutting process so as to identify areas for improvement. The benefits of the diamond-based technology are clear, with cutting-speeds two to three times faster than other techniques, a better surface finish, and less wasted material. Manufacturing of the diamond wires will soon begin and a prototype cutting line will be rolled out at Thermocompact in Annecy, France. 2

PREDICTING PV CELL PERFORMANCE WITH GREATER ACCURACY

Liten has developed a technology for mapping the intersitial oxygen in silicon ingots and wafers. Checking the concentration of oxygen atoms in a silicon structure is notoriously difficult. The phenomenon – which can be detrimental to PV cell performance – depends on how quickly the silica crucible dissolves and the conditions under which silicon fusion occurs. As part of a partnership with AET Technologies, we aim to leverage CEA patents and develop/commercialize equipment based on the technology. 3

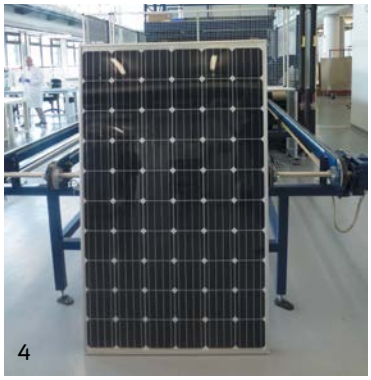






HETEROJUNCTION MODULES PASS IEC STANDARD TESTS

Our researchers are now capable of manufacturing heterojunction modules with output in excess of 260 watts on industrial-scale equipment. The modules are the first-ever to meet the IEC 61215 and IEC 61730 standards for reliability and safety. Losses recorded in thermal cycling and moist heat tests were around 1% – the standards allow up to 5%. The next step will be to validate the manufacturing process at a pre-industrial scale on a production line with a capacity of ten modules per hour; the production line will be set up at INES for pre-prototyping studies for manufacturers. 4



N-TYPE SILICON CELLS WITH YIELDS OF 20%

"Increasingly, n-type silicon is emerging as a solution for PV cell manufacturing – it is less sensitive to metal impurities, and cells made using n-silicon do not deteriorate under irradiance. With Liten's technology, cells can deliver yields of 20% for a large (six-inch) surface. The technology was validated on 60-cell modules, where it achieved power output of nearly 300 watts. Such results place Liten among the world's best for this type of technology. And the doping, passivation, and metallization phases offer additional room to push yields over the 20% mark. Because the cells are double-sided, they can convert light that hits the back side as well. Depending on the type of installation, the increase in power generation can range from 10% to 30% over traditional PV modules."

Jean-Pierre Joly,
Director, French National Institute for Solar Energy (INES)

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PV MODULES SHED WEIGHT AND CHANGE SHAPE

The new PV module concepts we developed to meet atypical weight and shape specifications are set to broaden the range of PV applications. Some of the innovations we are looking at include flexible modules that can be made into curved shapes and ultra-lightweight modules for dirigibles, tested as part of the Capazza project. Manufacturing these breakthrough modules will require new cost-efficient processes, from plastic injection molding techniques to lamination and thermoforming.

INK-JET-PRINTED PV MODULES

Our researchers have successfully used ink-jet printing to make 5 cm x 5 cm organic PV modules with conversion yields in excess of 2%. The modules' intrinsic stability was tested under continuous irradiation – with loss-of-yield limited to 20% overall and under 10% for certain cells after 3,000 hours of testing. Slightly better results were obtained using a process combining spin coating and vacuum evaporation for the top electrode. 2

ALSOLEN CONTINUES TO EXPAND

Alsolen, the company behind France's first-ever operational CSP plant, has rolled out a 30 m^3 rock-bed phase-change thermal storage system. The facility will be completed with a solar cooling unit. The company is also in the process of building a new CSP plant, "Alsolen Sup." The new plant will generate steam superheated to 450°C at 120 bar (vs. oil at 300°C for Alsolen's original CSP plant) and will include steam, phase-change, and liquid storage systems. 1

EFFICIENT, AFFORDABLE PV MODULES

"Improving performance while controlling costs is crucial not only for PV cells, but for PV modules as well. At Liten we are constantly striving to develop new materials and processes to meet this challenge. Manufacturers can count on us to help them meet even the most demanding specifications. For example, we are working with chemical manufacturer Arkema on Apolhya®, a thermoplastic compatible with solar panel manufacturing processes, and we are developing lightweight, flexible glassless PV module architectures. Cement maker Vicat turned to us to help it develop modules that can be integrated into concrete slabs. And we continue to pursue R&D on traditional PV modules from lab to industrial transfer, investigating subjects like how to improve cell interconnects by bonding – the resulting heterojunction cells meet the latest aging standards."

Stéphane Guillerez,
Head of CEA-Liten's PV Modules Department

IN SITU MEASUREMENTS OF OPTICAL REFLECTOR PERFORMANCE

Alsolen's CSP plant is equipped with portable reflectometers to measure the optical performance of its mirrors – crucial to the plant's overall yield. The reflectometers, developed specifically for CSP plants and in use at R&D centers worldwide, let researchers study solar fields or sites with natural irradiation exposed to harsh conditions (such as moisture, sand, and high temperatures). The data gathered is useful in calculating mirror durability, developing cleaning procedures, and determining the best mirror standby position.

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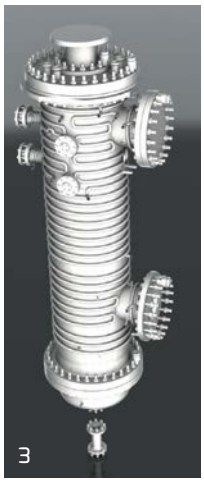
ELECTRIC ARC FAULT DETECTION TECHNOLOGY TRANSFERRED TO INDUSTRY

The algorithms we developed to detect electric arc faults on PV installations have been transferred to a French manufacturer, which plans to market a complete solution in 2014. The technology has a key advantage over competing solutions: a very low rate of false positives and false negatives, resulting in greater protection against electrical fires. Electric arc fault detection devices are mandatory in the US, and the EU will likely follow suit with similar regulations.

SOFTWARE DETECTS PV PLANT MALFUNCTIONS

We teamed up with Urbasolar to develop software capable of detecting PV plant malfunctions detrimental to achieving high overall yields and keeping an effective watch over the plant's operations. The software compares actual production with theoretical production based on current conditions, sending operators an alert if an anomaly is detected. The software is already being tested at several plants and will be rolled out for commercial use in 2014. 3



BIOMASS AND BIOFUELS

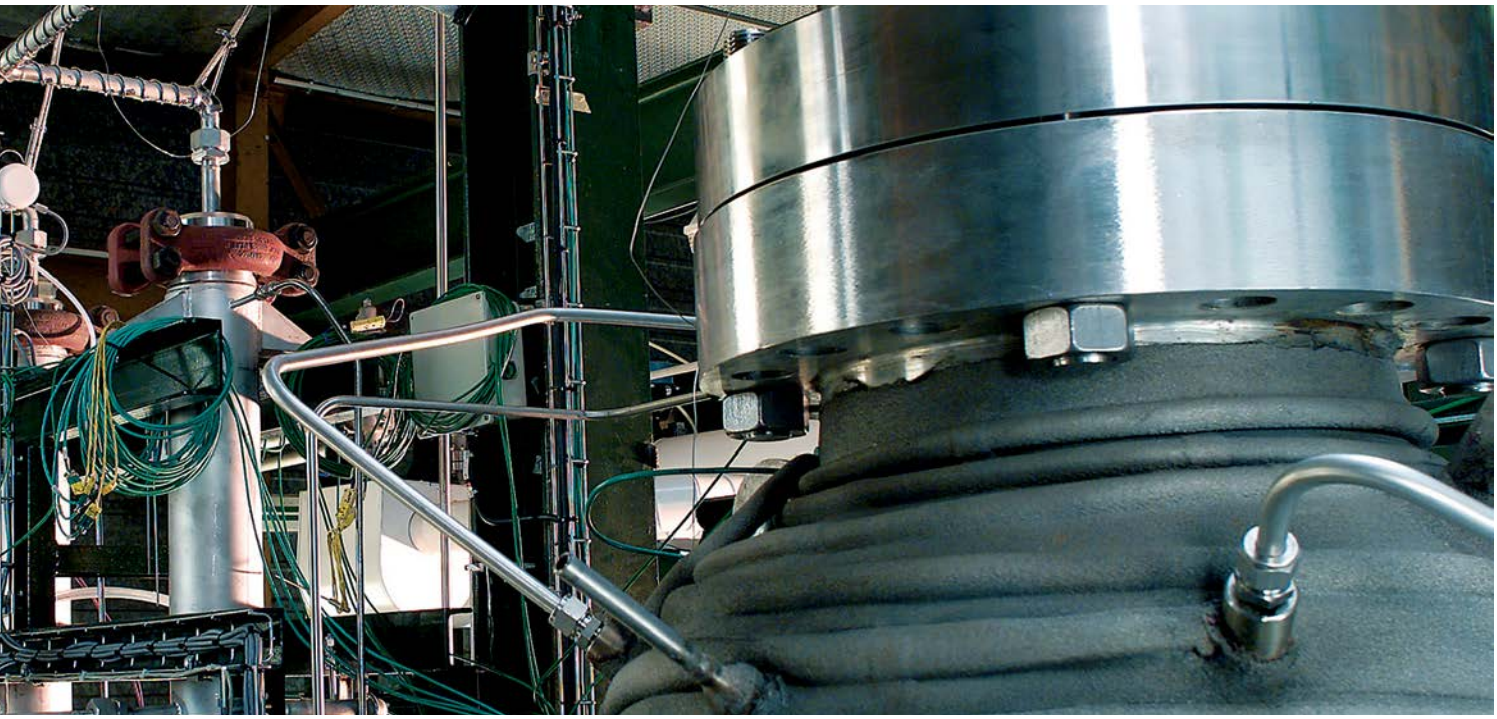
BIOMASS POWDER INJECTED AT 50 KG/H

Our researchers have demonstrated the feasibility of a new process for injecting biomass powder into a gasification reactor at rates of 50 kg/h. The tests were carried out as part of the Syndièse biomass-to-biofuel project. The 200-micron powder is injected by gravity with flow rate fluctuations of less than 5% for time intervals of several seconds. The next step will be to develop a complete process from the mechanical grinding of the biomass through to the injection of the resulting biomass powder. 3

FINDING NEW SOURCES OF BIOMASS FOR ENERGY

"Here at Liten we obviously study second and third generation biofuels like lignocellulose and algae. But we are also looking at how to use materials that normally go to waste – like demolition wood, non-recyclable packaging, and agricultural waste and other organic by-products that traditional recycling systems can't handle – by turning them into bio and other fuels, syngas, heat, electricity, and even chemicals. Manufacturers like Michelin and Valoneo are working with us on processes for used-tire recycling and wastewater treatment sludge gasification, for instance. The goal is to broaden the range of potential sources of biomass-based energy. Liten stands out in this exciting field with its Genepi lab planned to open in 2014 (the lab is funded by the French National Research Agency – the ANR – and run in partnership with CIRAD Montpellier and l'École des Mines d'Albi). The new facility will be equipped with pretreatment capabilities like grinding and torrefaction that can be used to validate innovative new processes."

Isabelle Maillot,
Head of CEA-Liten's Biomass Program



EXPLORING THE POTENTIAL OF TORREFACTION GASES

Our researchers have installed and tested a biomass torrefaction gas sampling and analysis system on a reactor. The system was developed to identify condensable substances that could be converted into useful chemicals; it can also determine their concentrations and model the kinetics of their development. Our research will ultimately be used to improve the recovery of high-added-value gases, develop more cost-effective processes, and obtain "trackers" to ensure that the torrefaction process moves forward as planned. 1

RECYCLING CO_2 AND PRODUCING BIOFUEL AT THE SAME TIME

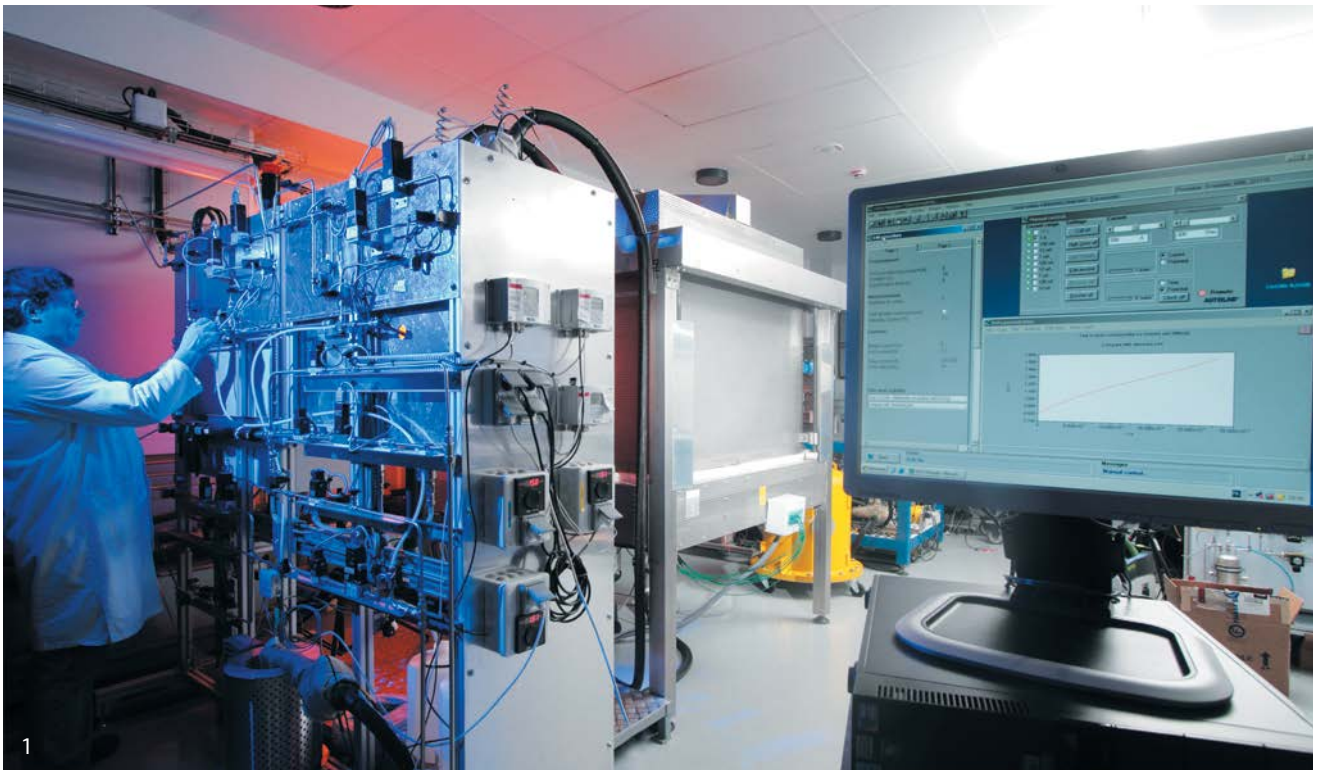
Tests conducted on a pilot reactor have demonstrated that injecting CO_2 during lignocellulose biomass pyrogasification in a fluidized-bed reactor can substantially increase carbon yields. The yields obtained during the tests were above 80%, which indicates that carbon is being recycled during biodiesel production. Our research also involved process modeling and a technical and economic feasibility assessment. The new method is now ready for the next phase: prototyping. 2

BIOFUELS AND HIGH-TEMPERATURE ELECTROLYSIS A WINNING DUO

A Ph.D. thesis completed at Liten demonstrated that high-temperature electrolysis, when combined with the thermochemical transformation of biomass to biofuel, increases the amount of carbon recovered – and lowers biofuel costs. The heat produced by the biomass generates superheated steam, which in turn generates hydrogen, which is reinjected into the thermochemical conversion process, thereby fixing more carbon. A model of the entire process was developed which is protected by a patent.

GENERATING BIODIESEL FROM ALGAE

We achieved promising results for biodiesel production using hydrothermal liquefaction of microalgae at high pressure and at temperatures of around 300°C. The resulting oil has an elevated higher heating value (HHV). The process garnered interest from several manufacturers and discussions on future R&D are at an advanced stage. In related research, we are looking at the hydrothermal liquefaction of food-industry by-products like whey, pomace, and blackcurrant dregs.



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THIN-STACK DESIGN VALIDATED FOR HIGH-TEMPERATURE ELECTROLYSIS

We have successfully tested several twelve-cell high-temperature electrolysis stacks – a major step towards transferring the technology to industry. Our thin-stack design, known as "TEAM," reached a major technological milestone with the full validation of several 10-12 cell stacks (a significant scale). The current densities obtained are between 1.5 A/cm^2 and 1.8 A/cm^2, with voltage dispersion coming in under the target specifications. The stacks produce 0.8 Nm^3/h of hydrogen for 2.3 kW of power consumed and have good watertightness. This progress paves the way for the next step: transferring this compact, low-cost design to industry. 1

HYDROGEN AND SYNGAS

HIGH-TEMPERATURE ELECTROLYSIS STACK EVALUATED IN COELECTROLYSIS MODE

The TEAM stack can be used in coelectrolysis mode (the production of CO and H_2 syngas from steam and CO_2) to make synthesized fuels (like methane and methanol). We tested a ten-cell stack in co-electrolysis mode, achieving performance levels very close to those of pure electrolysis. The composition of the gas produced was as we predicted. Our results demonstrate the feasibility of using coelectrolysis at a significant scale.

HIGH-TEMPERATURE ELECTROLYSIS PROVES TO BE FLEXIBLE

We carried out several cycling tests (fast, slow, ramped current, and trapezoidal loadings on a high-temperature electrolyzer to find out whether performance would be affected negatively as compared to stationary operation. The tests demonstrated good flexibility over a broad range of voltages, proof that high-temperature electrolysis can be used in tandem with renewable energy sources – which are by nature intermittent. The elevated temperatures are what give high-temperature electrolysis an advantage in terms of yield. 2

PEM ELECTROLYZER STACK COSTS SLASHED BY 70%

We have developed a new current collector for low-temperature proton exchange membrane (PEM) electrolyzers. Our novel collector design reduces stack costs by an impressive 70%. We are also contributing to research as part of the EU's NEXPEL project to reduce membrane-electrode assembly costs, and the early results – a decrease in the amount of catalyst required – are promising. These advances could substantially lower the cost of high-capacity electrolyzers. 3


2


3

8,000 ABSORPTION-DESORPTION CYCLES TESTED ON MAGNESIUM TABLET

Liten has designed a test bench equipped with a porthole and camera to monitor and analyze how the metal hydrides used to store hydrogen in solid form "breathe" (swell and retract). The goal is to gain a deeper understanding of the phenomenon – information useful in designing hydrogen storage tanks, which are subjected to major mechanical stress. Additional tests showed that the magnesium hydride tablets were capable of withstanding a record-high 8,000 cycles without losing storage capacity. 4


4

A PLACE FOR HYDROGEN IN THE NATURAL-GAS DISTRIBUTION NETWORK

"Our R&D looks not only at technologies to produce hydrogen, but also at ways to combine hydrogen generated from water electrolysis with CO_2 to synthesize a methane gas compatible with existing natural-gas distribution networks. We brought together two technologies – high-temperature electrolysis and a novel methanation reactor – into a unique configuration. Electrolysis at temperatures of 800°C can simultaneously electrolyze water and CO_2. This single step produces a blend of hydrogen and carbon monoxide – the starting point for synthesizing a range of fuels. The blend is transformed into methane in a reactor that uses the energy produced by the reaction, boosting the entire system's yield. Liten is a global pioneer in this technology, and has been selected to coordinate the EU's CEOPS project."

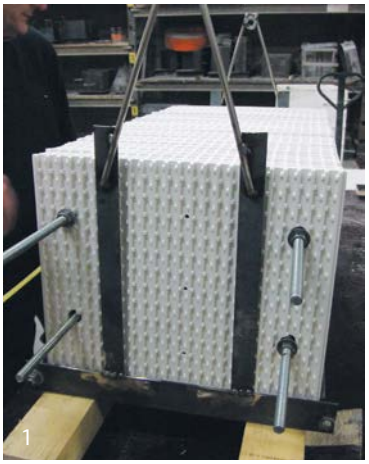
François le Naour,
Head of CEA-Liten's Hydrogen and Biofuels Program

Energy efficiency

RECOVERING, STORING, AND REDISTRIBUTING ENERGY

Finding solutions for managing the intermittent availability of power generated from renewable sources is critical if they are to be connected to the grid. That's why we are developing systems to store both renewable energies – like PV and wind – and surplus industrial process energy for use as electricity or heat when it is most needed. These systems can store energy from a few hours up to a few months, depending on the needs of the application.
We are also working to answer market/production/consumer needs by making buildings more energy efficient. Our in-depth knowledge of the behavior of how building materials and systems (concrete, glazing, and ventilation systems, for example) behaves is helping us achieve these goals. A vital research tool in this area is our state-of-the-art INCAS lab – a set of fully-instrumented low-energy-consumption homes.

ENERGY-EFFICIENT THERMAL SYSTEMS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SOLID-MATRIX, HIGH-TEMPERATURE THERMAL STORAGE

We tested two types of solid thermal storage materials – cordierite ceramic plates and basalt gravel – at a scale of 3 m^3 to assess their mechanical and thermal behavior with a view to integrating them into an 800°C heat storage system. The materials were placed in two tanks connected in a closed loop; a gas was used as the transfer medium. The project team was able to successfully confirm the technical feasibility of this high-temperature solid storage technique. 1

THERMAL SOLAR HEAT SHOWS POTENTIAL FOR A FUTURE ECO-NEIGHBORHOOD

Our researchers used modeling tools to study how to reinject heat from thermal solar collectors into the low-temperature heat distribution network of an eco-neighborhood planned for construction in Chambéry, France. The solar collectors could potentially cover up to 60% of the neighborhood's annual heat consumption – and be totally self-sufficient during the summer months. However, the results obtained are tightly correlated to the heat network's architecture and temperature settings. We are considering building a demonstrator to pursue the research.

3

THE SOLAMMOR ULTRA-COMPACT COOLING MACHINE

Liten built a pre-industrial prototype of an absorption machine to convert heat into cold, using the results of research generated since 2011. The machine, which is protected by several patents, is available in three versions: 1 kW, 5–8 kW, and 100 kW. And, at 74 L per kW of cold produced, it is the most compact machine on the market. The 5 kW version has been installed in a building demonstrator at INES, the French National Institute for Solar Energy, to study solar-powered air-conditioning applications. 2

A SOLAR COLLECTOR TO HELP DESALINATE SEAWATER

We tested and confirmed the feasibility of a new polymer component used as both a solar collector and steam generator for seawater desalination. The component would make desalination more energy efficient, thereby reducing the cost of the water produced. Tests on a scale model produced evaporation temperatures of 53.5°C and flow rates of 0.24 L/h. A full-size polymer component will now be built and installed on a system in Cadarache, France. 3

A 100 KW THERMAL ABSORPTION MACHINE FOR ALCEN

"In 2013, as a follow-up to the Solammor research project, we developed an ammonia-water absorption machine capable of converting heat into cold or ice. The high-performance, compact machine offers an impressive 5 kW of cooling power. Other cooling powers are also available to suit the needs of various applications. For example, we are currently working with Alcen to develop a 100 kW thermal absorption machine for a thermodynamic solar plant demonstrator. Alcen is designing the solar plant to supply isolated and semi-isolated power grids, such as those found in the desert. It is looking at ways to make the system as profitable as possible; one way to do this is by recovering the residual heat in the transfer medium when it leaves the turbo-alternator. Our technology can convert this residual heat into cold for air conditioning and, potentially, seawater desalination."

Patrice Tochon, Head of CEA-Liten's Thermal, Biomass, and Hydrogen Department

1

PREDICTING BUILDINGS' ENERGY CONSUMPTION TO WITHIN 3.3%

Liten has developed a new simulation method that can predict a building's annual energy consumption to within 3.3% accuracy after three weeks of experimental measurements. This is a significant improvement on our previous calculation method which took six months of measurement and calibration. The method is based on a new, more complex approach, which has been tested on three virtual building models, taking into account indoor and outdoor temperatures, heating power, and building use. The next step will be to test it on an actual building.

ENERGY-EFFICIENT BUILDINGS

RESEARCH UNDERWAY ON SEMI-TRANSPARENT PV DOUBLE-GLAZING

We joined forces with Crosslux to develop a process for manufacturing semi-transparent photovoltaic double glazing for commercial building applications. Energy performance and building occupants' visual comfort were modeled for a variety of different geographical areas, directional orientations, and degrees of transparency. This type of double glazing would be useful in meeting energy-positive building objectives.

ACTIVE ROOFTOPS FOR BETTER BUILDING ENERGY PERFORMANCE

A building's rooftop can host other functional facilities and more than just PV panels. Equipment like thermal solar collectors, hot water tanks, and air preheating and cooling systems are all appropriate for rooftop installation. Our researchers used a 35 m^2 instrumented prototype to study an "active rooftop" system made of easy-to-combine modules compatible with subassemblies (PV modules, tinted and clear glazing, etc.) of different thicknesses. The project team is now looking at the next step: transfer of the concept to industry. 1

VICAT ASSESSES BUILDING THERMAL PERFORMANCE

We have developed decision-support software for cement maker Vicat to quantify the effects of a building's thermal inertia on occupant comfort, both during the summer and between seasons. Thermal inertia can be a source of overheating in buildings or – on the contrary – can help smooth out temperature fluctuations. The software, designed for architects and construction engineers, takes into account the thickness of concrete walls and floor slabs, ventilation, local weather, and occupant usage patterns. 2


2

3


4


5

SOLÉHOM© HEAT-COLLECTOR WALL MODULE NOW ON MARKET

Our new solar air heat collector is only around 20 cm thick, making it easy to integrate into a building's exterior insulation. The collector is intended for use with positive-pressure mechanical ventilation. Heat is stored using a phase-change material, and the collector can be regulated to optimize heating and air conditioning savings. Manufacturers Elva and Ventilairsec will commercialise the product, called Soléhom©, which they unveiled at the Batimat 2013 construction materials trade show. 3

SILICA AEROGEL TESTED AS EXTERIOR COATING FOR BUILDINGS

Our researchers are currently testing tested hydraulic mortars containing a silica aerogel for use as an exterior building coating likely to limit energy loss. numerical models showed efficiency increases of up to 25% for new construction projects and up to 50% for the renovation of existing structures. As part of the Parex-It R&D project, the coating will be applied to the fourth experimental home at our INCAS lab, which has specially-designed brick walls 42.5 cm thick. The project team will measure the performance obtained by combining brick and coating. 4

HEMP CONCRETE SHAPING-UP AS A NEW BUILDING MATERIAL

We have designed, monitored, and instrumented a hemp-concrete wall (produced by cement manufacturer Vicat) with a view to validate this new material for commercialization. The research aimed to assess the material's hygrothermal behavior at both wall and building-level. When the research is completed, Vicat will have a calibrated numerical model that can be used to compare the material's hygrothermic performance and energy consumption to other solutions available on the market. 5

THE INCAS LAB, A KEY STEP IN TRANSFORMING CONCEPTS INTO PRODUCTS

"Our building-related R&D is backed by a lab unlike any other in Europe: INCAS. In 2013 we fitted INCAS with an integrated active rooftop for combined electricity, domestic hot water, and preheated air production. The proof-of-concept phase has been completed; all that remains is to get roofing materials and solar equipment manufacturers on board for industrial rollout. We also used INCAS to assemble and test industrially-manufactured concrete blocks made from a plant-based aggregate. The 18-month test gave us a deeper understanding of the material's hygrothermal behavior. The blocks could be ready for industrial-scale production next year. Finally, INCAS played a key role in the development of Soléhom©, a three-in-one heat-collector wall module marketed by Ventilairsec and Elva. The module collects, stores, and distributes solar energy and provides ventilation. The INES-designed prototypes were tested at INCAS."

Olivier Fléchon, Head of CEA-Liten's Buildings and Thermal Systems Department

1

STEADYSUN OFF TO A PROMISING START

Steadysun, a start-up founded in April 2013, provides solar-energy production forecasting services that leverage five years of Liten R&D. The company's solutions target stationary PV plants from 2 kW to 12 MW, with three distinct products for forecasts of several minutes, hours, or days. Steadysun has already won several contracts in its first few months of existence, and has expanded from one to six employees. Liten has an R&D agreement with the company to adapt its software for tracker-based PV plants, CPV plants, and thermodynamic solar plants.

steadysun

POWER GRIDS AND STORAGE

INERTIA WHEEL COULD SMOOTH-OUT CLOUD-RELATED PV PRODUCTION INTERMITTENCE

We assessed the ability of a 15 kW/300 kWs flywheel to smooth-out short periods of cloud-related PV production intermittence (with up to 80% loss of nominal power). The wheel's performance was measured, and then, as part of a simulation, paired with the production of a 17 kW PV plant. The next steps will be to determine the best command-control strategies and compare the inertia wheel's performance with that of lithium-ion batteries.

ISLAND-BASED PV PRODUCTION AND BETTER FREQUENCY-INSTABILITY MANAGEMENT

Using our own software and methods, we successfully conducted a quantitative intermittence study of PV production on Mayotte. The objective of the project was to assess a storage system that negated high-frequency instability. We used detailed monitoring from three plants and drew on a year's worth of production data from 70 plants on the island, and, in parallel, we performed research to determine the right size for the storage system. The same method will now be used on Martinique. 1

RENEWABLE ENERGY GENERATION-STORAGE SOLUTIONS: A HIGH-END MODELING TOOL

Validation testing on Odyssey software – used to assess the technical and economic performance of renewable energy generation-storage systems – was completed in 2013 on a CEA-Grenoble hydrogen chain as part of an R&D project spearheaded by McPhy Energy. The software can be used to assess the specification of equipment and establish and test operating rules. Software development is continuing as part of Ulisse, an R&D project funded by the Institut Carnot, with the goal of producing an application to scale and manage power storage systems.

2


3

ALSTOM COMBINES ENERGY STORAGE AND POWER CONVERSION

We have teamed up with Alstom Grid to develop innovative energy storage and power conversion systems. The partnership encompasses preliminary research on storage technologies and storage-system aging, as well as the development of battery-management algorithms and battery-scaling software. Another crucial component of our alliance is the design of power converters suitable for use with PV and storage systems and CPV plants.

CONNECTING BATTERIES TO THE SMART GRID

As part of the Reflexe project conducted in association with Fiamm, we tested a 132 kWh sodium nickel chloride battery over a period of several months with a view to developing operating algorithms for stationary applications. The goal was to get the battery ready for integration into a smart grid, where it will help smooth out fluctuating renewable energy supplies. We had previously completed element-level characterization on over 80 different batteries, making it possible to combine several different technologies – and optimize their management – on the same grid. 2

BATTMARK BATTERY-INDUSTRY BENCHMARK

Battery manufacturers and users can now compare the performance of different technologies with our Battmark battery benchmarking tool. Batteries undergo three types of tests: initial factory performance, aging during cycling, and aging over time. The test results are entered into the confidential Battmark database. Our partners can request an export of their own batteries' data, and see where their products stand relative to other manufacturers' (which are presented as anonymous data points on a cloud graph).

STORAGE: A KEY FACTOR IN THE STABILIZATION OF POWER GRIDS

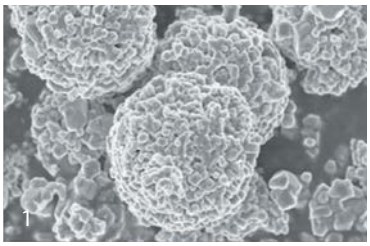
"RES integration into power grids creates local fluctuations that can be offset by storage systems like lithium-ion batteries. Our R&D covers the entire value chain, from battery-cell development through to secure processes for assembling cells into battery packs, and, finally, battery management. We also look at all electrochemical storage technologies for grid-integration applications, characterizing and modeling various systems to boost performance. For example, our battery monitoring and management algorithms can increase a storage system's lifetime, thus reducing the cost of stored power. And Liten is an active participant in several projects focusing on integrating storage systems into the grid. Under the Iperd project, funded by French energy agency ADEME, we developed a 65 kW storage system capable of stabilizing a test grid with 120 kW of PV production capacity and 26 consumers." 3

Marion Perrin,
Head of CEA-Liten's Electrical Systems and Storage Department

Electric and hybrid vehicles

VEHICLES FOR LAND, AIR, AND SEA

We strive to develop innovative electric drivetrains for all types of vehicles. All of the technological advances that come out of our labs meet the highest safety and performance standards – and are designed for the real-world constraints of industrial-scale rollout. Our researchers adopt a holistic approach to the drivetrain, from materials through to the operational demonstrator. They work on lithium-ion batteries, proton exchange membrane fuel cells (PEMFCs), and hybrid solutions combining the two technologies. They also draw on our Nanocharacterization Platform – the only facility of its kind in the world – to optimize each material for maximum component and overall product performance.



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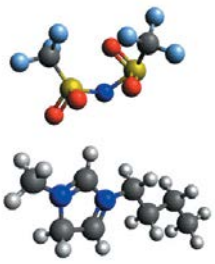

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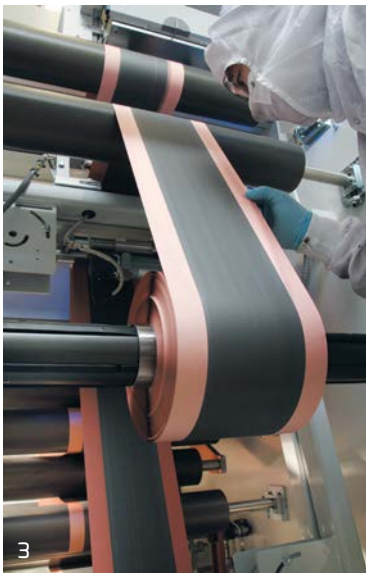

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BATTERIES

SPINEL OXIDE OBTAINED BY LIQUID SYNTHESIS A NEW ALTERNATIVE FOR ELECTRODES

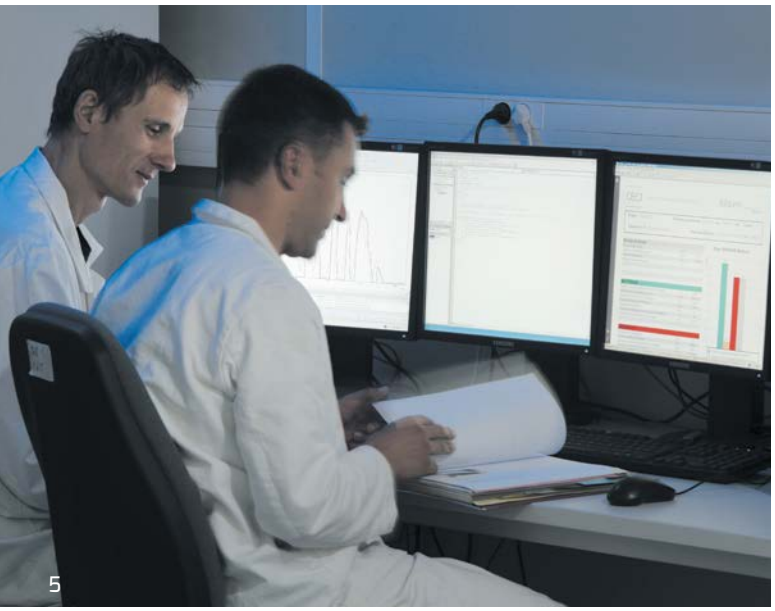
Until now, manganese oxide, a high-voltage positive-electrode material, has been produced by solid synthesis. But our researchers have successfully tested liquid synthesis, forming spherical particles that facilitate the inking phase of the coating process and improve performance during cycling at high temperatures. Furthermore, this liquid method also eliminates the grinding stage, thereby reducing costs. 1

NEW, SAFER ELECTROLYTES FOR LITHIUM-ION BATTERIES

New ionic-liquid electrolytes could make lithium-ion batteries safer. We synthesized and characterized the electrolytes to assess their flashpoint, vapor pressure, and stability over time – which proved to be much better than for conventional electrolytes. The next challenge will be to improve the electrolytes' conductivity at ambient temperature, a necessary step toward preparing them for new battery applications. 2

LITHIUM-ION PROTOTYPES AT MORE THAN 215 WH/KG

The prismatic lithium-ion battery cells we developed using high-voltage spinel/graphite technology have achieved an energy density of 217 Wh/kg. This remarkable performance is attributable to their prismatic format and substantial electrode thickness, which make it possible to pack more active material into the battery cells. This type of cell targets embedded systems for aerospace, display, and sensor applications, all of which require high energy densities. 3



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HIGH-POWER LITHIUM IRON ACCUMULATORS

Our researchers developed a 10 Ah lithium iron phosphate ($LiFePO_4$) accumulators, successfully characterizing its performance and safety behavior. The technology delivers high power up to 20 C (charging in three minutes), with excellent energy stability. Our R&D is now looking at improvements to the accumulators' cycling capacity, with the goal of reaching several thousand cycles at 2 C. The technologies are designed for transportation applications, most notably for the fast charging of electric vehicles while in use.

TOWARDS SAFER RECYCLING OF LITHIUM-ION BATTERIES

We are currently developing a hydrometallurgical process to make lithium-ion battery recycling safer and more efficient. The process would let manufacturers effectively recover electrolyte solutions and the lithium salts they contain by neutralizing the hydrofluoric acid and extracting the lithium. The expected recovery and recycling rates with the new process are much higher than with current industrial recycling methods – a real advantage in terms of lowering recycling costs. 4

OBSERVING AND PREDICTING BATTERY AGING

Our researchers performed several studies of battery-pack aging in actual use: one test covered 60,000 km (500 km to 600 km per day); another looked at aging during intensive use over one month (10,000 km); and yet another examined the impact of 24 hours of non-stop use with 11 fast charges. The results showed small decreases in capacity, suitable for the applications targeted by the battery packs. The results were used to develop a tool compatible with a wide range of batteries to predict battery-pack durability in actual use. 5

A "HEAVYWEIGHT" POWER PACK FOR GAUSSIN

We worked with Gaussin Manugistique, a specialist in portside container handling, to develop a three-ton, 80 kWh–240 kWh lithium iron phosphate ($LiFePO_4$) battery pack that can be assembled and disassembled in less than ten minutes – that gives Gaussin's electric-powered heavy vehicles a range of four to twelve hours. Given the name "Power Pack," the innovation was unveiled at a trade show in the Netherlands; one international customer has already ordered 40 Power Pack-equipped vehicles from Gaussin. We are continuing the R&D work ahead of commercialization in 2014.


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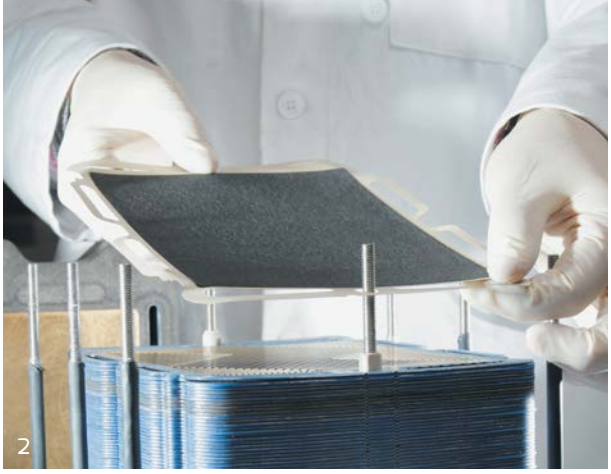
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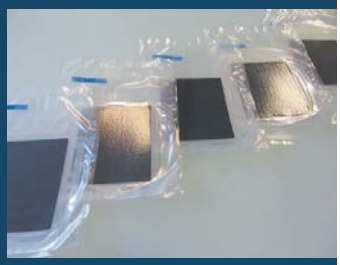
LARGE-SURFACE MEAs DEMONSTRATE SAME PERFORMANCE AS SMALL-SURFACE MODELS

Our latest generation of membrane-electrode assemblies (MEAs) measure 220 cm² and perform just as well as MEAs measuring 25 cm².
That's thanks to several improvements we made to the layers, assembly, and pressing to correct fluctuations during operation. Several patents have been filed to protect our innovations. Further research is looking at *enhancements to lower the platinum charge. MEAs with a platinum charge of 0.28 g/ kW at maximum power operated for 2,500 hours (dynamic cycling) in automotive-type operating conditions with no irreversible decrease in cell voltage.*



PEM FUEL CELLS

PEM FUEL CELL OPERATES FOR 1,000 HOURS ON REFORMED GAS

Our researchers tested a PEM fuel cell on reformed gas for a duration of 1,000 hours. The test employed cycles representative of use with a battery for temporary power variations. The main pollutant was carbon monoxide. The fuel cell reached the 1,000-hour goal with different reformed-gas compositions, with no irreversible decrease in the high-current operating point. The test results will be used to develop operating strategies and accelerated testing on fuel-cell stacks. 1

SYMBIO FCELL GETS NEW PEM FUEL CELL DESIGN

In association with Symbio FCell, we developed a new generation of bipolar plate – a component crucial to fuel-cell operation. The new plates are designed for mobility and transportation applications and meet the specifications for successful industrial rollout. The 2.9 kW/L "type-N" plates position Liten and Symbio FCell at the international state of the art in PEMFC performance. 2

LITEN ACTIVE IN EU HYDROGEN AND FUEL CELL R&D

"Liten has been a partner of choice for EU hydrogen- and fuel-cell-related research projects since 2008, participating actively in R&D on electrolysis, storage, distribution, and conversion. As the R&D representative for the Joint Technology Initiative (JTI) to coordinate EU research on these topics, we work closely with EU officials and manufacturers like Air Liquide and Daimler. Our role is to help develop multi-year R&D programs and assist with writing calls for EU projects. Liten has held this position on the JTI since its inception – taking advantage of numerous opportunities to make recommendations and gather valuable information about manufacturers' needs. Our role in the JTI has prompted us to participate in more than 20 R&D projects in the last five years, with a success rate well over 50%."

Florence Lefèbvre-Joud,
CEA-Liten's Scientific Director

Technology Platforms

NANOCHARACTERIZATION PLATFORM

The nanocharacterization platform (PFNC) studies the morphology and physical and chemical properties of nanomaterials and components – insights crucial to conducting nano-scale* research and development. The platform's advanced nanocharacterization resources are unique in the world, with equipment capable of generating 2D and 3D images of matter at close to the atomic scale. The platform also works with the ESRF and ILL to obtain even higher-resolution images. The platform supports CEA research programs, develops new analysis techniques, and works with around 20 scientific equipment and other manufacturers.

*1 nanometer = 1 billionth of a meter

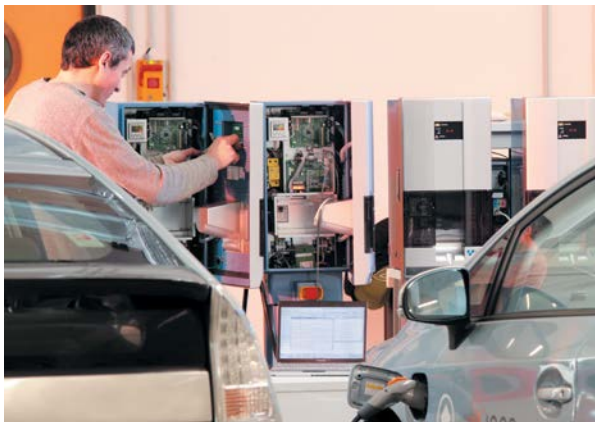
FUEL CELL PLATFORM

The fuel cell platform aims to improve fuel-cell performance and lifetime and decrease production costs. The platform's integrated approach covers materials, membrane-electrode assemblies, stacks, and testing in real-world conditions. The platform's resources include test benches and some of the most advanced equipment anywhere. Its R&D work, which targets transportation and stationary applications, is at the international state of the art. The platform has around ten industrial partners, including Symbio FCell and Areva Energy Storage.

BATTERY PLATFORM

The battery platform's R&D focuses on lithium-ion battery development and small-run production, from materials synthesis through to integration. The goal is to develop end-to-end production systems for applications ranging from hearing aids to electric-powered buses, with the broader objectives of cutting costs, increasing battery life, and improving reliability. Whether it is in terms of size or equipment, the platform, available for use by manufacturers, is unique in Europe.

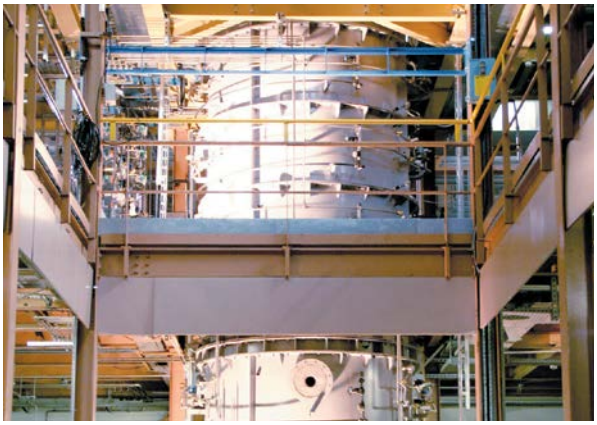
ELECTRIC MOBILITY PLATFORM



The electric mobility platform integrates battery and fuel-cell prototypes developed by the CEA into land, air, and marine vehicles and vessels, and tests them in real-world conditions. The platform boasts equipment ranging from assembly shops and test benches to charging stations and monitoring and analysis software. Tests, carried out on the open road/water or at closed facilities, provide valuable feedback on cycling, ageing, and other factors while facilitating market penetration for the ten or so participating battery, fuel-cell, and traditional and electric vehicle manufacturers.

R&D capabilities

BIOMASS PLATFORM

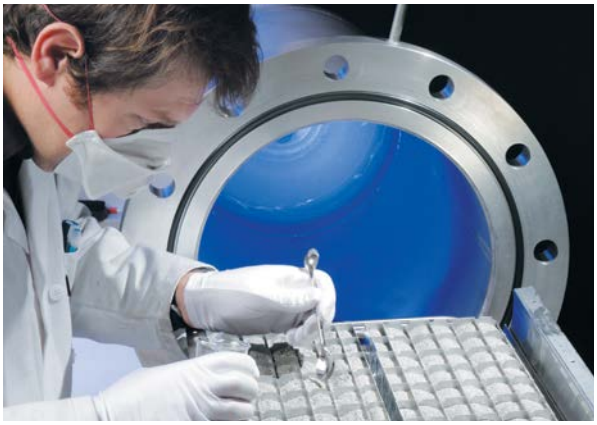


France's only biomass research facility of its kind, the biomass platform focuses on the grinding, torrefaction, and gasification of biomass from wood and farm and forest by-products. Potential energy sources studied at the platform include household waste, paper and pulp by-products, wastewater treatment sludge, and micro-algae. R&D at the platform focuses on the analysis and modeling of physical phenomena; experimentation at the lab and demonstrator scales; process evaluation; and demonstrator development – with the goal of devising economically-viable solutions by 2020. The platform works with around fifteen industrial partners.

PHOTOVOLTAIC SOLAR PLATFORM

The photovoltaic solar platform contributes actively to building France's solar industry. R&D at the platform, conducted in association with a large number of industrial partners, focuses on PV materials, processes, and equipment. The platform's signature asset is its Heterojunction LabFab, a pre-industrial production line capable of producing PV cells with yields in excess of 20%. The platform also helps France-based solar-energy SMEs grow their export sales and build turnkey PV solar plants.

HYDROGEN PRODUCTION AND STORAGE PLATFORM



The hydrogen production and storage platform develops hydrogen production, conversion, and storage processes for energy applications. It is one of the world's leading high-temperature electrolysis and SOFC patent-filers. The platform tests demonstrators of significant size – such as solid-hydrogen storage tanks with a capacity of 15 kg, the only ones of their kind in the world – with partner McPhy Energy. The platform's research also focuses on applying these hydrogen processes to other gases like carbon dioxide, natural gas, and biogas.

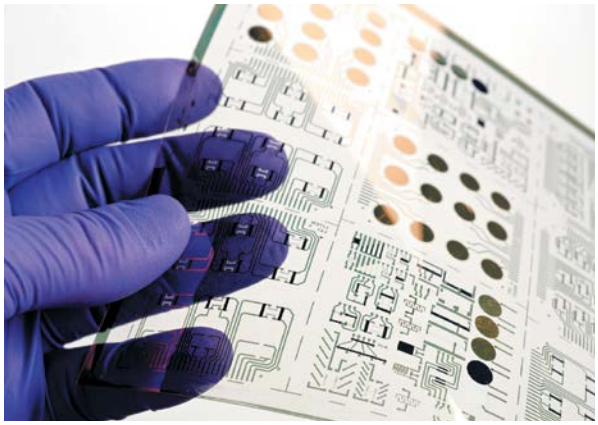
SMART-GRID SYSTEMS PLATFORM

The smart-grid systems platform looks at how to scale, operate, and optimize energy systems connected to intermittent power sources and electricity storage systems at the scale of an individual home, building, or neighborhood. The platform possesses a range of resources – both real and virtual – to test various configurations, manage individual system components, determine operating strategies, and optimize profits. R&D at the platform is carried out with around fifteen industrial partners.

THERMAL TECHNOLOGIES PLATFORM

Researchers at the thermal technologies platform work on concentrated solar power (CSP), thermal storage, and thermal systems for industry. The platform helps industrial partners deepen their understanding of thermal technologies, optimize their use, and develop new products. The platform possesses a full range of equipment including test loops, exchangers, solar-power systems, and rock-bed and phase-change-material thermal storage systems, used to build demonstrators and carry out testing.

LARGE-SURFACE PRINTING PLATFORM



The Pictic large-surface printing platform develops formulations for electronic inks and scales up printing processes for industrial rollout. Its novel printing technologies are used to give large (320 mm x 380 mm), flexible surfaces electronic functions like pressure or temperature sensing, signal conversion, and display capabilities. The platform's advanced printing and characterization equipment and innovative processes make it unique in Europe. It works with several manufacturers worldwide, including Grenoble, France-based Isorg.

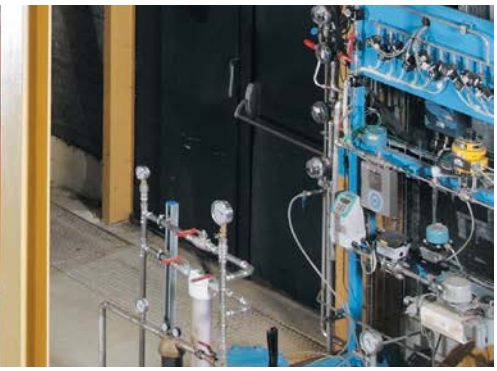
POWDER METALLURGY PLATFORM

The powder metallurgy platform develops magnets and other high-added-value metal and ceramic components characterized by their complex shapes, lightweight structures, special physical properties, or multi-material assemblies. The platform is the only R&D center in Europe to possess a complete range of semi-industrial and industrial equipment. It is capable of running an entire production process, from blending powders to manufacturing final components. The platform works with a variety of manufacturing companies. The components developed have applications in the connector, lighting, power electronics, healthcare, fine chemicals, and energy markets.

MICRO-ENERGY-SOURCE PLATFORM

The micro-energy-source platform develops micro-batteries, micro-fuel-cells, and energy-recovery systems (thermoelectric and pizoelectric) to power smart cards, sensors, laptop computers, and other mobile devices. The platform leverages a full range of pre-industrial equipment. Its R&D activities focus on innovative materials using a variety of physical and chemical vapor deposition processes. It works with numerous industrial partners including STMicroelectronics, Bic, and HotBlock OnBoard, a CEA spin-off.

R&D partnerships: from academia to Industry



R&D partnerships are our most precious asset. We run pump-priming programs with academic research labs to jump start the development of new technologies. Then we team up with manufacturers to nurture these technologies to maturity.

PARTNERSHIPS WITH ACADEMIC RESEARCH LABS

We work closely with Grenoble's energy-oriented academic research labs (SIMAP, LEPMI, Institut Néel, G2Elab, and LEGI, among others), as well as with national labs in Bordeaux, Paris, and Nantes. Our European partners include technology research institutes such as Fraunhofer and Helmotz in Germany, VTT in Finland, ENEA in Italy, SINTEF in Norway, EPFL in Switzerland, and TNO and ECN in the Netherlands.

All of these partners enjoy strong working relationships with our researchers, to the point that we even publish joint scientific articles and make patent applications together. For us at Liten, these partnerships provide valuable opportunities to raise our profile in a given field or acquire new knowledge crucial to our R&D.

Much of the R&D we carry out with partners is organized and funded in part through French National Research Agency and EU (FP7 and Horizon 2020) programs. Highly exploratory R&D is conducted under Institut Carnot Energies du Futur programs. Overall, new innovative research accounts for 20% to 25% of our budget.

JOINT VENTURES WITH MANUFACTURERS

We also run numerous applied research programs with major manufacturers like Renault and Zodiac Aerospace, and with innovative SMEs like Symbio FCell, McPhy Energy, Tronico, ECM, and CIAT. These alliances aim to make the technologies we develop more robust through instrumented experiments ranging from characterization during and after operation to modeling. We also provide technology auditing and consulting services. In short, our industrial R&D programs are designed to prime new technologies for industrial transfer.

DEVELOPING TOMORROW'S TECHNOLOGIES: 34 NEW INNOVATIVE RESEARCH PROJECTS IN 2013

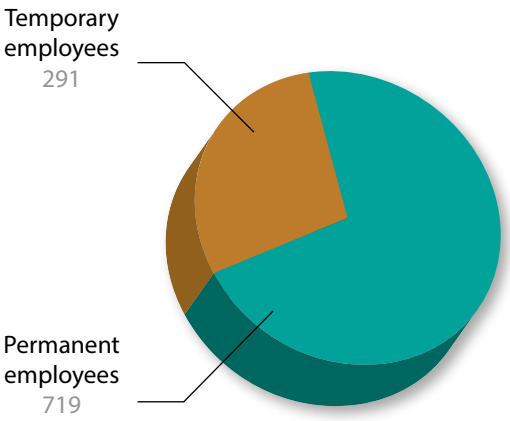
We and ten other Grenoble-based labs conduct early-stage R&D through Institut Carnot Énergies du Futur. In 2013 we spearheaded 34 innovative projects that received total funding of €6.8 million from the French National Research Agency (ANR). The 18–24-month projects focus on assessing breakthrough low-carbon-energy technologies – especially those related to producing solar energy – identifying new sources of biomass and converting them into energy, and storing energy as electricity, gas, or heat.

These programs also provide financial support for Ph.D. research as well as opportunities to validate new concepts on lab-scale demonstrators. Such programs are selected to align with the objectives of both Institut Carnot and Liten, with the longer-term goal of preparing new technologies for transfer to industry. The programs also result in the publication of academic articles and the filing of patents.

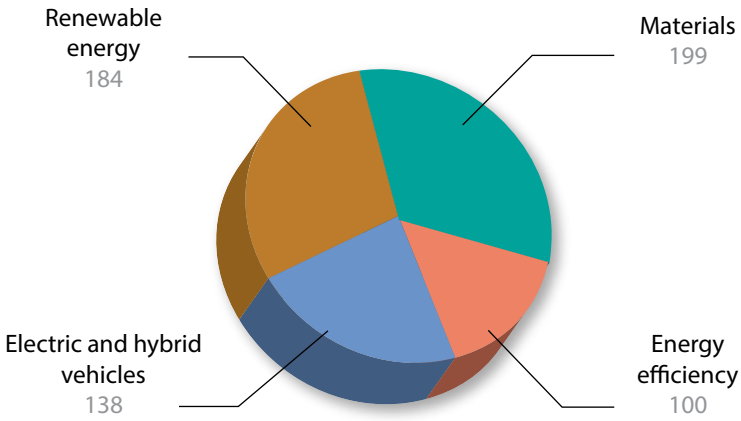
The financing provided by the ANR and Institut Carnot, in collaboration with joint research programs with Industry, serves as a platform to develop the technological innovations of tomorrow.

Key figures

Total staff

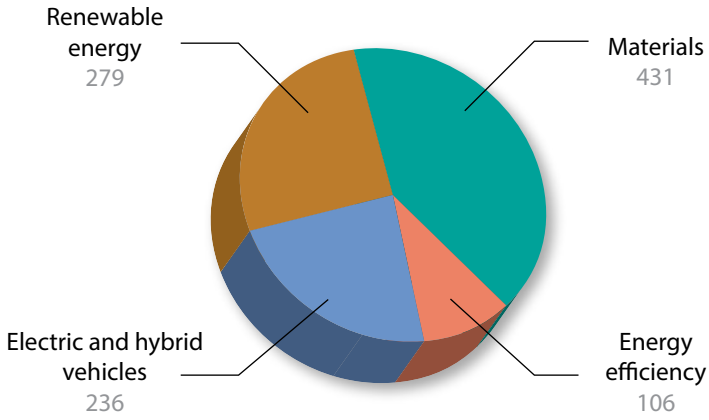


R&D staff by program



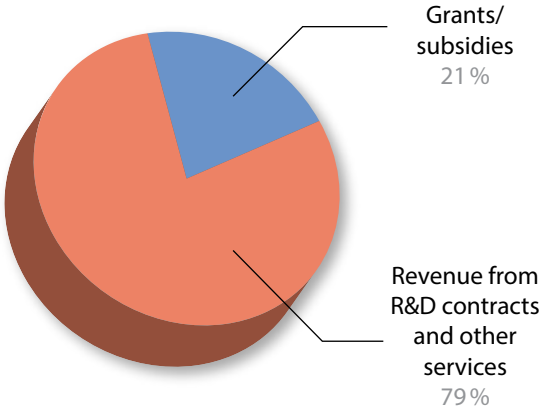
Breakdown of intellectual property

A total of 1,052 patents in portfolio as of end-2013



Budget

Operating budget: €170 million



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liten

WWW-LITEN.CEA.FR
CONTACT: INFO.LITEN@CEA.FR

Conception : PURE ARTMONY