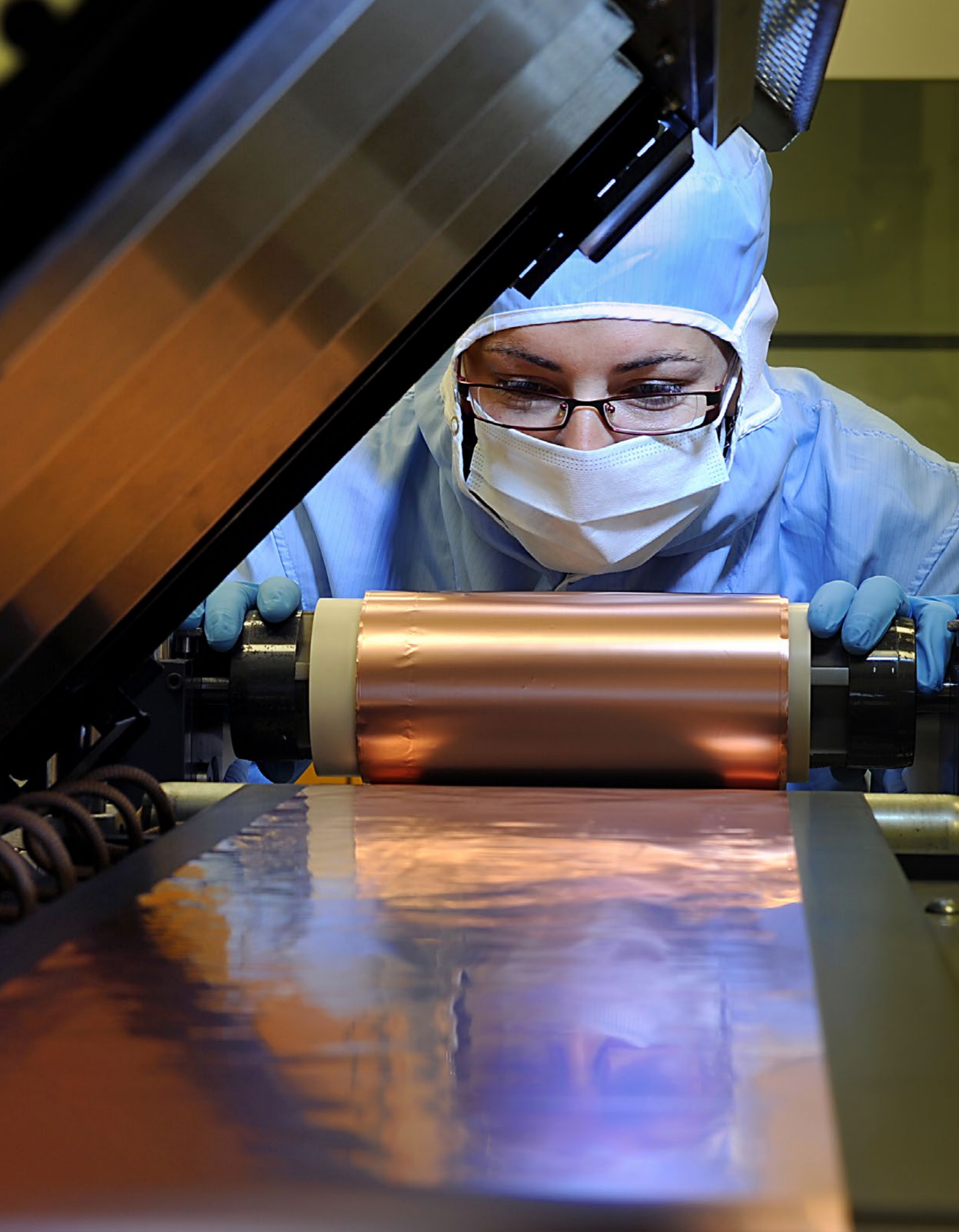
liten
cea tech

ACTIVITY REPORT 2019



FOREWORD

Florence Lambert,
Liten's CEO

Public awareness of environmental issues is growing. Europe is responding with far-reaching initiatives backed by climate roadmaps. The year 2019 was marked by the European Commission's Green Deal, which sets Europe on a path to carbon neutrality by 2050 and lays out the Union's vision of sustainable growth and a more just economy.

Against this backdrop of profound change, Liten is helping accelerate the energy transition, with technology development programs that are solidly anchored in the CEA's integrated approach to tomorrow's energy systems based on the use of multiple complementary low-carbon energy sources. The battery and solar photovoltaic industries are making a comeback, and new ones, like the flagship hydrogen industry, are emerging, creating new technological hurdles to overcome.

Renewable energy production, energy grid management, and energy storage are at the heart of Liten's research programs. And, because sustainable growth is now an imperative, the circular economy is a pillar of all Liten technology development projects.

This strategy made 2019 a record year for Liten, with research results we can be proud of, as you will see in the pages that follow.

In fact, our research results prove that Liten is right at home among the world's most innovative research organizations and demonstrate our capacity to create the kind of economic value that can make France and Europe more competitive in the global economy. /

SUMMARY

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LITEN: A MAJOR STAKEHOLDER

Liten (the Laboratory for Innovation in new Technology for Energy and Nanomaterials) is Europe's largest research institute entirely dedicated to the energy transition. Its main facilities are located in Grenoble and Chambéry, France. In just fifteen years, Liten, an institute of the French Alternative Energies and Atomic Energy Commission (CEA), has carved out a position as a leader in technology research for energy and the environment in support of economic growth. At Liten, our experience has led us to the conclusion that the energy transition can only succeed with the convergence of renewable energy, smart grids, and overall energy efficiency.

www.liten.cea.fr

A MORE FOCUSED RESEARCH STRATEGY ANNOUNCED IN 2019

Climate change is here, and the energy transition is gaining traction. Liten creates innovative solutions that respond to these major societal challenges. The institute sharpened its focus on renewable energy production and, in particular, solar photovoltaic energy. Liten also has programs on renewable energy storage, conversion, and use. In terms of renewable energy production, Liten is mainly addressing very-high-yield photovoltaic technologies and the integration of solar energy solutions into structures of all kinds, from roads and buildings to vehicles.

New ways of using electricity are emerging and intermittent, distributed renewable energy is making inroads into our grids, creating additional challenges. Grid management must be more responsive. This will require smart grid technologies that leverage multiple tools. Liten works closely with fellow CEA Tech institutes List and Leti to help develop the components and software that will be used to observe grids in real time. Sensors will capture data, which must then be processed to ensure supply-side and demand-side management strategies that optimize energy flows. Grid flexibility (and stability) will depend on a clever combination of centralized energy storage (stationary batteries or high-temperature electrolyzers to convert surplus electricity into hydrogen), distributed energy storage (electric vehicle batteries), and management (converters and EMSs). Additional flexibility could be obtained by coupling electricity grids with gas and heat networks. This is another topic that Liten is actively investigating.

Liten's goal for all of its technologies is to transfer them to companies that can bring them to the market on a large scale, creating a whole set of additional requirements. A technology has to work, of course. But it must also be priced realistically to succeed in the marketplace. And that is not all. Today, any new product has to be sustainable. This means building a number of factors (such as the availability of resources and lifecycle analysis from manufacturing to use to recycling) into the very earliest stages of the design process. More energy-efficient, non-toxic processes must be developed. Materials must be used more economically (such as through additive manufacturing). Last, but not least, all new technologies and their applications must be designed with societal acceptance in mind. /

IN THE ENERGY TRANSITION

HIGH-ADDED-VALUE CUSTOM R&D SERVICES FOR INDUSTRIAL COMPANIES

Innovation that drives business growth:

- Liten has built up **deep knowledge of many industries**, from transportation to energy and the environment, both in France and internationally.
- Our **integrated approach**, from component to system, positions us to focus on your area of interest while ensuring that the technology we develop for you fits seamlessly into the overall value chain.

Secure and leverage your R&D:

- Liten guarantees the **confidentiality** of your R&D projects
- **Exclusive licenses** to research results within the scope of the target product or application are possible.
- **Market research and benchmark survey** before starting R&D.

Save time:

- **Speed up technology development and scaleup** by getting immediate access to Liten's know-how and to a broad portfolio of patents so that you can overcome the technological hurdles to growth.
- **Transform ideas into actual innovations** by building proof-of-concept and functional prototypes.
- **Boost your technological capabilities rapidly** when Liten transfers know-how and tools to your organization.

Liten possesses thirteen technology platforms, a portfolio of more than 1,700 patents, and the knowledge of more than 1,000 scientists, technicians, and support staff.

KEY FIGURES

1,000 EMPLOYEES

ANNUAL OPERATING BUDGET: €160 MILLION

210 PATENTS AND 200 PUBLICATIONS IN 2019

MORE THAN 250 INDUSTRIAL R&D PARTNERS

LITEN: FOUNDING MEMBER OF INSTITUT CARNOT ÉNERGIES DU FUTUR

The Carnot seal, granted by the French Ministry of Higher Education, Research, and Innovation, encourages direct partnerships between research organizations and industrial companies. With a focus on new energy technology, Institut Carnot Energies du Futur is developing technologies at a variety of TRLs. It is made up of Liten and ten academic research labs. The diversity of resources the Carnot seal brings has benefited Liten for twelve years, helping the institute maintain a strong technological foundation and expand the pump-priming research that will ensure the levels of innovation and excellence required to remain a major stakeholder in tomorrow's energy systems. /

Learn more at www.energiesdufutur.fr

INES.2S, THE INSTITUTE FOR THE ENERGY TRANSITION

The Institute for the Energy Transition led by CEA-INES entered a new phase in 2019. It changed its name to INES.2S and shifted the scope and focus of its programs.

With technology research, development, and transfer capabilities that are unique in France, the INES.2S Institute for the Energy Transition has one mission: to make the development of solar energy a source of economic opportunity for France's industrial sector. It is this mission that earned INES the support of the French government (through national economic stimulus instruments). The institute's industrial R&D partners are committed to joint investments and multi-partner projects. To date, 2CA, CNR, Colas, and Renault are working side by side with and through INES.2S and will be joined by other companies engaged in France's photovoltaic ecosystem.
INES.2S has a sharp focus on the massive integration of solar photovoltaic energy at multiple scales: technological integration to address emerging applications, electrical and digital integration to support tomorrow's systems and grids, and economic integration to ensure that investments in solar energy are profitable.
INES.2S is fulfilling its commitments to the nation by creating competitive new industries in the burgeoning carbon-free energy sector. /

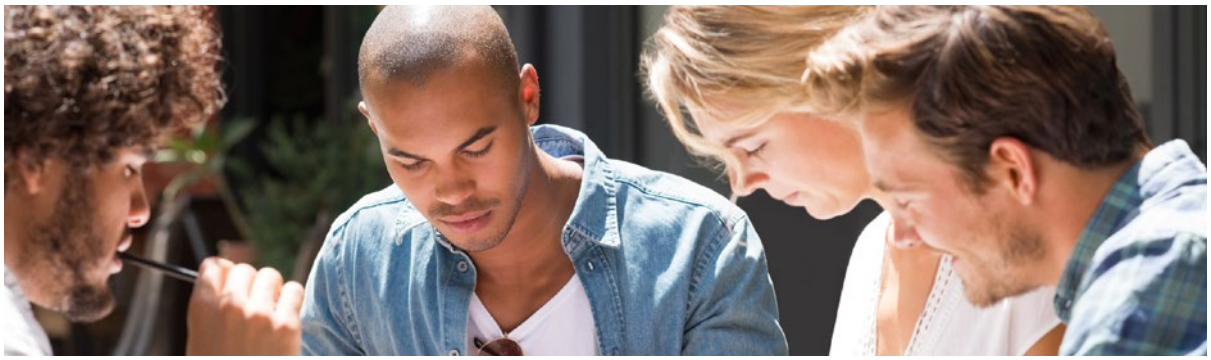
"The Institutes for the Energy Transition were created by the French government as part of its national economic stimulus package."

STARTUPS IN THE SPOTLIGHT

The CEA's startup programs play a vital role in transferring the technologies developed by CEA labs to the companies that will ultimately bring them to the market. Liten has set up processes to support its startups at all stages, from idea to business creation. Liten's support for its startups is delivered in cooperation with CEA startup experts. And, to continue to build on the growth of previous years, Liten spent 2019 developing new initiatives that will be introduced in 2020 to push the number of startups based on Liten technologies even higher! These include:

• Targeted awareness-raising campaigns to identify more potential projects across all Liten labs.

• More strategic support to speed up the development of the projects identified, and especially, support for setting up a business team and building relationships with financers.



Steadysun was founded in 2013 to develop and commercialize a production forecasting solution that adds value to solar energy by facilitating the integration of solar into our energy systems. Liten and Steadysun continue to work together on research that is adjacent to the company's current services. The year 2019 was marked by the development of electrical consumption forecasting software implemented under the Cordees project. /

Smart Energy Hub won a 2019 EARTO award in the "Expected Impact" category. EARTO awards recognize the year's best innovations. **Sylfen's** Smart Energy Hub is a hybrid CHP and energy storage system that can store surplus locally-generated electricity in the form of hydrogen to cover the majority of a building's energy needs. Sylfen designed the solution using rSOC, the CEA's reversible electrolyzer/solid-oxide fuel cell (SOFC) technology. /

PowerUp won the Cleantech Open France award in November 2019 and represented France at the Global Forum in Los Angeles. PowerUp CEO Josselin Priour went to LA to present the company's innovative solution, which leverages a smart battery charging system that can double battery lifespans. /

Sublimed obtained the CE marking for actiTENS® (a drug-free treatment for chronic pain) in 2018. The company brought home another win in January 2019, in the form of €3 million in fresh capital to speed up business development in France and on international markets. /

RENEWABLE ENERGY PRODUCTION

LITEN'S R&D CAPABILITIES COVER THE ENTIRE PHOTOVOLTAIC COMPONENT VALUE CHAIN. THE INSTITUTE LEVERAGES INDUSTRIAL-GRADE EQUIPMENT TO OBTAIN YIELDS OF 25% ON SILICON AND—ULTIMATELY—YIELDS OF 30% WITH TANDEM TECHNOLOGIES. LITEN IS DRIVING ADVANCES IN MORE THAN JUST COMPONENTS. THE INSTITUTE ALSO DEVELOPS INNOVATIVE SYSTEM ARCHITECTURES DESIGNED TO BRING CONVENTIONAL "ON-THE-GROUND" SOLAR POWER PLANTS TO GREATER LEVELS OF PRODUCTIVITY AND TO SUPPORT THE EXPANSION OF PV INTO BUILDINGS, INDUSTRIAL PARKS, VEHICLES, AND ALONG ROADS AND RAILWAYS.

HETEROJUNCTION PV GETS CLOSER TO INDUSTRIAL SCALEUP

Liten has been conducting intensive heterojunction (HET) PV R&D for fifteen years. The institute's work addresses materials, cells, and the assembly of cells into modules. The cumulative impact of innovations in these three areas has allowed Liten to set new yield records year after year.

The institute possesses extensive characterization resources and works closely with silicon suppliers to select the best materials according to crystal homogeneity, resistivity, carrier lifespan, and the nature and concentration of the oxygen present in the wafer.

In addition, constant innovation in cell fabrication processes has resulted in ongoing improvements to conversion yields. In late 2019 industrial-scale (244 cm^2) busbarless HET cells achieved a certified yield of 24.63%; HET cells with busbars achieved yields of 23.9%. The yields were made possible by optimizing the PECVD process used to obtain the amorphous silicon thin (nanometric) films, by improving the conductive transparent oxide layers, and by reducing damage to the wafers during handling by production robots.

From cell to module

The cells are interconnected, and then integrated into modules. While modules can be assembled from whole cells, half-cell assembly is currently more popular. Liten is also innovating bifacial modules that boost yields by capturing surface albedo. The institute's innovations in the materials (glass, backsheet, etc.) that make up the modules are helping improve yields and lengthen lifespans. In 2019 Liten built 348-watt busbarless half-cell (120 half-cells) and 412-watt, 6-busbar half-cell (144 half-cells) modules on M2 wafers. The gradual scaleup to larger wafers (M6) will further increase module productivity.

Tests in real-world environments were completed in Chambéry and Cadarache, France; additional tests in the Atacama Desert in Chile are underway. Liten researchers are pursuing their efforts to optimize scaleup of HET technology. Specifically, they are seeking manufacturing cost reductions, quality improvements, and productivity gains. The short-term target is a 25% cell conversion yield. /

EUPVSEC

Liten's Florence Lambert chaired EUPVSEC 2019 in Marseille, Europe's largest PV conference.

IN BRIEF

Enel Green Power recently cut the ribbon on Europe's first industrial-scale heterojunction PV panel production line in Catania, Italy. Liten worked on developing and scaling up the technology for fifteen years. /

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Liten is engaged in five of the ten H2020 projects on solar energy spotlighted by the European Union in its energy technology strategy: NextBase, DISC, AMPERE, PVSITES, and CPVMatch. These projects address cell fabrication, scaleup, and transfer of HET technology, BIPV, and CPV. /

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Thinning (by cutting or chemical processes) a CRYSTALMAX™ substrate and annealing it at 830°C substantially lowered the impact of the light-induced degradation (LID) that affects monolike silicon on a PERC-type cell architecture. /

1.3-TON G8 MONOLIKE SILICON INGOT CRYSTALLIZED

A 1.3-ton, G8-format monolike silicon ingot was produced using directed-solidification equipment developed in partnership with ECM Greentech. The monocrystalline fraction of the ingot obtained is similar to that of the G6 (650 kg) versions obtained.

The quality of the monolike material in the G8 format was also validated at each step in the value chain. It is compatible with diamond-wire cutting and the PV conversion yields are at least as good as (if not better than) those of the G6 ingots, and the light-induced degradation of PERC cells is low (maximum relative degradation of 2% to 3%). There is still room to improve the process: Ingot sizes could be increased to up to 1.5 tons and the number of defects, or dislocations, in the crystal structure could be reduced further. Ultimately, these optimizations could bring the material's performance in line with that of monocrystalline silicon. /

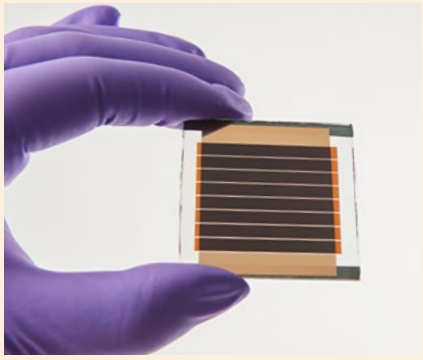
WAFERS' MECHANICAL RESISTANCE NOW UNDERSTOOD

To better understand the influence of thickness on the mechanical resistance of wafers used to make PV cells, slices of different thicknesses from 180 microns to 100 microns were cut from several grades of ingot (monolike, monocrystalline, and multicrystalline). The wafers obtained were tested for flex resistance along two axes. For a given material, thickness did not affect the mechanical resistance regardless of the direction tested. However, the tests did reveal that monocrystalline silicon is more resistant than monolike and polycrystalline silicon, both of which appear to suffer from the slicing process. The researchers will now investigate the other cutting-related mechanisms that affect wafers' mechanical resistance. /

PEROVSKITE CELLS OFFER POTENTIAL ALONE AND IN TANDEM TECHNOLOGIES

Perovskite-based photovoltaic technology offers some major competitive advantages. The materials and processes are low-cost, and the potential yields are high.

Liten, which has been developing perovskite photovoltaics since 2015, set a new record with an eight-cell (connected in series) module produced using both deposition and laser structuring techniques. The module obtained a yield of 20.3% for an active surface of 11.2 cm^2 with a geometric fill factor (GFF) of 93%. This result is among the best worldwide on this size of cell. Liten also optimized the process, making it possible to maintain 90% of the initial yield after 1,200 hours of constant exposure to light. This achievement is a major step toward scaling the technology up for manufacturing. /



TOWARD TANDEM MODULES

However, the next technological breakthrough could very well come from tandem architectures combining silicon and perovskite cells. Liten obtained yields of more than 22% on a silicon HET-perovskite tandem architecture with a 9 cm^2 active surface. In other research with NTU Singapore, the potential of HET technology for the lower cell of a four-terminal configuration was evaluated. The architecture's potential yield (the sum of the perovskite and the filtered HET yields) was determined to be greater than 25%.

In this configuration, the current produced by the tandem cells is determined by the limiting subcell (the cell producing the weakest current). To boost yields, the currents produced by the two subcells must be maximized and balanced by managing the flow of photons to limit optical losses due to reflection and parasite absorption. Optical simulations carried out on a standard n-i-p structure revealed high losses due to reflection that limited the current to 15 mA/cm^2. However, several strategies that could potentially push current beyond 19 mA/cm^2 for 30% efficiency were identified. /

PRODUCING MORE PV ENERGY WITH LESS SILICON

Industrial-sized (244 cm^2) heterojunction cells were thinned down to 40 µm (instead of the standard 150 µm) by mechanical or chemical abrasion with the goal of reducing the "gram of silicon per watt-peak" indicator.
Multiple batches of several hundred cells from 100 µm to 40 µm were produced. The conversion yields obtained were in excess of 22% in the 80 µm to 100 µm range, and nearly 20% for the 45 µm cells. The amount of silicon needed to produce 1 watt was less than 1 g, and was closer to 0.5 g for the thinnest cells. The average is 1.5 g to 2 g.
Very thin or ultrathin wafers could help lower the final cost of cells that contain 30% silicon and make it possible to produce lightweight, flexible modules. /

IN BRIEF

Japanese functional-materials manufacturer Toyobo kicked off a partnership with Liten to develop innovative organic photovoltaic cells and modules to be integrated into indoor and outdoor products for the construction industry. /

DIGITAL PROTOTYPING: ELECTRO-OPTICAL MODELING OF PV MODULES

When photovoltaic cells are assembled into modules, optical and/or electrical losses occur. A generic model of these losses can be used to create digital prototypes and rapidly identify the most promising architectures very early on in the development process.

The model developed considers each cell as an equivalent electrical circuit whose parameters are modified when the cell is assembled into a module. The effects of different types of glass, encapsulating materials, and backsheets; different types of interconnections (ribbon or shingle); and balance-related losses due to differences between cells, can all be modeled. The tool was used to explore the possibilities offered by flip-flop architectures, where every other cell is "flipped" to reduce the distance between cells and maximize the module's active surface. /

SOFTWARE TO PREDICT LOSSES IN SOLAR PHOTOVOLTAIC POWER PLANTS

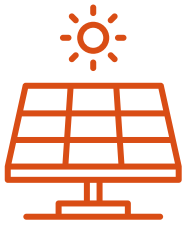
Liten is developing an algorithm to identify and measure the different types of losses in PV plants, from when sunlight hits the panels to when the electricity produced is injected into the grid. The algorithm uses measurements taken from around 20 instrumented plants. Software leveraging the algorithm is currently being tested on a selection of power plants with different configurations to confirm that it is robust.

The software will be used with the CEA monitoring database to generate loss diagrams and other indicators that can be used to get an accurate picture how efficiently a plant is operating. And, when compared over time, the loss diagrams can provide insights into degradation affecting a plant's equipment. This information rounds out natural equipment aging calculations. The software will be made available to plant operators. /

REAL-TIME MONITORING OF AROUND 60 PV PLANTS

France's energy market regulator chose Liten to monitor nearly 60 PV plants producing total of 338 MWp. The measurement data is collected and stored on secure servers. The data will be used to develop and test performance assessment and fault detection algorithms.

These algorithms will calculate performance indicators, estimate the impact of fouling on yields, and identify production losses. Additional indicators that provide more detailed information about energy losses within PV plants are also being developed to improve maintenance. /



338 MWc

MONITORING ON 60 PV PLANTS

PUTTING BIPV TO THE TEST WITH A DYNAMIC ADAPTIVE FAÇADE DEMONSTRATOR

Liten has developed a dynamic adaptive building façade demonstrator that can control the amount of sunlight let into a building while maximizing photovoltaic energy production. The system is based on a patented slat-like structure that uses PV modules that twist. Two-way motorization and bifacial heterojunction solar cells allow the system to let in a controlled amount of sunlight for optimal occupant comfort. The system is visually appealing and can be customized.

The modules are laminated just once during manufacturing, and dynamic mechanical testing revealed high fatigue resistance. The modules were integrated into a structure representative of a real-world use case and coupled with motors to open and close the slats, which proved to be mechanically stable even when used intensively. The mechanical stability of the system was demonstrated during intensive use tests. /

TEST BENCHES SPEED UP ROLLOUT OF BIPV

The impact of system configuration and weather on the operating temperatures of new building-integrated PV module concepts is being investigated in research conducted under the BESMART project. Comparative measurements are being gathered over a year-long period using the same testing protocol at INES and EPFL sites and at facilities in Norway and Cyprus.

Two types of bi-glass monocrystalline silicon PV modules with glass of different thicknesses will be tested. The test benches will be used to assess integrated and non-integrated performance at different angles according to standard IEC TS 63126, which is well-suited to this purpose. Weather data will also be gathered and the modules will be equipped with thermocouples. /

IN BRIEF

AVERAGE GAIN

4 KM/DAY

Rigid, curved glassless solar modules were designed and built for the body panels of a electric vehicle. Solar energy will give the vehicle an estimated four additional kilometers per day (more than ten in summer, but less than two in winter). /

14 > 25

ENERGY GRID MANAGEMENT

LITEN IS DESIGNING NEW HARDWARE AND SOFTWARE TO DELIVER REAL-TIME, MULTI-SCALE GRID MANAGEMENT CAPABILITIES AND INTEGRATE INTERMITTENT RENEWABLE ENERGY. AS INTERMITTENT RENEWABLE ENERGY INTEGRATION RATES INCREASE, GRIDS WILL NEED TO BECOME MORE FLEXIBLE. LITEN IS ALSO DEVELOPING HYDROGEN AND BATTERY-BASED ENERGY STORAGE SOLUTIONS THAT CAN PROVIDE THIS FLEXIBILITY. THESE TECHNOLOGIES ARE A NECESSARY STEP TOWARD THE CONVERGENCE OF ENERGY VECTORS AND APPLICATIONS IN AREAS LIKE CLEAN MOBILITY.

AN INTEGRATED VISION OF ENERGY IN A COMPLEX WORLD

Interview with Hélène Burlet, Deputy Director of Energy Programs, CEA

What exactly is an integrated vision of energy?

The energy transition is here, and the target of carbon neutrality by 2050 has been set. So, we thought about what France's energy landscape could look like in 2050, starting with what it looks like now. New ways of using and producing energy are emerging. Renewable energy is growing. But most of France's electricity currently comes from nuclear power plants. So, our future energy system will be a complex one in which all of these components interact with each other. We feel that a system-level approach is absolutely vital. You have to factor in all of the potential interactions between all of the components of our future energy system.

In France, our energy system in 2050 will necessarily combine nuclear and renewable energy.

What role can the CEA—and, especially, Liten—play in building France's energy future?

In France, our energy system in 2050 will necessarily combine nuclear and renewable energy. The CEA has all of the know-how required to address our energy challenges at system level and is ideally positioned to help build the nation's energy future. Our integrated vision of energy is shared by all CEA institutes. For the past year, nearly 1,200 people at the CEA have been working together to create new research programs that address tomorrow's energy systems from this holistic perspective.

And how has this integrated vision impacted programs at Liten?

Certain programs won't be affected significantly. I am referring to basic renewable energy technology bricks. However, as new problems arise, new programs will be created to address them and to ensure that the solutions being developed are not counterproductive. One example is how we are looking at different sources of electricity to power the electrolyzers that will produce hydrogen on an industrial scale. If hydrogen production is too electricity-intensive, it will only put more pressure on the grid. And if the grid has to turn to thermal power plants to meet demand, it would risk increasing greenhouse gas emissions. So, we would want to investigate how a source of renewable energy production would have to be dimensioned to meet this kind of need. And that is just one of many examples. /

DIMENSIONING SOFTWARE FOR PV-DIESEL-STORAGE SYSTEMS

Liten developed a dimensioning and simulation software tool called Diesol for hybrid energy systems combining PV, diesel generators, and energy storage. The software was transferred to France-based Cap Vert Énergie, which builds and operates these kinds of hybrid systems. The software can provide three simulations: dimensioning and control strategies, dynamic behavior (to confirm that the future system will be stable and provide quality electricity), and cost and ROI projections over the lifespan of the system—generally 20 years to 30 years.
Diesol is much more customizable and configurable than commercially-available software. It will be used by Cap Vert Énergie engineers and could potentially be expanded (with the integration of new models) to cover other kinds of energy production. /

ELECTRIC VEHICLES: PROGRESS TOWARD A SINGLE-STAGE POWER CONVERTER

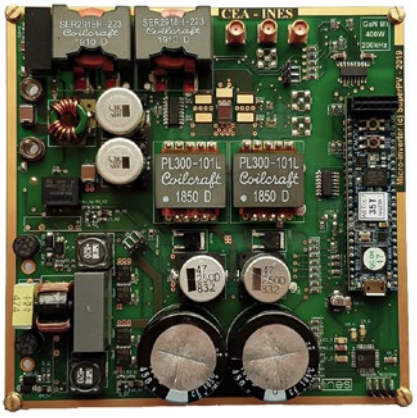
A 3 kW power converter for electric vehicles was developed in conjunction with Leti and tested in the lab at one-third of its total power. Conventional power converters have two or three stages. This single-phase, single-stage converter effectively combines power and yield (95% currently) to meet automotive requirements.
Simplifying the hardware in this way resulted in a more complex command architecture. Simulators were used to optimize the architecture to obtain the best possible yields in all operating configurations.

This converter could be used either for EV charging or for vehicle-to-grid applications. Five patents have been filed to protect the innovation. /

3 kW
SINGLE-PHASE CONVERTER'S POWER

GaN BOOSTS THE PERFORMANCE OF MICRO-INVERTERS FOR SOLAR ENERGY

A 400 W micro-inverter for photovoltaic modules was developed for the European SuperPV project. The micro-inverter, built on GaN transistors, stands out for its power density (0.85 kW/liter) and 200 kHz operating frequency. And there is still room for improvements that could further increase overall yield, currently at 95.5%.
The current-switching topology used helped keep the micro-inverter very compact, a factor that is particularly important given that it will be used on bifacial modules. Switching losses were limited by an original active clamp architecture that was designed especially for this project and patented. The micro-inverters developed optimize each module individually. This is especially beneficial due to the fact that a chain of panels connected in series can be negatively impacted if a single panel fails. /



EnRSim, CALCULATOR FOR MULTI-RENEWABLE-ENERGY PRODUCTION FOR HEAT NETWORKS

The first functional version of the EnRSim software suite was delivered to French energy agency ADEME. The software is designed to facilitate the integration of renewable energy into heat networks. EnRSim calculates energy mixes and dimensions multi-renewable-energy production equipment that includes biomass, solar thermal, heat pumps, and thermal energy storage.

EnRSim leverages models of the target plant to evaluate the heat network's energy loads and solar energy resources. It can also generate environmental impact, energy, and economic assessments. All of the software's features are accessed from a single user-friendly interface. It will be made available free of charge to engineering firms and government agencies on the INES website. /

THERMAL MANAGEMENT: "FAKE" CELLS HELP OPTIMIZE SYSTEMS

Liten developed and patented fake cells to test cell cooling systems without the risk of thermal runaway. The fake cells, which can withstand temperatures up to 150 °C, have the same thermal conductivity as the real ones being tested, but without real cells' chemical activity. They have been used in two contract research projects for industrial companies.
The first project addressed a carbon-fiber battery back with oil-cooled cells. It was characterized on a test bench designed and operated at Liten. The fake cells were used to validation-test the cooling system's thermal-hydraulic performance before testing it on real cells.
The second project focused on the thermal management of an innovative pack of battery modules to limit the amount of energy used to maintain optimal operating temperature. Two configurations (one combining rock wool and a polymer thermal barrier, and the other with vacuum insulating panels and a thermal barrier made from cork) were characterized in different operating modes and analyzed, once again on the fake cells.
Liten also broadened its thermal management research to space applications through various other projects that led to innovations for heat pipes and for a mechanically-pumped diphasic loop evaporator for the cooling of electronic components. /

THERMAL ENERGY STORAGE: A FIRST OPERATIONAL EQUIPMENT ON AN URBAN HEAT NETWORK

A phase-change-material energy storage unit designed by Liten was implemented in March 2019 in an urban eco-neighborhood with 450 housing units under construction in Grenoble, France.

The storage unit, connected to the city's urban heat network, was dimensioned to offset peaks in demand for domestic hot water in the morning and evening. The unit has a capacity of 180 kWh, with storage/destorage capacity of 60 kW. The design is based on a shell-and-tube heat exchanger; a fatty alcohol is used as a phase-change material.

The unit was implemented under the European Cityzen project and is the first ever of its kind in France. It has outperformed the dimensioning objectives initially set. Thermal storage has proven to be very flexible, with 80 kW peak power for 1.5 hours during charging and stable operation even with fluctuating and higher-than-expected incoming water temperatures. The unit's instruments provide continuous monitoring data for R&D purposes. /

RECOVERING WASTE HEAT FROM INDUSTRIAL PROCESSES

In other thermal energy storage news, Liten dimensioned, had built, and commissioned a 400 kWh sensible energy storage system with a dual-material (quartzite gravel and inorganic salt) thermocline to a secondary aluminum production plant. The system is designed to recover waste heat from the plant's smelter reactors, which operate for four six-hour cycles per day, and to reuse the heat continuously in the process. The temperature of the heat recovered ranges between 400 °C and 800 °C. The investment will pay for itself in four years. This development was made under EU H2020 project Smartrec. /

400 TO 800 °C

HEAT RECOVERED TEMPERATURE

METAL-ORGANIC FRAMEWORKS PROVIDE A NEW AND MORE EFFECTIVE WAY TO REUSE COBALT

A family of organic molecules that allow cobalt to react selectively was identified. When a nickel-manganese-cobalt solution comes into contact with the organic ligand, a hybrid material (metal-organic framework or MOF) whose inorganic portion is mainly made up of cobalt is formed. The other elements (nickel and manganese) do not react and are filtered out. The MOF formed in this way can be used directly to synthesize lithium lamellar oxides for Li-ion batteries.
The effectiveness of the process was demonstrated using models, and was then tested on a solution prepared from spent batteries. The MOF obtained using the ligand is in the form of a powder, which, after washing, contains 95% cobalt. /

THE QUEST FOR SOLVENT-FREE Li-ION BATTERY ELECTRODES IS ON

Manufacturing Li-ion battery electrodes by extrusion rather than by slurry-casting would have two advantages. First, it would reduce the amount of solvent used in the process fourfold. Second, it would lower costs by limiting the drying required to remove the solvent. And Liten has obtained some encouraging results. Functional nickel-manganese-cobalt electrodes were made by extrusion with a solvent content of just 10%. The material was successfully blended and fed into the extruder despite the low solvent content. SEM observation showed that the NMC particles are well dispersed but not damaged.
The researchers are now looking at several possible improvements, including increasing the amount of active material and eliminating the solvent altogether without negatively impacting the porosity of the electrode. In 2020 the lab will add two extruders to the two it already has. /

IN BRIEF

A cell selection and battery pack dimensioning tool leveraging the ESTOR database was developed. For a given application, the tool recommends a selection of cells depending on their specific energy, specific power, and mass. /

THERMAL RUNAWAY: PREVENTION IS THE BEST WAY TO KEEP BATTERIES SAFE

Liten developed two systems to detect the warning signs of thermal runaway in Li-ion battery cells. The first is a strain-gauge-based system that measures deformation; the second is an acoustic probe, well-known in the field of non-destructive testing.

The two techniques effectively monitor a battery's "respiration" during cycling. Battery materials expand slightly during this process. If there is a problem, abnormal expansion of a cell can be detected anywhere from a few minutes to a few hours before the battery begins to pose a safety hazard.

The systems were developed and successfully tested on different battery types and formats. Ultimately, they could outfit batteries of a reasonable size (1 kWh, for example) or be used to ensure the safety of batteries used to power critical systems. /

UNDERSTANDING THE DEGRADATION MECHANISMS THAT AFFECT LITHIUM-ION BATTERIES

Liten is running a number of research projects to better understand the mechanisms that lead to the degradation of the negative electrode in lithium-ion batteries. SEI (solid electrolyte interphase layer) formation at the negative electrode is another area that is being investigated intensively. Here, a methodology that leverages the two stable lithium isotopes was developed. The isotopes are inserted at key locations in the electrochemical system and the respective dynamics of the ^{6}Li and ^{7}Li are observed using ToF-SIMS and NMR. Another in operando method for the characterization of the lithium in the electrochemical cells was also developed. NMR observation of the ^{7}Li is used to detect the formation of metal lithium at the negative electrode. Together, these and other research projects, plus the use of multi-physics, multi-scale models, will lead to improvements in the nature and composition of battery electrolytes, electrode designs, and fast-charging management by the BMS, all of which will lengthen battery lifespans. /

A LOOK DEEP INSIDE BATTERY ELECTRODE MICROSTRUCTURES

Studying battery electrodes' microstructures is an effective way to better understand (and thus model and control) the degradation mechanisms that affect the electrodes. Liten has designed and tested a comprehensive characterization chain to observe these microstructures. Ion-beam characterization is used in conjunction with FIB-SEM imaging. Special pre- and post-observation processing steps have also been implemented.

The characterization chain can measure, at a scale in the tens of microns, three parameters crucial to transport properties: electrode porosity, surface area, and tortuosity (an indicator of how resistant the electrode is to the transport of mass and charge). The measurements confirmed those taken during lab experiments, providing insights that will also fuel improvements to electrode models. This early-stage research demonstrates the potential of advanced treatment of microstructural images. /

THE ART OF ASSEMBLING BATTERIES FOR SPACE APPLICATIONS

An innovative process for assembling batteries used in space applications was developed and transferred to an industrial partner. The process, designed for 1.5 kWh modules for satellite constellations, was also used for communications satellites (up to 3.5 kWh) and rocket batteries.

The goal was to lower module manufacturing costs while continuing to meet the stringent requirements of these applications. Liten modified two proven techniques from the automotive battery industry: automated cell bonding (76 cells to 240 cells per battery) and laser welding of the electrical connections. These process steps are compatible with high-throughput manufacturing and offer excellent repeatability. They also boost reliability, which is a crucial factor for some satellites, which circle the Earth every two hours (the duration of a cycle) for six or seven years.

The batteries assembled using the process passed space qualification tests. They were used to power six micro satellite demonstrators launched in February 2019 and 34 more launched in early 2020. Liten has filed two patents to protect these assembly processes. /

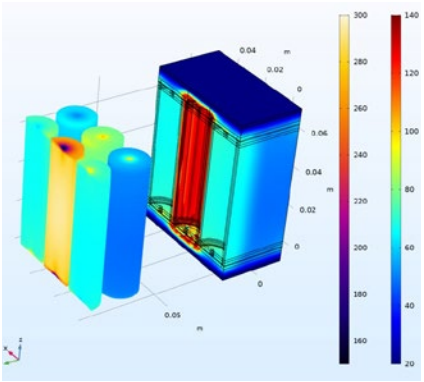
AN ELECTRIC VEHICLE BATTERY THAT PACKS IN THE INNOVATIONS

An innovative Li-ion battery pack for electric vehicle drivetrains was designed, prototyped, and validation tested. The battery is cooled directly by a dielectric oil that circulates between the cells; a unique internal coating serves as a seal while allowing gas to escape in the event of thermal runaway.

In terms of safety, each cell is protected against overvoltages and has a valve to let gas escape, preventing explosion. The battery pack, built using commercially-available cells, has other unique features like a lightweight, rigid carbon fiber housing that is both pressure resistant and non-inflammable.

Finally, the electronics, which have their own tiny converters, supply the 12 volts needed for auxiliary vehicle systems like brakes, steering, and lights. Seven patents have been filed to protect the innovation. /

THERMAL RUNAWAY PROPAGATION MODEL ADDRESSES BATTERIES AT THE SCALE OF A MODULE



The analysis of thermal runaway in lithium-ion batteries will be essential to the batteries' widespread use in transportation and energy-storage applications. Liten had previously developed a multi-physics model of thermal runaway in cylindrical cells. More recently, the institute added a new model that addresses the scale of a module. This first-ever model describes how thermal runaway propagates from one cell to the others. The tool leverages several models at different scales and will be improved with more predictive capabilities in the future. Ultimately, it will help reduce the number of experiments that must be completed to design and validate new architectures. A beta version of the software is available for design engineers who would like to test it. /

H2LAB, FRANCE'S HYDROGEN EQUIPMENT TESTING RESOURCE

H2Lab is a public-private partnership funded by Bpifrance (France's government investment bank) to offer its members a single access point for all of the most relevant testing capabilities backed by the most advanced know-how available from CEA and CNRS (France's national center for scientific research) labs.

To date, around 60 pieces of equipment on four sites have been made available through H2Lab. Initially, the goal is to respond to manufacturers' performance and endurance testing needs for their electrolysis (mainly high-temperature), embedded PEMFC, and pressurized hydrogen tank solutions. /

SMART OPERATIONAL MANAGEMENT SYSTEM FOR JUPITER 1000

A smart operational management system was developed for the Jupiter 1000 power-to-gas demonstrator plant. The system optimizes operations depending on gas and electricity prices. The Pommier Vx software implemented by CNR (the utility operating the plant) schedules tasks (drawing down electricity, determining how much hydrogen and syngas to inject, etc.) depending on predictable economic factors (spot electricity price forecasts and production forecasts for CNR's wind farm at Fos-sur-Mer) and equipment status data up to 36 hours in advance, sending information at 30 minute intervals.

Liten's Callisto software takes the task scheduling data from Pommier Vx and translates it into operating instructions sent more frequently (around every five minutes) to the different components of the system (electrolyzer, methanation reactor) depending on their actual status and based on non-linear models that allow for more granular simulations of the system. /

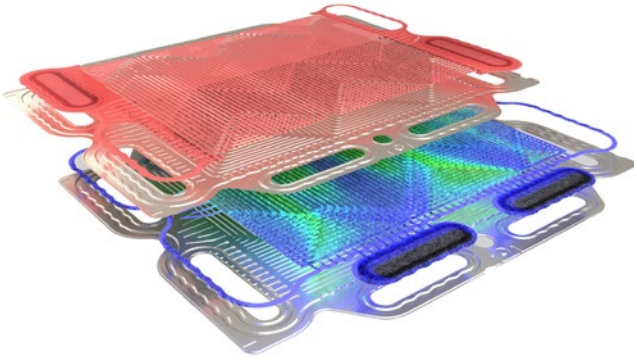
HYDROGEN EMBRITTLEMENT, A VALUABLE AREA OF EXPERTISE

ArianeGroup collaborated with Liten and LaSIE* to test the influence of additive manufacturing on launcher engine parts made from superalloy Inconel 718. Specifically, ArianeGroup was interested in sensitivity to hydrogen embrittlement and oligocyclic fatigue. SEM and TEM images provided a detailed analysis of the material's microstructure and grain size and distribution. The alloy's bi-modal grain size and distribution is the only major difference with regard to the forged material.

A number of tests were then completed to gain an understanding of how hydrogen interacts with the metal. Gas permeation and thermal desorption spectroscopy were used to examine the different ways in which the hydrogen is trapped in the material. The material's lifespan under oligocyclic fatigue is shortened due to the increase in plastic activity due to hydrogen interactions and dislocations that modify the embrittlement mechanisms at work. Liten is also investigating other scenarios, such as the influence of hydrogen content on utility GRTgaz's natural gas pipes. /

* A La Rochelle University-CNRS environmental engineering lab

PEMFCs: A STEP CLOSER VERY-HIGH-RESOLUTION SIMULATION



Currently, PEMFCs are 3D simulated using models whose geometrical representations have been simplified so that they can be executed. However, this simplification comes at the price of approximate results and numerous uncertainties. Liten has developed a standard-setting multi-scale 3D simulator called Trust_FC that overcomes these limitations. Built on the CEA's TRUST thermohydraulics code, Trust_FC is compatible with HPC and available on an open-source basis. It will be used to perform complete simulations from CAD data and to validate the simplified representations incorporated into other, less resource-intensive models.

The basic modules are already operational. They cover fluid flows, cooling circuits, heat diffusion in the bipolar plates and channels, and transport phenomena in the fuel-cell core. Trust_FC models could potentially process more than a billion data points and more than ten variables for each data point. /

IN BRIEF

The first Smarthyes high-temperature reversible electrolyzer demonstrator developed by Liten and Sylfen operated for 2,000 hours at an Engie site. It boasts a reversible high-temperature electrolyzer developed by Liten coupled with batteries, a hydrogen compression and storage system, and solar PV panels. Engie Lab Crigen presented the development at the Solid Oxide Fuel Cells 16 conference in Kyoto in September, 2019. /

2,000
OPERATING HOURS

PEMFC PING-PONG ARCHITECTURE BRINGS BENEFITS

A recent PhD research project investigated an innovative PEMFC anode circuit architecture. Two hydrogen valves are switched in a synchronized manner to deliver an alternating supply, giving the "ping pong" architecture its name. This new architecture ensures better fluid management at the anode than conventional architectures without adding complexity to the associated fluid circuit.

Tests carried out on a 5 kW stack demonstrated yields far higher than dead-end anode architectures and similar to anode recirculation architectures. The overall cost of the circuit is half that of conventional architectures, however. Aging is also more homogeneous, both inside the cells and from one cell to another.

A second PhD research project on Liten's patented ping-pong architecture is underway. /

KNOW-HOW TRANSFERRED TO FAURECIA FOR THE DEVELOPMENT OF A 100 KW FUEL CELL

The CEA transferred PEMFC stack design and manufacturing know-how to Faurecia, which recently transferred its fuel-cell business line to Symbio*. The associated R&D project led to the development of a new stack technology for automotive and, more generally, transportation applications.

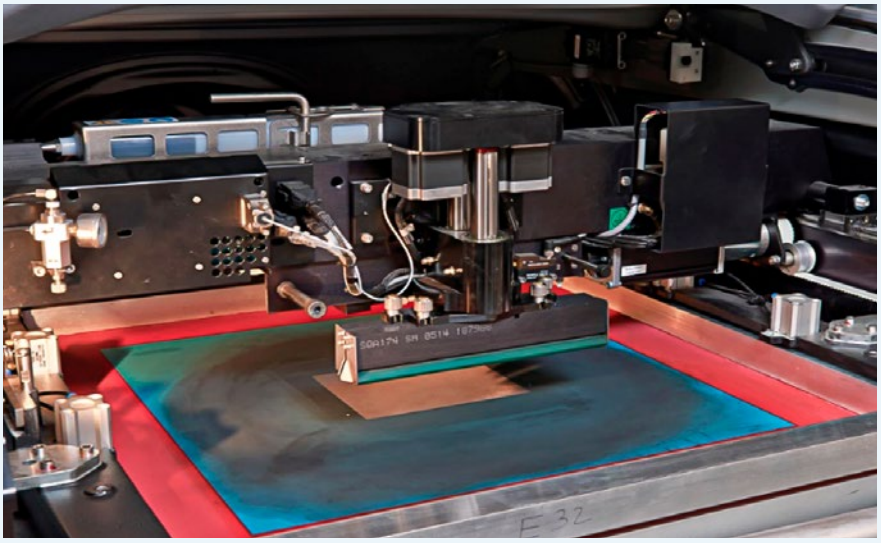
Several testing and validation steps were completed, and a stack of more than 85 kW containing several hundred cells was built and used to demonstrate the performance of this technology, which is at the European state of the art. Improvements to the fluidics and bipolar plates and carefully-selected components boosted the stack's surface and volume power densities and allowed for simpler manufacturing processes. /

*Symbio is jointly owned by Michelin and Faurecia

FIRST-EVER 1 KW STACK MADE FROM PRINTED COMPONENTS

A first-ever proof of concept of a 1 kW PEMFC stack made from printed components was completed. The conventional stamped-metal bipolar plates are bumping up against pattern size limitations. Liten decided to experiment with more flexible printing techniques as a potential solution to this problem.

A 1 kW stack was made from around 20 cells whose patterns were screen-printed using a carbon-based ink. The power density obtained was similar to what is observed with metal bipolar plates. As pattern sizes decrease, power densities will increase, which means that Liten's patented printing technologies will open the door to some very substantial improvements. /



FIRST-EVER SOC STACK PRODUCED ON LITEN'S PILOT LINE

A pilot SOC (solid-oxide cell) manufacturing line was created at Liten in 2019. The goal is now to ramp up the line's production capacity from one stack per month to one to two stacks per week. The line has all of the equipment required to produce the stack components in one place. It is organized by process to give an idea of what tomorrow's industrial-scale lines could look like.

The new equipment was delivered to Liten, connected, and validation tested, and a first stack was assembled from components produced on the line, packaged, and tested. The stack's performance was in line with expectations. /

SOLID-OXIDE FUEL CELL TO EQUIP CRUISE SHIP

In 2022 a solid-oxide fuel cell will equip a liquid-natural-gas-powered cruise ship built by Chantiers de l'Atlantique—a world first. The 50 kW fuel cell demonstrator, designed by Liten in research conducted with partners under the PACBOAT project (financed by French energy agency ADEME), will be Liten's SOFC/SOEC research team first fuel-cell-only system.

The technology offers several advantages for marine applications. First, it operates at high temperatures (700 °C to 800 °C), which means that the fuel (methane or natural gas) can be reformed internally. This makes the process simpler than that of competing fuel cells. Second, it can run off of different fuels (methane, methanol, ammonia, hydrogen, and others) without any major modifications. This flexibility means that it could run off of green fuels when they become available. Plus, it delivers higher electrical yields than conventional internal combustion engines (with a PACBOAT project target yield of 60%) and can also produce heat that can be used in the cruise ship's different systems. /

IMPROVING ELECTRODE PERFORMANCE IN SOLID-OXIDE FUEL CELLS

The microstructure of a LSCF-CGO*O_2 electrode for solid-oxide fuel cells was optimized by combining numerical simulation and lab testing. The improved electrode's state-of-the-art performance extends to its durability, which is particularly important given that SOFC electrodes are subjected to temperatures in excess of 700 °C and must withstand strong polarizations.

Liten leveraged models of the electrochemical processes at work in order to numerically optimize the material's microstructure. Specifically, Liten improved the electrode's composition, porosity, and solid particle size distribution. Further improvements to the electrode's durability are currently being investigated. /

* Lanthanum strontium cobalt ferrite-gadolinium-doped cerium oxide

REDUCING THE OVERALL ENERGY FOOTPRINT

IF THE ENERGY TRANSITION IS TO SUCCEED, THE ENERGY FOOTPRINT LEFT BY PRODUCTS AND PROCESSES OF ALL KINDS WILL HAVE TO BE REDUCED. AND THIS MEANS FACTORING IN A NEW SET OF IMPERATIVES. MATERIALS IS ONE OF THESE IMPERATIVES. LITEN IS DEVELOPING NEW TECHNOLOGIES LIKE ADDITIVE MANUFACTURING AND STRUCTURAL ELECTRONICS THAT MAKE MORE ECONOMICAL USE OF MATERIALS. LITEN IS ALSO INVESTIGATING SUBSTITUTES FOR CRITICAL MATERIALS AND APPROACHES TO RECYCLING AND ECO-INNOVATION RELEVANT TO THE INSTITUTE'S FLAGSHIP INDUSTRIES. FINALLY, LITEN IS LEADING THE WAY IN THE THERMOCHEMICAL CONVERSION OF CARBON-CONTAINING BIORESOURCES.

BRINGING INNOVATION AND ECO-DESIGN INTO NEW ENERGY TECHNOLOGIES

The Eco Innov'NTE project, financed by the Carnot Institute for the Energy of the Future (Institut Carnot Energies du Futur), is focusing on an eco-innovation methodology with the capacity to boost the environmental performance of new energy technology development projects from the earliest project phases.

Liten, for example, has implemented an original approach to lifecycle analysis that is integrated into the innovation process. The objective is to ensure that the latest environmental requirements are factored in from a project's inception.

And, to facilitate the use of ecodesign approaches, Liten has set up a network of resource people covering a range of research topics and with analysis tools to support eco-innovation in new energy technologies. Employee awareness-raising campaigns and training programs have also been set up. The multi-partner work carried out through this Carnot program has brought new approaches that fully integrate circular economy methods and technologies into Liten labs working on new materials and processes. /

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Liten structures his eco-innovation approach upstream of his projects, thanks to a network of internal referents.

A MORE PROFITABLE Li-ION BATTERY RECYCLING PROCESS

As part of an R&D project conducted with Orano, Liten developed a hydrometallurgical recycling technique for lithium-ion batteries. The process developed is more profitable than conventional recycling methods. Extracting the manganese in the batteries is a major economic hurdle to profitable Li-ion battery recycling. Liten's new process simultaneously dissolves the metals (Ni, Mn, and Co for NMC chemistries) in the positive electrode and separates the manganese in the form of an oxide. This reduces the number of process steps and the quantities of reagents required. The new process was implemented in a 5-liter reactor, where it obtained high yields in line with projections (96% to 100%).

Liten is now working on new breakthroughs, including a method for ensuring the safety of Li-ion batteries before recycling—a prerequisite to any hydrometallurgical recycling process. /

%

Yield obtained:

from 96%

to 100%

A PROCESS FOR RECYCLING SMALL VOLUMES OF ENGINEERED PLASTICS

A new process for recycling small volumes of high-added-value plastics was recently investigated under the EU Display project. The kinds of materials studied in the research would undergo mechanical reprocessing and reconditioning before being reused in additive manufacturing processes.

The feasibility of the process (grinding, addition of functionalizing fillers and other additives like nanoparticles, and extrusion in tube form) was tested in the lab on polylactic acid (PLA). The compatibility of the plastic tubes produced with 3D printers was also tested. The mechanical properties of the parts 3D printed using the recycled material were virtually identical to those of parts made using non-recycled material. /

IN BRIEF

Liten's optimized Li-ion battery recycling method won first prize in the Federec "Trophées d'Innovation Recyclage" 2019 in the academic research category. /

TROPHÉES INNOVATION RECYCLAGE

STRIP CASTING STRATEGIC PERMANENT MAGNETS SAVES CRITICAL MATERIALS

Liten's NdFeB permanent magnet development work, which aims to reduce the use of rare-earth minerals, is supported by an end-to-end pilot line covering the entire production chain, from strip-casting the alloy to powder metallurgical forming processes. The Poudr'Innov platform is home to proven strip casting capabilities. It is the strip casting process that determines the final magnet's composition and microstructure and, as a result, its performance.

Liten can run tests on 15 kg to 20 kg strip casting runs for companies interested in developing new compositions with lower rare-earth mineral content or in implementing short-loop recycling processes for their spent products. /

15 TO 20 KG

WEIGHT OF THE RUNS STUDIED

MAGNETS INJECTED INTO A 150 KW MOTOR ROTOR

A 150 kW electric-vehicle motor was developed in research conducted under the EU ModulEd project. Liten helped develop a rotor with injected magnets to replace the conventional sintered NdFeB magnets. Injected magnets offer the advantage of being free from heavy rare-earth minerals like dysprosium, terbium, and other critical materials; they can also be produced in a wider variety of shapes than conventional magnets. Once the magnets' geometry had been fine-tuned for optimal mechanical and magnetic performance, Liten researchers designed an injection module specific to the process. The module can produce and magnetize all 66 of the rotor's magnets in a single process step. The motor with the injected magnets performed similarly on the test bench to an equivalent motor with sintered magnets. /

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IN BRIEF

Liten is coordinating the UPGRADE project, which is financed by the Raw Materials EIT, a consortium of Europe's major magnet-industry stakeholders. The purpose of the project is to improve the microstructural quality of NdFeB alloys. The alloys' critical material content (Tb, Dy) could be reduced, leading to the production of high-performance NdFeB magnets with less critical material. /

IN BRIEF

A new health, safety, and environment (HSE) program for additive manufacturing was introduced in conjunction with several partner companies. The program resulted in improvements to protocols and best practices for using additive manufacturing machines. /

> *CEA at major European trade shows 3DPrint and Formnext*

ADDITIVE MANUFACTURING FOR THE ENERGY INDUSTRY

The FAMERGIE platform, established in conjunction with AddUp, a company specializing in metal 3D printing solutions for industry, and financed in part by the Auvergne-Rhône-Alpes regional government, will speed up the adoption of metal-based 3D printing processes by energy component manufacturers. FAMERGIE will help manufacturers achieve technological breakthroughs (new designs, new levels of performance, lower mass) through metal 3D printing.
Liten and AddUp recently developed a laser fusion process applied to a 304L stainless steel alloy. Traditionally, conventional casting and machining processes are used on 304L stainless. Liten and AddUp made improvements to an industrial-grade printer's operating parameters to 3D print parts (methanation exchangers) with satisfactory static mechanical resistance in service and adequate surface quality coming out of the printer. /

FINGERPRINT SENSOR PROTOTYPE MADE USING PRINTED ELECTRONICS

A low-cost, flexible "four-finger" fingerprint sensor demonstrator was made in research and development conducted under the EU PYCSEL project. The demonstrator, built with organic electronic components, combines an innovative active heat sensor made from PVDF (a temperature-sensitive pyroelectric material) and a 64 cm^2 array of IGZO thin film transistors. With a resolution of 500 dpi, the demonstrator is effective at recognizing fingerprints. When a finger touches the sensor, the ridges in contact with the pixels absorb heat, creating a difference in temperature with the furrows, which are not in contact with the sensor.

PYCSEL won the OE-A (Organic and Printed Electronics Association) Best Demonstrator award at the annual European flexible electronics conference, LOPEC. /

500 DPI

DEMONSTRATOR RESOLUTION

IN BRIEF

Startup S2ED set up and tested a screen printing line at the PICTIC platform to prepare to launch a plastronics (plastic parts with integrated electronics) production line at its Bordeaux, France plant. The pilot line at PICTIC is being used to produce samples for S2ED's customers. /

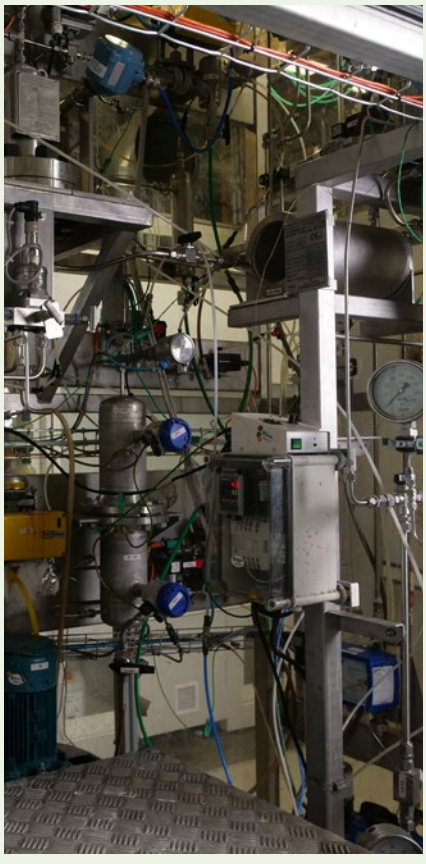
TORREFACTION BIOCOAL* FOR INNOVATIVE METALLURGICAL APPLICATIONS

In non-ferrous metallurgy, cokefied coal is used both as an energy source and as a reductive agent in the chemical reaction of the metallurgical process. Replacing this coal with torrefied carbon-containing material is one alternative that could reduce the industry's carbon footprint. The EU CIRMET project is exploring just such a technology.
Liten is running tests on the Génépi platform's Centorré furnace to determine the ideal torrefaction temperature and duration for oak and poplar. The fixed carbon content of biocoal obtained from torrefaction at 350 °C met the specifications for the project. The compatibility of this biocoal with the manufacture of zinc from zinc oxide waste is currently being assessed. /

* Biocoal is to torrefaction what biochar is to pyrolysis or carbonization.

HYDROTHERMAL GASIFICATION OF METHANIZATION CODIGESTATE

The CO-METHA project, run in partnership with Vinci Environnement, is exploring ways to convert the residual organic fraction of household waste and wastewater treatment sludge from plants operated respectively by SYCTOM and SIAAP into fuel. Liten's role in the project was to confirm the feasibility of the supercritical water process for gasifying the digestate obtained from co-methanization of the residual organic fraction and sludge into CH_4 suitable for injection into the utility grid.
Tests on lab equipment, process evaluations, and energy integration studies led to the method's validation and to optimal operating specifications for injecting the gas obtained into the grid. The research, carried out with Vinci Environnement, provided a good idea of what a future co-treatment plant (for the residual organic fraction and sludge) with a supercritical water gasification unit could look like. /



IN BRIEF

The Franco-German CatVIC project for the catalytic conversion of industrial carbon is investigating how to efficiently convert large volumes of intermittent renewable energy leveraging green hydrogen production by high-temperature electrolysis. /

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After three years of research and development, the Vasco2 project led to the production (at laboratory scale) of diesel fuel from a biocrude obtained from the hydrothermal liquefaction of microalgae. The microalgae were fed with industrial stack emissions in open ponds using strains that were not specially selected or treated in any way prior to use. /

DIGITAL AND TECHNOLOGICAL PLATFORMS

OUR DIGITAL AND TECHNOLOGICAL PLATFORMS COMBINE MEANS AND SKILLS, AND ALLOW TO INNOVATE BOTH IN PRODUCT AND PROCESS R&D. CONVINCED THAT COMPETITIVENESS REQUIRES, AMONG OTHER THINGS, THE DEVELOPMENT, TESTING AND VALIDATION OF INNOVATIONS ON PRE-INDUSTRIAL EQUIPMENT, LITEN CONTINUOUSLY INVESTS TO KEEP ITS PLATFORMS AMONG THE BEST IN THE WORLD.

PHOTOVOLTAIC SOLAR PLATFORM

The mission of this platform is to support the expansion of France's solar-energy industry by developing all of the components that make up PV solar energy systems. The platform innovates in materials, processes, and equipment to enable high-yield PV solutions. It also has a pilot manufacturing line capable of producing heterojunction cells with a throughput of 2,400 wafers per hour and with high reproducibility.

4 major equipment renewed for the PV Modules platform

SMART-GRID SYSTEMS PLATFORM

This platform uses a mix of emulators and actual components to size, manage, and optimize energy systems that include fluctuating production sources and electricity storage. Specifically, the platform is designed to study a variety of configurations, test components, and develop and evaluate management strategies.

BUILDINGS & ENERGY PLATFORM

This platform optimizes the integration of solar energy into buildings and addresses the convergence between residential buildings and transportation systems. This 1:1 scale testing facility provides builders and equipment manufacturers with the resources they need to assess innovative solutions likely to boost building energy performance.

VISIT OUR WEBSITE FOR MORE INFORMATION: HTTP://LITEN.CEA.FR/PLATEFORMES

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, store it for later use, and use it efficiently for industrial applications.

HYDROGEN PRODUCTION AND STORAGE PLATFORM

This platform focuses on the use of hydrogen as an energy source, most notably through research and development on reversible high-temperature electrolysis technology and coupling the technology with renewable-energy production sources. A special prototyping workshop enables Liten to develop and test large demonstrators, from stacks up to complete systems.

BATTERY PLATFORM

This platform focuses on lithium-ion batteries in particular, from materials and components through to pack assembly, systems integration, and testing. The platform targets both stationary and mobile applications from high-power equipment down to small mobile devices. Unlike any other R&D center in Europe, the battery platform possesses advanced semi-industrial equipment and know-how.

The Battery platform strengthens its resources with the introduction of abusive testing platforms.

FUEL-CELL PLATFORM

The fuel-cell platform takes a unique approach to PEMFC-type fuel-cell design and optimization, addressing materials, membrane-electrode assemblies, stacks, and testing in representative conditions. The platform's mission — backed by an aggressive intellectual property strategy — is to speed up the transfer of technology from lab to market.

The PEMFC platform ramps up with the acquisition of a 100kW test bench.

ELECTRIC MOBILITY PLATFORM

This 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 provide valuable feedback on battery and fuel-cell performance, cycling, and aging.

VISIT OUR WEBSITE FOR MORE INFORMATION: HTTP://LITEN.CEA.FR/PLATEFORMES

POUDR'INNOV 2.0 POWDER METALLURGY PLATFORM

The platform develops and produces high-added-value components from metal, ceramic, semiconductor, and magnetic powders. Complex-shaped parts can be made directly from these powders using additive manufacturing techniques without the need for subsequent machining processes.

Poudr'Innov strengthens its additive manufacturing division with the commissioning of Add Up 3D metal printing equipment.

BIOMASS PLATFORM

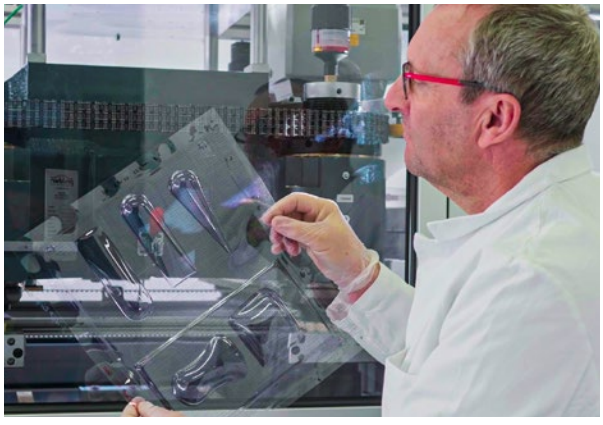
The purpose of this platform is to convert waste to energy, achieving high process yields. R&D at the platform torrefaction, hydrothermal liquefaction, and gasification at a scale that can be extrapolated to industrial processes.

NANOSAFETY PLATFORM

The nanosafety platform investigates protection, health, and safety 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. The platform's broad range of activities makes it a unique resource in Europe.

NANOCHARACTERIZATION PLATFORM

The development of nanomaterials and components requires in-depth knowledge of the underlying morphology and chemical and physical properties. The 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.



LARGE-SURFACE PRINTING PLATFORM

This platform develops smart plastics, papers, and textiles made by printing electronics directly onto these materials' flexible surfaces, for dimensions of 320x380mm². The potential applications for these printed electronics include human-machine interfaces, smart lighting, interactive displays, and environmental monitoring.

Thermoforming equipment complements large surface printing means for the development of structural electronics.

VISIT OUR WEBSITE FOR MORE INFORMATION: HTTP://LITEN.CEA.FR/PLATEFORMES

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