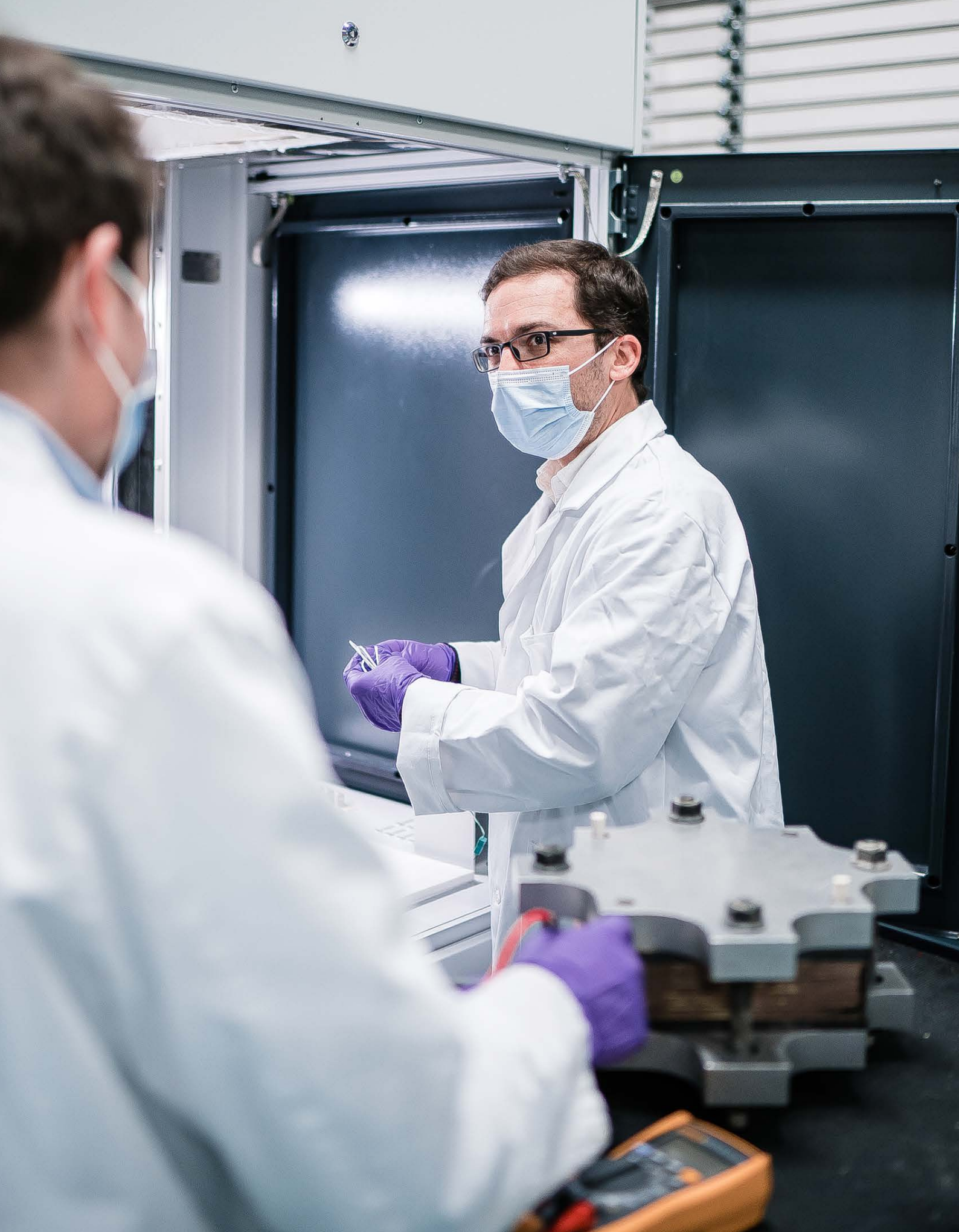


ANNUAL REPORT 2020







François Legalland,
CEA-Liten's CEO

Throughout 2020, the Covid-19 pandemic and resulting global public health and economic crises highlighted the major role research and innovation will play in solving society's greatest challenges, from climate change to reducing dependency on exports. The EU and national governments rolled out major economic recovery programs and initiatives to support national sovereignty on key technologies. The EU set up the Important Project of Common European Interest (IPCEI) on batteries and hydrogen, and the French government announced it will invest €7.2 billion in hydrogen between now and 2030. At the same time, renewable energy is rapidly gaining traction as solutions become more cost-competitive. CEA-Liten is carving out a position as one of the world's leading centers for new-energy-technology research and development and playing a vital role in France's industrial renewal strategy and move to a carbon-neutral economy. CEA-Liten researchers possess know-how in all energy vectors (electric, thermal, and gas) from production, transmission and distribution, and conversion, to storage. Year after year, our scientists continue to stand out for their capacity to develop breakthrough technologies like heterojunction PV, solid-state batteries, and high-temperature electrolysis. We develop technologies and innovate across the entire value chain from materials to systems to components and equipment. This end-to-end approach consistently produces results for our innovation partners. The following pages present the highlights of our research in 2020. You will discover how we develop differentiating technologies and bring them to the appropriate readiness level so that our R&D partners can access the major innovations they need to remain competitive.

4 > 7

LITEN

LITEN, LEADING THE ENERGY TRANSITION	4
CEA-LITEN SHAPING TOMORROW'S ENERGY LANDSCAPE THROUGH CARNOT ÉNERGIES DU FUTUR.	5
LITEN: YOUR TRUSTED R&D PARTNER	6
SECURE YOUR INNOVATION PROJECT WITH THE AUVERGNE-RHÔNE-ALPES REGION'S EASYPOC PROGRAM	7

8 > 13

RENEWABLE ENERGY PRODUCTION

HIGH-YIELD PV	9
NEW-GENERATION PHOTOVOLTAICS	11
PV EVERYWHERE	12
PV FOR SPACE APPLICATIONS	13

14 > 23

ENERGY STORAGE AND FLEXIBILITY SOLUTIONS

TOMORROW'S BATTERIES	15
BATTERY CHARACTERIZATION & SIMULATION	16
BATTERY THERMAL MANAGEMENT	17
EUROPEAN STRATEGY HYDROGEN AND BATTERIES	18
HIGH-TEMPERATURE ELECTROLYSIS	20
HYDROGEN PRODUCTION AND TRANSPORTATION	21
PEMFCs	22

24 > 27

SYSTEMS, GRIDS AND ENERGY EFFICIENCY

DIGITAL TOOLS	25
MANAGING ENERGY SYSTEMS	26

28 > 35

CIRCULAR ECONOMY

ECO INNOVATION	29
RECYCLING	30
MAGNETS	31
PROCESS SAFETY	32
PRINTED ELECTRONICS	33
ADDITIVE MANUFACTURING	34
CARBON CIRCULAR ECONOMY	35

36 > 39

DIGITAL AND TECHNOLOGICAL PLATFORMS

CEA-LITEN, LEADING

CEA-Liten is an institute of the CEA (the French Alternative Energies and Atomic Energy Commission) and is a member of the Institut Carnot Énergies du futur, a consortium dedicated to research partnerships with businesses. CEA-Liten has facilities on the CEA-Grenoble campus and at French national solar energy research institute INES in Chambéry. CEA-Liten research programs focus on the energy transition. Specifically, the institute explores solar energy, grid management, and energy storage, including batteries and hydrogen. Energy efficiency and the circular economy form an integral part of CEA-Liten's research. The technologies developed address several markets, from power generation and distribution to transportation, and from industrial processes to greentech.

Over the past fifteen years, CEA-Liten has leveraged its position within the CEA, one of the world's most innovative government research organizations, to lead the development of complementary, cost-competitive, and more environmentally-friendly solutions to support an energy strategy built on multiple energy vectors and time and space scales.

www.liten.cea.fr/en/

CEA-Liten's main research programs address:

- The development of high-performance solar photovoltaic components and their integration into innovative, cost-competitive systems
- The design and development of future generations of batteries capable of delivering performance, safety, and long lifespans
- The design of hydrogen and hydrogen-enabling energy production, storage, transmission/distribution, and conversion technologies
- The design and use of digital technology to optimally dimension and manage energy (electricity, gas, heat) systems and grids
- The development of electrical and thermal energy management components for generation, conversion, and storage
- The integration of the circular economy principles of "reduce, reuse, recycle" into all research and development projects to reduce the impact of the energy transition on raw materials supplies
- The development of technologies to convert CO₂ and other sources of carbon into synthetic substances that can be used in the energy and chemical industries

With thirteen technology platforms, a portfolio of more than 1,750 patents, and some 1,000 scientists, technicians, and support staff, CEA-Liten possesses the resources and know-how to effectively carry out its mission.

KEY FIGURES



**1,000
EMPLOYEES**



**150
PHD CANDIDATES
AND POST-DOCS**



**ANNUAL
OPERATING
BUDGET
€140 MILLION**



**210 PATENTS
AND 200
PUBLICATIONS
IN 2020**



**MORE THAN
200 INDUSTRIAL
R&D PARTNERS**

THE ENERGY TRANSITION

CEA-LITEN SHAPING TOMORROW'S ENERGY LANDSCAPE THROUGH CARNOT ÉNERGIES DU FUTUR

The French Ministry of Higher Education, Research, and Innovation renewed CEA-Liten's membership in the Carnot Network in 2020 for an additional four years. Carnot facilitates partnerships between research organizations and companies and supports pump-priming research to ensure a pipeline of new technologies to fuel tomorrow's innovations. Membership in the Carnot Network is subject to a rigorous review process and members must fulfill a number of commitments.

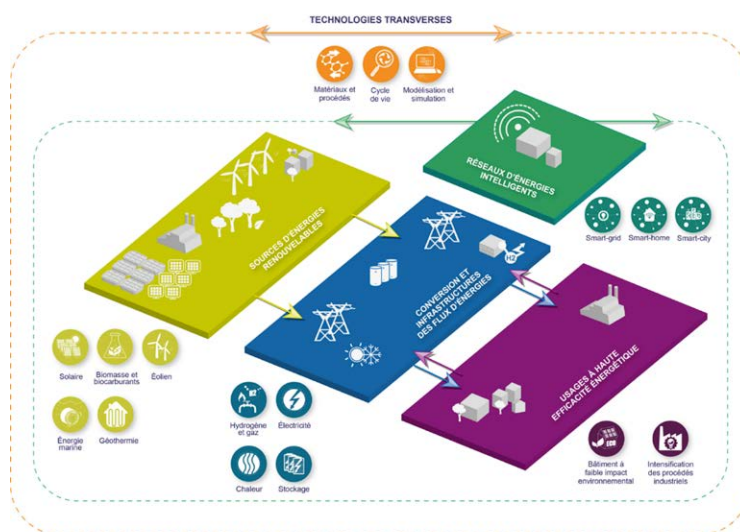
CEA-Liten and ten academic research labs make up Carnot Énergies du futur, whose mission is to provide interested companies with a range of innovations at various technology readiness levels.



Learn more at: www.energiesdufutur.fr

ECOTECH Énergie conference

CEA-Liten, as a member of Carnot Énergies du futur, worked with other members of the Carnot EnergiCs consortium for a low-carbon energy industry, PEXE, a federation of small- and medium-sized companies engaged in the energy transition, and the French government's New Energy Systems Policy Committee to organize the *EcoTech Énergie* conference on December 15, 2020. The day-long conference for research organizations and companies involved in the ecological and energy transitions included presentations, networking, and one-to-one meetings. The *EcoTech Énergie* conference is supporting excellence in France's burgeoning renewable energy industry.



Carnot EnergiCs: a wide range of themes covering the entire energy chain.

LITEN: YOUR TRUSTED

In 2020, CEA-Liten collaborated with more than 200 industrial partners.

The relationships of trust established have made it possible to continue the collaborations initiated and to launch new ones, all with the objective of innovation and acceleration in the sectors of the future to meet the major challenges of our society.



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

INNOVATION THAT DRIVES BUSINESS GROWTH:

- CEA-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

SAVE TIME:

- **Speed up technology development and scaleup** by getting immediate access to CEA-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

SECURE AND LEVERAGE YOUR R&D.

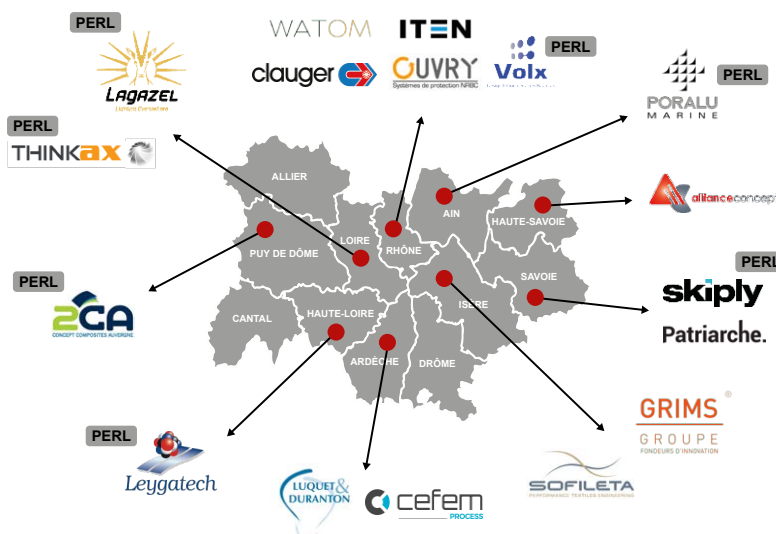
- **Liten guarantees the confidentiality** of your R&D projects
- **Exclusive licenses** to research results within the scope of the target product or application are possible
- **Market research and benchmark survey** before starting R&D

R&D PARTNER

SECURE YOUR INNOVATION PROJECT WITH THE AUVERGNE-RHÔNE-ALPES REGION'S EASYPOC PROGRAM

EasyPOC is for small to mid-sized (fewer than 2,000 employees) companies from all industries looking for support bringing technological innovation into their organizations. The idea is to secure innovation projects with high-tech content by **financing proof-of-concept (POC) development and testing**.

The program, which is 100% financed by the Auvergne-Rhône-Alpes Region (AURA), is administered by the CEA and draws on the CEA's expertise in key enabling technologies for the **digital, healthcare, and energy sectors**. Since EasyPOC started in 2020, a total of 17 CEA-Liten partner companies have received support. EasyPOC projects begin with a feasibility study to identify the technological hurdles to be overcome. Work then begins on proof-of-concept development and testing with the goal of determining whether or not a given technology brick is relevant for the target use case, thus securing the first stage of the innovation process.



“GRIMS, a medium sized company that owns two aluminum manufacturers, Gravitec and FTB, developed an innovative regular metal foam manufacturing process called NéoLATTICE®. EasyPOC enabled us to work with the CEA to design a hyper-compact thermal energy storage demonstrator leveraging bio-sourced PCMs* built on our NéoLATTICE® concept. We are now ready to diversify into equipment manufacturing, targeting markets like urban heating networks, commercial buildings, residential, and isolated residential properties.

*PCM: Phase Change Materials

Cyrille GRIMAUD, CEO, GRIMS

GRIMS
GROUPE
FONDEURS D'INNOVATION

“France-based Alliance Concept is an innovative SMB founded in 1991. The company is an international leader in thin film vacuum deposition equipment. The ability to work on a day-to-day basis with the CEA, a local partner, on perovskite processes for PV applications represents a real opportunity for us. The project has helped us understand the latest technological developments so that we can prepare for tomorrow's processes and materials and innovate for the PV market.

Gaël DUCRET, CEO, Alliance Concept

allianceconcept

“Luquet & Duranton was established in 1898 in France's Ardèche region. The company specializes in consumables for the medical and office supply market. This small business is constantly seeking innovations to add new features to its products. The project on printed electronics with the CEA was a great opportunity for us to leverage technology to bring smart, communicating capabilities into our products, a real differentiator.

Max Braha-Lonchant,
Co-CEO, Luquet & Duranton

LUQUET & DURANTON

RENEWABLE ENERGY PRODUCTION

CEA-LITEN RESEARCH ENCOMPASSES THE ENTIRE SOLAR PHOTOVOLTAIC COMPONENT VALUE CHAIN. THE INSTITUTE LEVERAGES INDUSTRIAL SCALE EQUIPMENT TO PRODUCE MODULES WITH YIELDS OF 25% ON SILICON.

THE ULTIMATE GOAL IS TO OBTAIN YIELDS IN EXCESS OF 30% WITH TANDEM TECHNOLOGIES. IN ADDITION TO OUR WORK ON COMPONENTS, WE ALSO DEVELOP INNOVATIVE SYSTEM ARCHITECTURES TO INCREASE THE PRODUCTIVITY OF GROUND-MOUNTED SOLAR POWER PLANTS AND TO INTEGRATE SOLAR PANELS INTO ENVIRONMENTS RANGING FROM BUILDINGS AND INDUSTRIAL PARKS TO RAIL AND ROADWAYS.

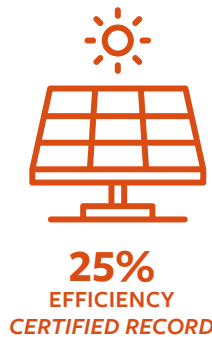


25% CERTIFIED EFFICIENCY OBTAINED ON HETEROJUNCTION CELLS

CEA-Liten and ENEL Green Power obtained a certified efficiency of 25% for heterojunction photovoltaic cells, a record. The cells were made on M2 silicon wafers on the CEA's pilot manufacturing line at INES (France's national solar energy research institute). The processes and layers used were representative of an industrial PV cell manufacturing environment, which makes the results obtained more remarkable.

The record was achieved on a cell measuring 212.84 cm^2 (a 244.33 cm^2 cell whose edges were masked). The

next step will be to obtain the same conversion yields of 25% or more on a total surface of 244.33 cm^2 at the ENEL Green Power manufacturing plant in Catania, Italy.



GETTING PASSIVATED-CONTACT SOLAR CELLS READY FOR SCALEUP

CEA-Liten researchers obtained a yield of 23% on a large (244.3 cm^2) polysilicon-on-oxide passivated-contact PV cell.

The results were obtained on SEMCO Smartech boron diffusion and low-pressure chemical vapor deposition (LPCVD) equipment at INES and were certified by Caltech. The research was presented at the EU-PVSEC conference in September 2020.

ENEL GREEN POWER BANKING ON HETEROJUNCTION TECHNOLOGY

ENEL Green Power cut the ribbon on its 3SUN plant in Catania, Italy. It is Europe's first bifacial heterojunction PV solar panel manufacturing facility. ENEL Green Power's technology was developed in collaboration with CEA-Liten at INES. The new plant is expected to produce around half a million (200 MW) solar panels per year. |

GOING TO M6 WAFER SIZE

CEA-Liten has integrated M6 wafers into its LabFab platform for new generations of heterojunction cells in order to adapt to the rapid increase in wafer sizes used in the PV industry, while continuing to ensure high yields. A $120\frac{1}{2}$ -cell module of nearly 365 W, with a cell-to-module ratio of 102% was produced using these cells. |



A NEW KIND OF SHINGLED SOLAR MODULE

The first-ever industrial-scale shingled solar module was made using bifacial heterojunction solar cells manufactured at the CEA LabFab at INES. In shingled modules, the cells are interconnected by overlapping them in a staircase pattern. This eliminates the conventional metal ribbon connectors and space between the cells, boosting the module's active surface area by around 8%.

The increase in active surface area results in higher power output with standard quality cells than a conventional module of the same size with state-of-the-art cells. The modules are also extremely reliable. Last, but not least, shingled modules are much less of an eyesore than conventional modules, making them good candidates for buildings and automotive applications.



CEA-LITEN MODULE CHARACTERIZATION CAPABILITIES AMONG THE BEST AROUND THE WORLD



To be commercialized successfully, the PV modules performance over time has to be known. The reliability of CEA-Liten's PV module measurement and characterization capabilities has been put to the test for a project that involved 25 international laboratories. The institute came out on par with international certification organizations.

CEA-Liten also performed accelerated aging tests on its HET modules according to the IEC 61215 standard. The modules were tested for resistance to humidity, heat, UV rays, and combinations of the three, at exposures three to four times more severe than the standard requires. All of the modules were within the degradation-related loss (<5%) limits in the standard. |

THE FUTURE OF PV COULD BE IN PEROVSKITE-SILICON TANDEM CELLS



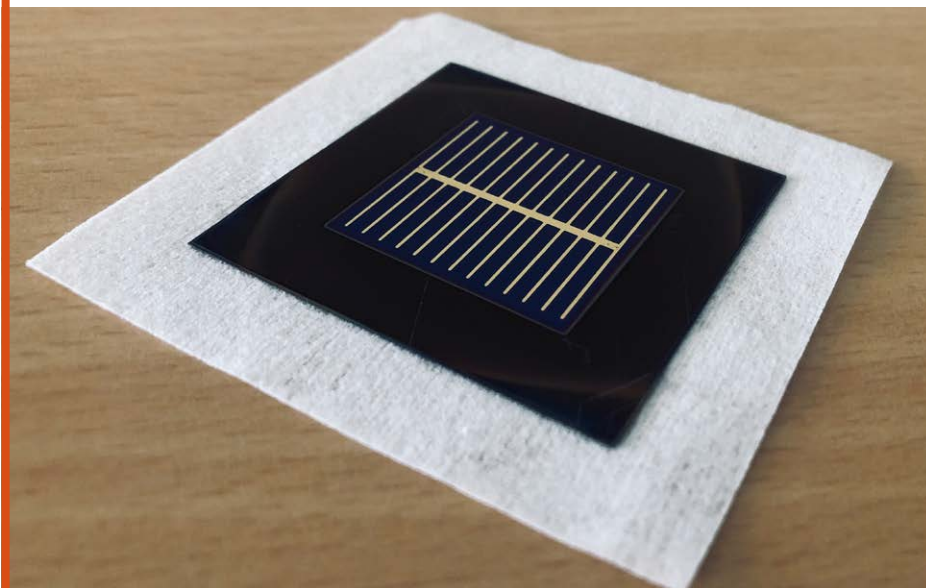
The work we are doing at INES to support the energy transition focuses on PV solar and, specifically, perovskite-silicon tandem cells. In tandem cells, two layers of different materials are stacked, which can increase conversion yields. And perovskite materials are particularly promising due to their remarkable optoelectronic properties.

Plus, they are pretty easy to produce.

Here, we are using perovskites on silicon heterojunction cells that we know how to manipulate in laboratory conditions. These perovskite-silicon tandem cells have the potential to deliver much greater performance than today's silicon cells at a cost that is only marginally higher. This is why so many experts feel that the future of solar energy is in perovskite-silicon tandem technology. In 2020, we achieved conversion yields of over 23% on relatively large cell sizes. We hope to be able to transfer the technology to a manufacturer soon.” |



Olivier DUPRE,
a scientist
at the Tandem Cell Lab



PROGRESS MADE TOWARD A HIGH-YIELD PEROVSKITE PV CELL

IPVF and CEA are working together on a perovskite-silicon heterojunction technology to develop a high-yield tandem cell ready to scale up and transfer to a manufacturer. Their goal is to speed up the development of a technology that should result in 30% yields. |

SMALL ORGANIC PHOTOVOLTAIC CELLS PRODUCE RECORD YIELD

Researchers from Japan-based chemical company Toyobo and CEA-Liten at INES have made small organic photovoltaic cells on glass substrates, achieving the highest conversion yield anywhere in the world in low-light conditions.

Toyobo developed a material specially formulated to produce high electrical power from minimal light sources. A conversion yield of around 25% was obtained under low fluorescent lighting at 220 lux. When fabricated on a PET

film substrate with an active surface of 18 cm², the module produced around 130 microwatts under the same lighting conditions. The material could be used to power temperature-humidity and motion sensors. |

PROGRESS TOWARD THE WIDESPREAD ROLLOUT OF LINEAR PV POWER PLANTS

“When it comes to the deployment of conventional ground-based PV plants, the scarcity of available land is an issue. So, the industry is now moving toward linear PV plants in the tens of kilometers in length. In France alone, railways, waterways, and highways offer tens of thousands of kilometers of potential linear PV capacity. At the CEA, we are developing technical and economic assessment tools to help improve linear PV architectures. The idea is to lower the energy losses that plague today’s linear PV plant designs. One way to do this could be to increase the voltage of the equipment to the thousands of volts. There are no major

technical hurdles and manufacturers are showing increasing interest. So, this is a realistic medium-term goal.” |



Hervé COLIN
researcher, Applied PV
Systems Laboratory

OUT-OF-THE BOX HOME ENERGY RENOVATION KITS

An energy renovation kit for residential properties was rolled out on the INCAS test home platform at INES. The kit includes prefabricated facade and roofing modules that come factory-mounted with windows, cladding, and solar panels as needed. The appearance of the solar panels is also the focus of development work. Solutions like printed glass, glass with a thin filtering coating, and glass with an encapsulated screen-printed resin layer are all on the drawing board. HVAC and domestic hot water equipment is located in a shed adjacent to the



house. Here, a test house was equipped with nineteen photovoltaic panels on the facade and roof, for a total of 31 sq. m. producing 6 kWp. |

The research was part of the INES.2S Institute for the Energy Transition, which is financed in part by the French government’s economic stimulus program (grant number ANR-10-IEED-0014-01) and by French energy agency ADEME through the ESOPE project (grant agreement 1882C0020).

EVALUATE THE CLEANING OF SOLAR PANELS

CEA-Liten developed and implemented a novel testing platform that can evaluate a wide range of dry and wet cleaning techniques used on solar panels. The equipment can also be used to reproduce events such as dew and light to heavy rain containing varying degrees of mineral and other particles. |

NEW FUNCTIONS FOR SOLAR ROADS

The partnership between CEA-Liten and COLAS at INES reached a milestone in 2020 with the market release of the Wattway Pack and the transfer of the Flowell LED signage tile manufacturing process to the company that will make the product for COLAS. |

The research was part of the INES.2S Institute for the Energy Transition, which is financed in part by the French government’s economic stimulus program (grant number ANR-10-IEED-0014-01).

CEA-LITEN, A NEW SOLAR TECHNOLOGY PROVIDER TO THE SPACE MARKET

With the influx of new private-sector entrants on the space market, everything about satellites, including how they are manufactured, is changing. CEA-Liten at INES has been ramping up its research on solar technology for space applications since 2016. Specifically, the institute has been focusing on photovoltaic solutions capable of reducing the specific mass (kg/W) and footprint

of folded PV modules, while keeping costs at a level that remains acceptable to industry stakeholders. To ensure the production yields required by the market, the solutions developed leverage models and production methods from ground-based PV systems. CEA-Liten utilizes its advanced characterization capabilities to assess solar panel performance and offer innovative qualifi-

cation testing solutions that are easy to integrate into production lines. Because space applications are synonymous with severe environments, CEA-Liten has acquired thermal chambers with a temperature range from -180°C to 150°C under atmosphere, and from -120°C to 120°C under vacuum conditions. This new equipment rounds out the production machines on the Module Platform. |



FLEXIBLE PV PANELS FOR HIGH-POWER SPACE APPLICATIONS

The eight-partner ALFAMA project is investigating on how to provide electricity on board space missions, which generally require a power supply of more than 25 kW in extremely compact form factors. The aims of the project are to boost the current power-to-mass ratio by more than 50%, leverage ground-based PV module assembly processes to reduce costs, and increase power density fourfold. CEA researchers at INES are developing the printed substrate, composition, and the manufacturing process for the future flexible panels. The III-V cells developed by the partners will be used by the CEA to manufacture large solar panel prototypes to be integrated into a deployment structure. |

ENERGY STORAGE AND FLEXIBILITY SOLUTIONS

ENERGY STORAGE WILL BE CRUCIAL TO THE DEVELOPMENT OF INTERMITTENTLY-PRODUCED RENEWABLE ENERGY AND TO ACHIEVING A CARBON-FREE TRANSPORTATION SECTOR. CEA-LITEN IS WORKING ON TWO MAIN SOLUTIONS: BATTERIES AND HYDROGEN. OUR BATTERY R&D FOCUSES ON INCREASING ENERGY DENSITIES WITHOUT SACRIFICING SAFETY OR RELIABILITY.

OUR APPROACH TO HYDROGEN IS COMPREHENSIVE, WITH RESEARCH ON PRODUCTION (USING HIGH-TEMPERATURE ELECTROLYSIS), STORAGE, TRANSPORTATION, AND CONVERSION (BY FUEL CELLS).



A STEP CLOSER TO TOMORROW'S BATTERIES



THREE QUESTIONS FOR

Séverine JOUANNEAU,
who heads CEA-Liten's Department
of Electricity and Hydrogen
for Transportation (DEHT)



What role does CEA-Liten play in the battery industry?

The European Union has made batteries a priority, and CEA-Liten provides research and development services for manufacturers across the battery value chain. Our research addresses electrode materials, manufacturing processes, electrolytes, and chemistries and spans everything from basic research to implementing the technologies we develop on prototype cells for testing purposes.

Right now, for example, our materials research is focused on reducing the amount of cobalt used in the lamellar components of positive electrodes to lighten the environmental footprint of these components. All of our research involves advanced characterization of the phenomena that occur at the interfaces. If we can understand the mechanisms at work, we can improve them and achieve better overall performance.

What were some of the past year's milestones on CEA-Liten's battery development roadmap?

In 2020, we fabricated and integrated the first-ever electrodes made using extrusion rather than coating processes! Unlike coating, extrusion does not require the use of toxic solvents that are difficult to reprocess. We produced our first cells, and initial performance tests indicate that the results should be in line with our expectations.

In other materials research, we were able to identify several potential pathways to hybrid and perhaps even solid electrolytes, which could enable more compact and safer cell designs than today's liquid electrolytes. Our electrode research resulted in improvements to existing materials last year. We also selected materials for the first third-generation lithium-ion batteries to be produced by factories in France, with a time horizon of 2023 or 2024.

What are the challenges and issues ahead?

The third generation of lithium-ion batteries is almost ready for manufacturing, so we will now be shifting our focus to the next one. Next, we will need to make our selection from the potential electrolytes we have identified and complete test implementations to determine which materials will allow us to achieve the performance targets set. Fine-tuning the interfaces in solid-state batteries to maintain good ion and electron conductivity is one of the challenges we will need to overcome.

And we are already looking at fifth-generation batteries and beyond. This earlier-stage research includes exploration of breakthrough technologies like lithium-sulfur that could potentially help us make a big leap forward in terms of performance. Lastly, we are investigating environmental impacts, lifecycle considerations, and recycling. These issues will guide future developments, affecting everything from components and processes to the actual designs of future generations of batteries. |



SIMULATING PHASE CHANGES IN GRAPHITE



Marion CHANDESRIS,
scientist, Multiscale Modeling
and Performance Monitoring
Laboratory

“ We have developed tools that can simulate phase changes in graphite, the active material used in most lithium-ion batteries. Graphite is made up of sheets of graphene. The lithium is stored between these sheets, much like on shelves, and is ordered in different ways, filling one out of four, one out of three, or every other shelf, for example. It can also form little islands. Depending on how dense the lithium is, the graphene sheets can shift in relation to each other. We recently introduced lithium ordering parameters into our equations to simulate this phenomenon.

We are still validating our multi-physics simulation tools by comparing them with electrochemical data and with in operando structural data obtained at ESRF. It is vitally important to be able to simulate these phase changes so that we can modify the materials' properties to enable faster and safe battery charging.”



DETAILED PHYSICAL SIMULATION OF LITHIUM-ION BATTERIES

The CEA started a major new program on multi-scale battery simulation for electrode materials. The idea is to leverage a more predictive approach to simulation—one that tightly integrates physical modeling and laboratory characterization—to speed up the development of Li-ion battery technologies. The purpose of this cross-disciplinary program is to create new R&D opportunities at the national and EU levels. |

NEW INSIGHTS INTO ELECTRODE MICROSTRUCTURES

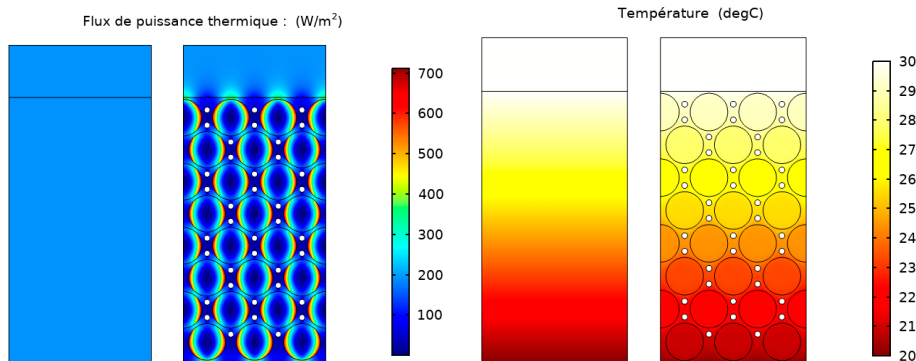
Battery electrodes are made of a granular, porous medium in which the electrolyte circulates. 3D characterization of electrode microstructures can provide insights crucial to improving battery operation. In conventional microscope images, grains cannot be distinguished from porosities, however.

In research conducted for the Carnot CARMA Energie project, CEA-Liten developed a focused ion beam milling and scanning electron microscopy method suitable for segmenting 3D images of negative battery electrodes. Images captured by two different detectors were combined and analyzed using an artificial intelligence algorithm, correctly classifying each pixel. |

A COMPREHENSIVE THERMAL BEHAVIOR SIMULATOR FOR COMPLEX BATTERY PACKS

Complex battery packs contain more than 5,000 parts, including an array of change-phase materials. Assessing the thermal behavior of these complex systems quickly can be a challenge. Researchers at CEA-Liten came up with a way to avoid having to model the behavior of each type of part individually. Instead, they opted for an equivalent “porous”

model. It works by replicating the behavior of a material that corresponds to the assembly of cells and other components inside the target operating environment. The pack’s thermal behavior can be evaluated in different operating conditions and phases to ensure that actual operation is compliant with specifications. |



IMPROVING CONTROL OF THERMAL RUNAWAY IN TEST MODULES

To study thermal runaway in lithium battery modules, you have to be able to trigger the phenomenon reproducibly. A “trigger” cell is integrated into the module, and thermal runaway is propagated from this cell throughout the rest of the system. Of the methods evaluated, a heating wire device was selected to trigger the thermal runaway. The temperature of the trigger cell can rise to more than 200 °C while keeping the surrounding cells at around 50 °C.

This improved control over the trigger cell will make it easier to simulate and study the propagation of thermal runaway to the other cells in the module. Because the process is more reproducible, the data used to validation test and dimension batteries will be more reliable. |

MORE EFFICIENT BATTERY COOLING



In research conducted for the Carnot REDBAT project, CEA-Liten is investigating a diphasic fluid cooling system for high-power lithium-ion batteries. The researchers developed a test loop to characterize the typical flows between battery pack cells immersed in an insulating fluid circulated by a pump. The fluid used has a relatively low boiling point (about 65 °C), which

is what makes the system different from other solutions. When the temperature reaches this boiling point, the fluid vaporizes at the hot spot. This in turn creates high heat absorption exactly where it is needed for targeted, efficient cooling. The system’s performance is currently being tested in the lab. The results will be compared to existing systems for use in electric vehicles. |

LITEN AT THE CENTER HYDROGEN AND



Simon Perraud,
CEA-Liten Associate Director



Laurent Antoni,
Public Affairs Manager at CEA-Liten,
Hydrogen Technologies

What is the European strategy on hydrogen and batteries?



Simon Perraud:

The European Green Deal and new industrial strategy both make achieving a carbon-free economy a priority. For mobility, for example, hydrogen and batteries, when used together, are a good solution. Batteries will be used for light vehicles and over short and medium distances.

Hydrogen will be more for heavy vehicles and long-distance transportation. Grid flexibility is another area where hydrogen and batteries make a good combination for storing intermittently-produced renewable energy. Again, batteries will provide storage over short time horizons, while hydrogen will be used for longer-term storage. Finally, hydrogen, as both an energy vector and a raw material, can also help limit the carbon footprint of the chemical, steel, and other industries.



Laurent Antoni:

Today, the European Commission is advocating a transition to clean hydrogen production. This will need to be backed by an aggressive policy to build electrolyzers to address the use cases Simon mentioned. Working toward a carbon-free economy responds to environmental imperatives, of course. But there is also a desire to strengthen the EU's energy and economic sovereignty.



OF THE EUROPEAN BATTERY STRATEGY



How will the strategy be implemented?

Laurent Antoni:

European alliances in both sectors, mobility and industry, will drive implementation. First, IPCEIs will be set up to address industrial development issues. Second, European PPPs in Horizon Europe will be encouraged to effectively prepare for the future. In particular the FCH 2 JU on Hydrogen will be extended. The CEA, as a research stakeholder, is the number-one beneficiary of the JU.

Simon Perraud:

In terms of solutions for industry, two IPCEIs on batteries, backed by several billions of euros in public funding and private-sector investments, have been set up. It is our hope that the hydrogen IPCEI will ramp up to the same level by the end of 2021. CEA-Liten, one of Europe's leading centers for R&D, is a member of the two nonprofits (Hydrogen Europe Research and BEPA) that represent the private-sector members of the PPPs in Horizon Europe.

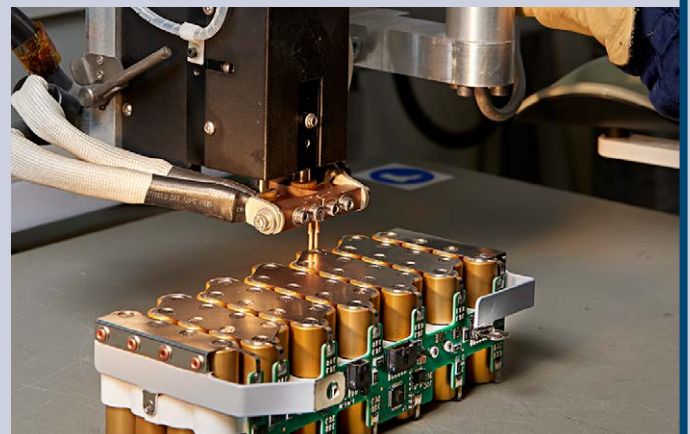
What can we expect to see in France?

Laurent Antoni:

The French government unveiled its hydrogen strategy in September 2020, announcing €7.2 billion in funding by 2030. This far-reaching strategy makes France a top player in Europe's industrial hydrogen landscape. This has translated into several financing instruments. First, the French government will contribute €1.5 billion to the IPCEIs; second, French energy agency ADEME-backed projects will provide a framework for the CEA to support French companies with the development of innovative enabling technologies; and, finally, the PEPR (*Programme et Equipements Prioritaires de Recherche*) program on hydrogen was created. The CEA and French national center for scientific research, CNRS, are leading this program. Their objective will be to prepare for the future through education and training and through research to support the emergence of breakthrough technologies.

Simon Perraud:

These measures will position CEA-Liten to build new partnerships and ramp up the transfer of innovative technologies to industry. Our recent partnerships with Symbio, Genvia, and battery-industry stakeholders are great examples of what to expect.





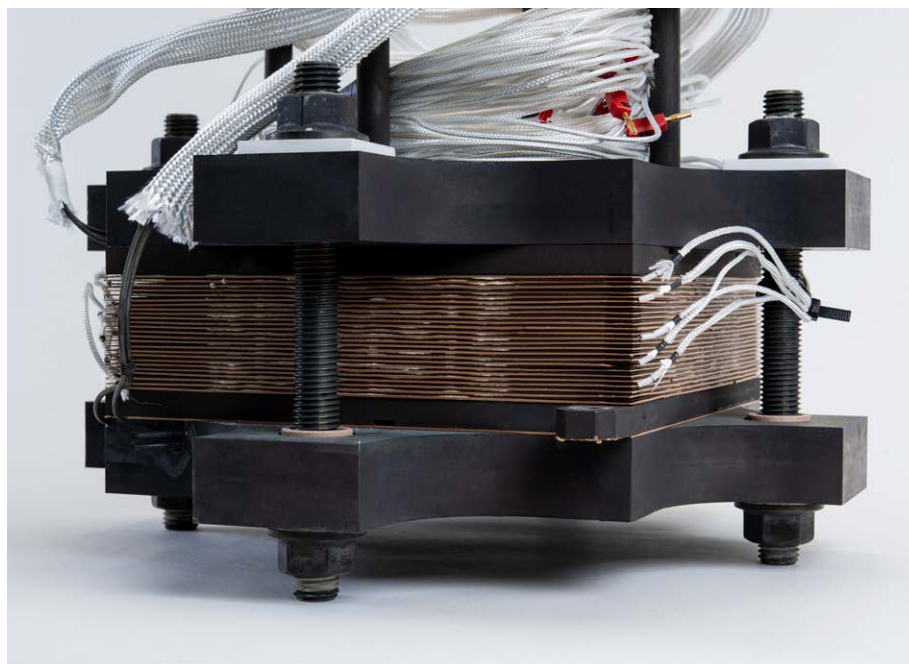
COST-COMPETITIVE CARBON-FREE HYDROGEN WITHIN THE NEXT DECADE



The high-temperature electrolysis technology CEA-Liten has been developing for more than fifteen years will soon be commercialized by Genvia, a joint venture created by CEA, Schlumberger, Vinci, Vicat, and AREC in March 2021.

CEA-Liten's research on high-temperature electrolysis (HTE) for the carbon-free production of hydrogen goes back years. Hydrogen, with its capacity to store energy over long periods of time, is widely accepted as a local energy vector with the potential to ensure grid stability and flexibility. Over the past fifteen years, CEA-Liten has developed a high-temperature electrolyzer that can deliver conversion efficiencies fifteen to twenty points higher than today's alkaline and PEM (proton-exchange membrane) solutions. CEA-Liten's electrolyzer offers more than just high conversion efficiency, however. It is also reversible, which means it can operate in both electrolyzer and fuel-cell modes, and it can electrolyze carbon dioxide (CO_2). The electrolyzer, which is protected by more than 40 patents, is now ready to scale up. CEA-Liten plans to develop larger, more efficient stacks and modules to lower system costs and gear up for the next generations of electrolyzers.

Several major steps forward were made in 2020. CEA-Liten's research mainly focused on two issues. The first was how to improve the ceramic cell's lifespan. Here, the institute investigated the degradation mechanisms that affect the cells, and specifically, their microstructure. Early research on new stack formats also generated results. A new high-power stack architecture (with a capacity six times that currently produced at the CEA) was validation tested on lower-power stacks made on the pilot line and tested on equipment at CEA Grenoble. The results obtained are in line with the technology development roadmap's milestones of producing demonstrators in the hundreds of kW by 2023, followed by MW demonstrators in 2024. The goal is to bring the cost of hydrogen produced using this technology to under €2 per kg by 2030 - a price that is deemed to be financially competitive. |



A SOC TESTING PLATFORM FOR MODULES UP TO 120 KW



CEA-Liten designed and built a SOC (solid-oxide cell) testing platform for modules with total power of up to 120 kW DC. Modules made from several stacks can be operated reversibly on the testing platform in electrolysis and/or fuel cell mode. H_2 and CH_4 can be used as fuel. Prior to the implementation of this new platform, CEA-Liten could only

test individual stacks with power of up to 15 kW DC. CEA-Liten decided to ramp up its testing capacity to prepare for demand from R&D and manufacturing stakeholders. This kind of total power can only be achieved with architectures in which multiple modules made up of multiple stacks are assembled—the exact number depends on the power

output required by the target application. To successfully scale up its testing capabilities, CEA-Liten had to use different technologies and redimension certain testing platform components while effectively addressing safety issues at this larger scale. |

HYDROGEN COULD BE STORED IN A NEW BIO-SOURCED LIQUID ORGANIC CARRIER

A liquid organic carrier in which a chemical compound is hydrogenated and dehydrogenated, storing and releasing hydrogen as needed, could provide an alternative to liquid and compressed hydrogen storage solutions. Today's hydrogen carriers necessitate platinum-based catalysts and are plagued by stability issues, making them less than ideal. To make matters worse, losses of 25% limit the energy yields that can be obtained by the reaction. Lastly, these carriers are made using fossil-based resources.

CEA-Liten developed a new GBL-BDO carrier that solves some of these problems. Copper-based catalysts are used in the dehydrogenation reaction, which consumes about 15% of the energy in the hydrogen. Next, the hydrogen mass stored in chemical form, currently 4.5 g per 100 g of compound, will have to be increased. |

SOLAR GASIFICATION TECHNOLOGY GOES TO INDUSTRIAL SCALE

CEA-Liten used numerical simulation and testing at high temperatures to study a solar gasifier concept at different scales from lab to industrial.

They leveraged a 3D model of the gasifier to develop a hybrid heating mode in which oxygen is injected in a controlled manner to support solar heating. The successful testing of this dynamic control solution marks a step toward scaling up around-the-clock concentrated-solar gasification of biomass and waste. |

SYMBIO AND CEA SIGN FRAMEWORK R&D AGREEMENT

Symbio and the CEA have been working together for more than a decade. The partners are ramping up their collaboration through a recent framework R&D agreement on hydrogen to support the energy transition in transportation. The agreement will accelerate the scaleup of cheaper, more efficient systems that are easier to integrate into vehicles. |



TOWARD THE SAFETY OF HYDROGEN ENERGY SYSTEMS

“ When it comes to hydrogen as an energy carrier, the issue of safety is of central importance. In research conducted

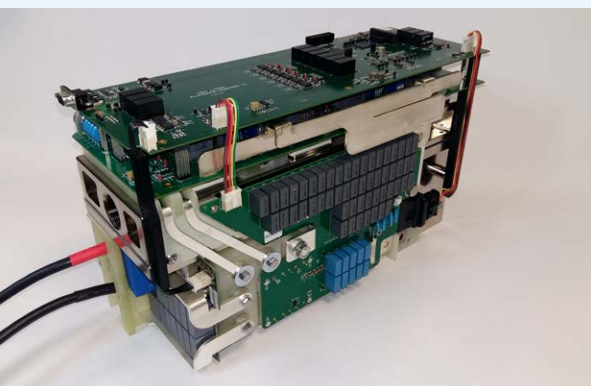
for the EU HYTUNNEL project, CEA-Liten is helping investigate the three main hazards associated with hydrogen: dispersion, fire, and explosion. Lab experiments will be used to validate the established models and predicted results. One of the things we are trying to ascertain, for example, are the impacts of ventilation and tunnel structure on hydrogen dispersion. A better understanding of the phenomenon could help predict how hydrogen flaring around a vehicle could affect passenger evacuation in the event of a fire inside a tunnel. For hydrogen explosions, we want to know how the tunnel profile affects the safety of people and property. In 2020, we did a unique full-scale experiment in the Mortier tunnel in the Vercors mountains near Grenoble. We compiled a substantial database that we are currently analyzing so that the information can be used to create future regulations for structures as well as for vehicles.” |



Didier BOUIX,
scientist,
PEMFC systems laboratory



A PEMFC WITH INTEGRATED VOLTAGE CONVERTER



CEA-Liten developed a modular integrated system that could result in lighter, more compact PEMFC-converter assemblies. They integrated the DC/DC step-up converter into the stack end plate, where it shares some of the stack's mechanics and cooling circuit. The solution is built on a novel hybrid cooling system, plus tighter integra-

tion between the system's mechanics and electronics. The target form factor was achieved and the prototype must now be tested. Ultimately, the solution could be of interest for aeronautics and other applications where temperature, vibration, and other environmental factors are a concern. |

IMPROVING THE PERFORMANCE OF GRAPHENE PEMFC ELECTRODES



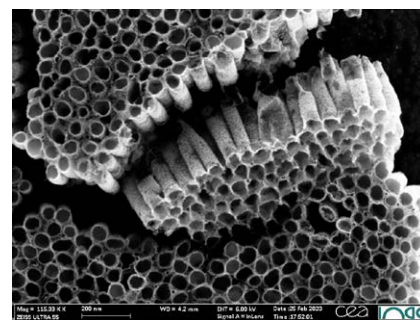
Scientists are experimenting with catalyst materials as a way to lengthen PEMFC lifespans. In a research conducted for the CORE 2 project, CEA-Liten scientists tested new catalysts whose carbon-containing structure is made from graphene sheets, a material that is much more corrosion-resistant than the amorphous carbon traditionally used.

This graphene-based catalyst was made by an industrial R&D partner and implemented by CEA-Liten. The target performance of 1 A/cm² at 0.6 V was obtained due to advances on the ink formulation, the coating process used to deposit the ink, and the hot transfer process used to assemble the layers of the catalyst. The battery's lifespan is currently being tested on a 1 kW stack, which already has 800 hours of operation under its belt. |

MULTI-SCALE AND MULTI-PHYSICS SIMULATION

CEA-Liten made a major advance in the simulation of coupled electrochemical problems on real 3D fuel cell and lithium-ion battery structures. The institute developed a software library that can be used to write the complex set of electrochemistry equations needed for these simulations in a simple language that is much more accessible than the computer codes employed in the field.

The solution leverages symbolic computation and on-the-fly compilation to rapidly and automatically calculate the complete Jacobian matrix for the coupled electrochemical problem, a key step toward robust and rapid problem solving. The software can then solve the problem on very large supercomputers with an unprecedented level of quality, in the billions of points. |



NOVEL ELECTRODES COULD IMPROVE PEMFCs

CEA-Liten recently helped develop new carbon-free platinum nanotube electrodes. The advance was part of research that aims to reduce the amount of platinum used in proton exchange membrane fuel cells (PEMFCs) while continuing to boost the fuel cells' performance. Platinum nanoparticles were assembled to form an organized set of hollow tubes 50 nm in diameter and 400 nm to 500 nm long. These self-supporting carbon-free nanostructures outperformed conventional electrodes in terms of activity and stability. Adding nickel further improved the speed of the reaction and mitigated current losses. Research on these electrodes is still in the early stages, and scaleup is still a long way off. For now, the electrodes will be very useful in the lab to gain a better understanding of PEMFC operation and, ultimately, identify new research and development opportunities. |

SYSTEMS, GRIDS, AND ENERGY EFFICIENCY

NEW SCENARIOS LIKE THE INTRODUCTION OF INTERMITTENTLY-PRODUCED RENEWABLE ENERGY INTO GRIDS; EMERGING MODES OF CONSUMPTION LIKE ELECTRIC VEHICLES, ELECTROLYZERS TO PRODUCE HYDROGEN, AND SELF-CONSUMPTION; AND THE COUPLING OF DIFFERENT ENERGY VECTORS LIKE ELECTRICITY, HEAT, COLD, AND GAS ARE ALL HALLMARKS OF THE ENERGY TRANSITION. CEA-LITEN LEVERAGES MULTI-ENERGY-VECTOR TEST PLATFORMS AND DEEP KNOWLEDGE OF ENABLING TECHNOLOGIES TO DEVELOP ITS OWN SOFTWARE TO OPTIMIZE THE DIMENSIONING AND CONTROL OF ENERGY SYSTEMS AND GRIDS. CEA-LITEN ALSO DEVELOPS ELECTRICAL AND THERMAL ENERGY MANAGEMENT COMPONENTS FOR GENERATION, CONVERSION, AND STORAGE TO MAKE ENERGY SYSTEMS AND GRIDS AS EFFICIENT AS POSSIBLE.



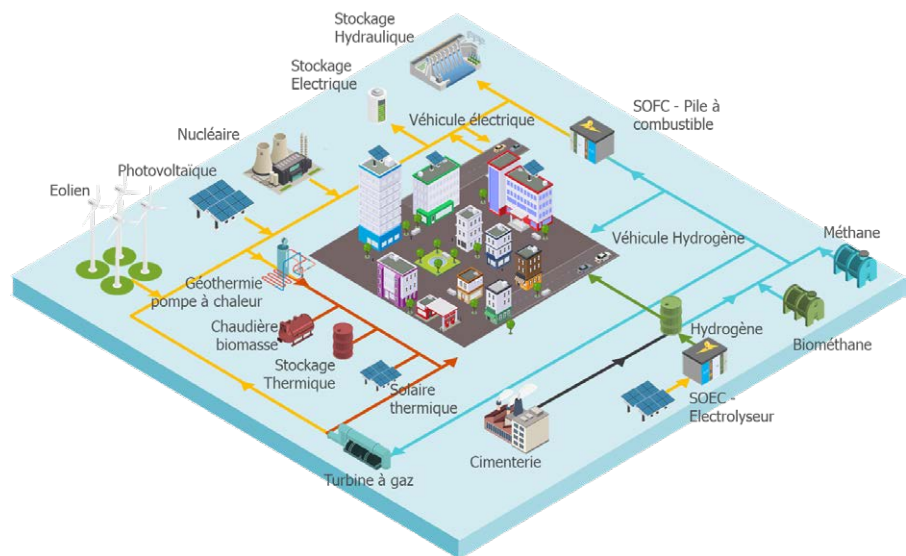
SOFTWARE MAKES ACHIEVING THE BEST ENERGY MIX EASIER



Mathieu VALLEE,
Scientist,
local energy systems lab

“ We also develop software at CEA-Liten. One example is our electrical-system dimensioning software, which we recently updated to include multi-energy grid architectures. We drew upon our know-how in technical, economic, and environmental analyses; in energy-usage modeling; in heat, electric, and gas grid simulation; and in mathematical optimization techniques to develop this new software.

Users enter the type of energy production that is already in place, for example, and the software determines the best architecture in terms of meeting the needs expressed within the technical, economic, and environmental requirements of the project. The software can be used on projects at different scales, from a single building or industrial facility to an entire city. In 2020 a Carnot Énergies du Futur grant allowed us to use the software to model a case study of Grenoble's Cambridge neighborhood. The project, which included heat, electricity, and gas, was a relevant proof-of-concept at the neighborhood scale. This software will soon serve as the foundation for a multi-energy-vector simulator being developed under the Trilogy project.” |



INTEGRATING RENEWABLE ENERGY INTO THE GRID

Large-scale integration of renewable energy into the grid creates new technical challenges. While the balance of networks is currently ensured by adapting production to demand, the intermittent nature of renewable energy production requires new compromises to be found. A decision support tool to find optimal storage solutions for a given energy mix at different time scales has been developed at CEA-Liten.

Once the specifications for the system have been entered, the proposed tool allows to optimize the choice of storage methods to balance the network over a given period of time, from hour to year. In the short term, it appears for example that the best storage is the one with a good yield, even if it is expensive to buy. The reverse is true for longer-term storage scenarios. |

ELECTROLYZERS, PLAYERS IN THE GRID REGULATION

Used to produce hydrogen from electricity, electrolyzers can help to maintain the balance of the electrical grid. CEA-Liten involved in the EU Qualygrids project which aimed to set up a unique and standardized European testing protocol that can be used to determine the ability of an electrolyzer to meet the constraints associated with participation in grid services.

The idea is to make the testing protocol available to electrolyzer manufacturers and operators as well as for use on demonstrator projects to test the integration of an electrolyzer into grid services models, for instance.

The ISO197 Technical Committee on hydrogen technologies has started work to turn the testing protocol into a standard. |



THE TESTING PROTOCOL
IS AVAILABLE ONLINE

TOWARDS A COORDINATED MANAGEMENT OF MICROGRIDS

Microgrids, which are generally at the scale of a neighborhood, include energy production, storage, and distribution equipment. They can be connected to the main grid or operate independently in the event of a blackout. Within the framework of the EU m2M-grid project,

CEA-Liten has developed innovative tools to ensure the coordinated management and coherent interaction of microgrids. The goal is to meet each microgrid's individual requirements while also responding to the needs of transmission and distribution system operators. The

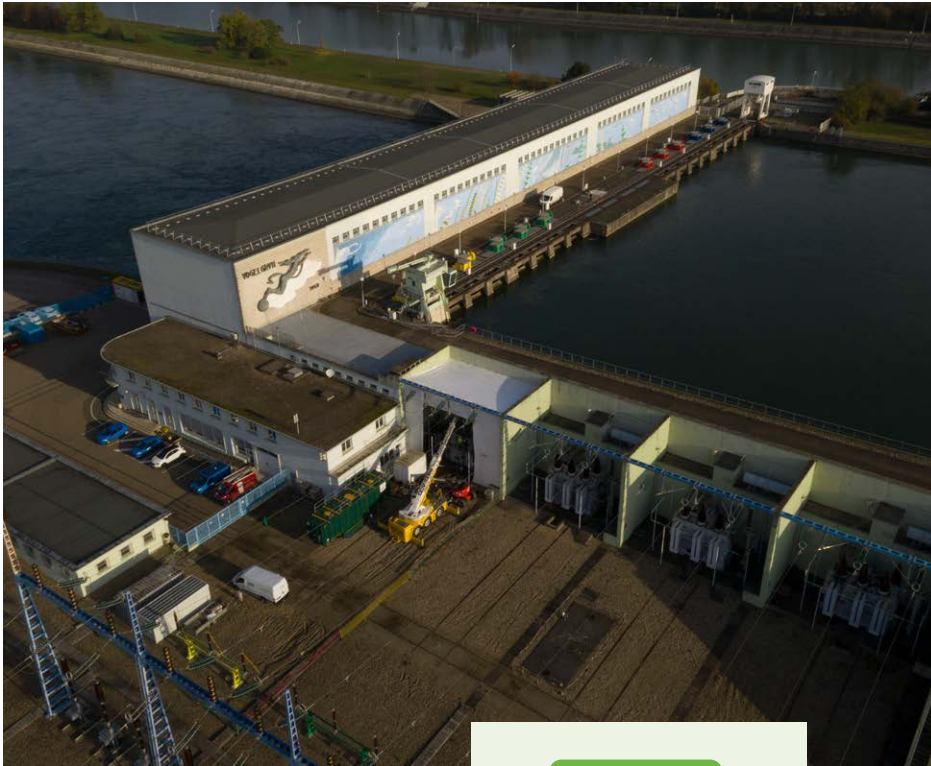
goals are to boost penetration of renewable energy and ensure grid stability in all circumstances by maintaining sufficient voltage and power quality. The tools developed were tested successfully on a real network operated by SOREA. |



BATTERIES COULD HELP MAKE HYDROPOWER MORE FLEXIBLE

As part of the EU XFLEX Hydro project, CEA-Liten researchers studied the dimensioning and control of Li-ion batteries coupled with a 35 MW hydroelectric turbine. The project focused on the design of a system capable of responding in just seconds to frequency fluctuations on the grid, which will occur more often as integration of renewable energy into electricity grids increases.

The system designed was built on a 650-kVA converter coupled with a set of batteries with 380 kWh total capacity. Smart control algorithms were used to ensure the delivery of grid services requested by operators while limiting system aging. Control power was reached in under 30 seconds and the mechanical stress of frequency regulation on the control devices was reduced by 35%. |



380 kWh

BATTERIES
ON BOARD ENERGY



MAKING DEEP GEOTHERMAL ENERGY MORE FLEXIBLE

CEA-Liten contributed to the EU Geosmart project to design thermal storage systems for two deep (2,000 meters underground) geothermal sites in Turkey and Belgium. The systems leveraged a 2 MWh storage solution built on phase-change materials, a 5 MWh steam accumulator, and three pressurized-water thermocline modules for a total of 15 MWh. The main technical challenge was to design systems suitable for the unique conditions at each site. A patent was filed to protect the steam accumulator management system, which limits the negative impact of incondensable gases in brine, a highly mineralized water, on storage capacity. Today, it is possible to use deep geothermal energy to produce electricity continuously. The purpose of this project was to make this source of energy more flexible. |

C I R C U L A R E C O N O M Y

CIRCULAR ECONOMY CONSIDERATIONS WILL NEED TO BE A MAJOR FACTOR IN TECHNOLOGICAL INNOVATION IF THE IMPACT OF THE ENERGY TRANSITION ON RAW MATERIALS CONSUMPTION IS TO BE LIMITED. CEA-LITEN RESEARCH BRINGS THE CIRCULAR ECONOMY PRINCIPLES OF REDUCE, REUSE, RECYCLE INTO THE ECO-DESIGN AND RECYCLING OF NEW ENERGY TECHNOLOGIES.

NEAR-NET-SHAPE MANUFACTURING PROCESSES (LIKE 3D PRINTING) AND STRUCTURAL ELECTRONICS ARE TWO EXAMPLES OF HOW CEA-LITEN DEVELOPMENTS ARE MAKING MORE ECONOMICAL USE OF MATERIALS. THE INSTITUTE ALSO DEVELOPS MATERIALS, PROCESSES, AND SYSTEMS FOR THE CIRCULAR CARBON ECONOMY, I.E. THE CONVERSION OF CARBON-CONTAINING RESOURCES INTO MOLECULES OF INTEREST FOR ENERGY OR CHEMISTRY.



CIRCULAR ECONOMY ASSESSMENT TOOL

One of the pillars of the circular economy is to reduce the consumption (and waste) of raw materials and non-renewable energy. A CEA-Liten lab with a staff of 200 people is sharpening its focus on the circular economy. A two-year project to investigate circular economy issues resulted in a list of action items the institute began rolling out in 2020. To date, two-thirds of managers have been trained in the fundamentals of eco-design. The ICE-T (*Indicator of Circular Economy Tool*) assessment has been released for testing by employees. ICE-T, inspired by the Ellen MacArthur Foundation Circulytics® circularity

measurement tool, utilizes the answers to multiple choice questionnaires to calculate a “circularity score” for an on-going or completed research program, lab operations, or a strategy, for example. The tool also generates recommendations for improvements. Four guides outlining circular economy methods have been written for different user profiles.

The training, assessment tool, and guides will help CEA-Liten gradually develop a circularity management system and a project management process integrating the continuous improvement of circularity. |



STRONGER BIOSOURCED THERMOPLASTIC POLYMERS

Poly lactide is a 100% biosourced and biodegradable thermoplastic polymer.

CEA-Liten researchers made the material stronger by incorporating 20% plant fibers. The material's elastic modulus, an indicator of stiffness, was increased by 80%; its resilience, or impact resistance, got a 140% boost. The cellulose fibers, which are polar, were chemically pre-treated to make them more compatible with the apolar and hydrophobic polymer matrix. Adding plant fibers also helped make this biocomposite material cheaper to manufacture.

The researchers are also investigating how to make initially-immiscible biosourced polymers compatible with functionalization of the melted material. The EU INN-PRESSME project, which kicked off in early 2021, is addressing this topic. |



NEW PREPARATION AND DISMANTLING PROCESSES FOR SAFE BATTERY RECYCLING

In a research conducted for the Recybat project, whose aim is to bring Li-ion battery processing and recycling technologies to maturity, CEA-Liten helped develop an innovative process for separating and regenerating the materials inside the battery cells. The main focus is automotive batteries.

The project is also addressing preparation processes to make sure the batteries are safe to dismantle. A target charge state is determined depending on whether the cells are going to be recycled or destroyed. This prevents short circuits and thermal runaway and preserves cell function for reuse scenarios. |

RECYCLING FOR RENEWABLE-ENERGY TECHNOLOGIES SOON TO INCLUDE PEMFCs

The purpose of the EU Best4Hy project is to bring PEMFC and SOFC recycling processes to maturity by using technologies developed specifically for these systems or by modifying existing technologies. CEA-Liten brings years of experience developing chemical processes for battery recycling to this project. Most notably, the institute is testing ion metallurgy techniques to recover platinum. CEA-Liten is also working on synthesizing catalysts, manufacturing MEAs from recycled materials, and developing MEA dismantling processes. Finally, the institute is utilizing its materials characterization and component testing know-how for this project. |



GIVING SOLAR PANELS A SECOND LIFE

CEA-Liten developed an energy-efficient, minimally-polluting end-of-life recycling method for solar panels. A diamond wire is used to cut through the PV cells, separating the front face, made from glass, from the back face, made from a mix of polymers. The technique, tested on lab-scale equipment, proved effective at separating the two faces even though they are just microns apart. It took around a half hour to process a module measuring one square meter. The glass recovered can be recycled into new products; the metals present in the cutting residues can be recovered and separated using hydrometallurgical processes, and then recycled. |

PERMANENT MAGNETS AND RARE EARTH ELEMENTS: REDUCE, REPLACE, RECYCLE

CEA-Liten presented a roadmap to reduce the use of rare earth elements in NdFeB permanent magnets, used in electric motors and wind turbines. The roadmap is built on three main strategies. The first is to develop magnets that can be manufactured in complex shapes without machining. The second is to use less of the “heaviest” rare earth elements (Nd/Pr) and replace them with lighter (and more abundantly available) ones. The third is to improve the reuse and recycling of end-of-life magnets. The institute is engaged in several R&D partnerships and European projects that address these topics. CEA-Liten’s Poudr’Innov 2.0 powder metallurgy platform is instrumental in this research. |



REDUCING DEPENDENCE ON NEODYMIUM-RICH PERMANENT MAGNETS

Research conducted for the EU Novamag project has resulted in some promising advances towards reducing the amount of neodymium in NdFe₁₂ permanent magnets.

These innovative magnets could contain up to 35% less neodymium. CEA-Liten eschewed the conventional book mold casting process in favor of strip casting, a method widely used in NdFeB permanent magnet manufacturing. Alloys with 97% 1:12 phase were obtained. The nitriding

of this phase substantially increased the material’s magnetocrystalline anisotropy and Curie point. Different nitriding parameters were tested and optimized without breaking down the 1:12 phase. The material’s magnetocrystalline anisotropy increased from 2T to 11T and the Curie point increased from 147 °C to 288 °C. The coercivity value is still low for a permanent magnet, but improvements to the microstructure of the nitride powders should solve this problem. |

KEEPING GaN POWER COMPONENTS COOL

In order for GaN power components to take hold on the market, researchers must find a way to keep them from overheating. CEA-Liten drew on more than fifteen years of thermoelectricity research to develop thermal management sensors and, for the first time ever, adapted these sensors to a GaN HEMT (high-electron-mobility transistor) technology developed in partnership with CEA-Leti.

The sensors, fabricated at the same time as the GaN transistors, dissipate heat and convert it into an electrical signal, which can then be used in readout systems and feedback loops, which, in turn, predict and prevent overheating of the transistors and circuits, keeping the components operating as intended. The solution is compact and does not require a power supply. |



NITROGEN OXIDE FILTERS FOR AUTOMOTIVE PASSENGER CABINS

Automotive catalytic converters are already equipped with nitrogen oxide filters. However, these filters are only active at high temperatures. CEA-Liten developed filters that work at normal room temperature and atmospheric pressure. Conventional mechanical particle filters were coated with an active material to trap polluting gases. The coating contains a substance known to capture nitrogen dioxide (kept confidential) and a second substance developed to augment the first substance's nitrogen oxide capture capacity fourfold. This improved filter could be used to purify the air in automotive passenger cabins and to filter out between 50% to 80% of nitrogen dioxide between two car inspections (around every 30,000 km). A patent to protect the innovation is pending; research is ongoing to also be able to convert nitrogen oxide into nitrogen dioxide so that it, too, can be filtered out. |

CEA-LITEN CONTRIBUTES TO THE FIGHT AGAINST COVID-19



Back in March 2020, when the first wave of the Covid-19 pandemic was reaching its peak, surgical masks were in short supply. Scientists from CEA-Liten and the Y.SPOT open innovation center teamed up with Voc-coV, a grassroots maker movement, to invent a mask that made the most efficient possible use of filtering materials. They designed the OCOV® mask with three times less filtering media by total surface area than a disposable FFP mask. They also found a high-performance, washable filtering media that can be reused up to twenty

times. The mask is now manufactured and distributed by a company called Ouvry. In other Covid-19 news, the MA-KAIR project leveraged the speed and flexibility of 3D printing and the know-how of CEA scientists to design and prototype an artificial ventilator in a record two months.

In April 2020, in response to a request from the French Directorate General for Enterprise (DGE), the CEA-Liten Nano-safety Platform was selected as an independent expert and asked to help test and certify consumer masks. |



7TH Nanomaterials Health and Safety Conference:
100% ONLINE
AND 100% A SUCCESS!



247
ATTENDEES



161
ABSTRACTS



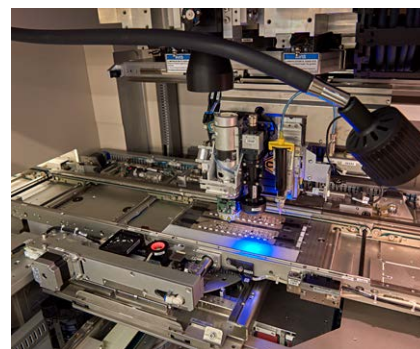
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PRESENTATIONS

PLASTRONICS COULD SOON BE INTEGRATED INTO CAR DASHBOARDS

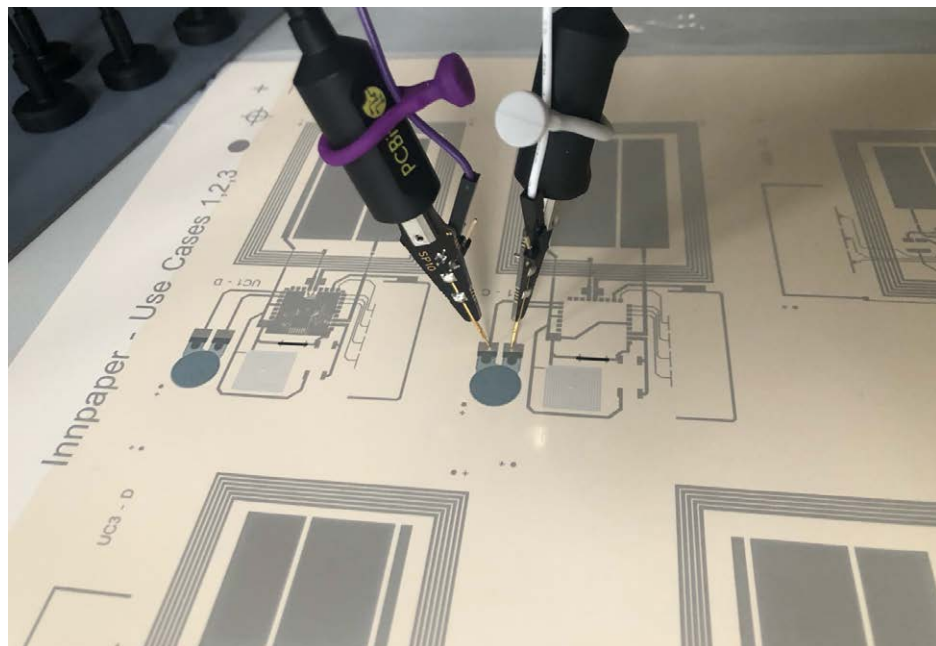
Plastronics, or electronics integrated into plastic materials, could soon be found in car dashboards. CEA-Liten worked with startup Symbiose to produce a capacitive plastic part prototype with six control buttons and LEDs as a light source. The screen-printed plastronic components had to be made more mechanically robust to withstand the rigors of the manufacturing process and,

especially, high pressure during plastic injection molding.

Low-cost, thin plastronic parts can enhance dashboard controls. Plus, the parts are easy to assemble using an overmolding process and can be covered with decorative films. The researchers are now doing aging-resistance testing on the prototypes. |



PRINTING ELECTRONICS ON... PAPER!



Paper could very well be the perfect flexible substrate for printed electronics. Because, unlike polymers, paper is not made from petroleum-based substances.

In research conducted for the EU Innpaper project, which focused on printing electronics on paper, CEA-Liten helped develop a hybrid multifunctional platform on a paper substrate. The platform is made up of connectors, an antenna, a battery, a display, and an RFID chip and can control sensors for a wide variety of applications, including caffeine, drug, bacteria, and virus detection. A smart food label to monitor the cold chain was manufactured and interfaced with this new hybrid platform.

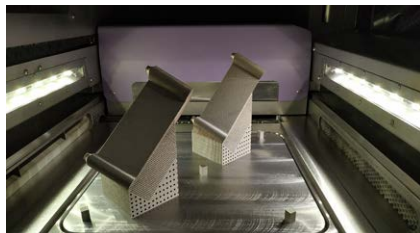
The components were fabricated on CEA-Liten's PICTIC structural electronics line. |

STRAIN GAUGE PRINTED ON A STRETCHABLE SUBSTRATE

A strain gauge printed on a stretchable substrate has been developed. Almost 40 different inks references and more than 10 different stretchable substrates were tested to obtain a gauge capable of resisting a 30% elongation, and whose strength variation remains stable during at least 500 bending cycles. |



ADDITIVE MANUFACTURING HELPS IMPROVE HEAT-EXCHANGER PERFORMANCE



Metal 3D printing has the capacity to substantially reduce the amount of material used to manufacture heat exchangers while improving energy-transfer efficiency. The Carnot FAMERGIE* project explored the relationship between laser powder-bed fusion (also called selective laser melting) process parameters and the microstructure and mechanical properties of the material obtained to design heat exchanger-reactor models. Specifically, the geometries were optimized, and then the exchangers were manufactured and tested on a thermal-hydraulic bench. Advanced characterization methods were used to investigate the microstructure of the nickel alloy samples obtained. The density of the material was greater than 99% and the characterization data gathered provided insights into the tensile strength measurements taken. The researchers modeled several 2D-channel exchanger-reactor geometries and optimized the designs to improve performance. Models made using laser powder-bed fusion were tested and the results revealed 7% higher performance for circular channel sections over square sections. |

*This project was financed by Carnot Énergies du futur fund and used the equipment and resources available at the FAMERGIE platform.

3DPRINT SCOPE EXPANSION

The multi-partner Hub 3DPRINT project on 3D printing technology brings together a broad range of expertise to address the needs of stakeholders in a variety of markets and support the emergence of new industrial models. The scope of the project is expanding. The goal is to leverage MultiJetFusion technology to get polymer 3D printing to manufacturers, speeding up time-to-market for innovative new products made using the technique. CEA-Liten is working with

Arkema on materials, with Siemens on software, and with HP on printing.

In 2020 the Hub 3DPRINT project team helped develop, prototype, and test a new artificial respirator for Covid-19 patients in a record of just two months, a prime example of the flexibility and agility additive manufacturing brings to the product development cycle. The 3DPRINT Hub project will continue to gain traction with the entry of new members in 2021. |



STATISTICAL ANALYSIS OPTIMIZES POWDER PROCESSING

CEA-Liten scientists developed a mathematical model based on the statistical analysis of characterization data of more than 60 316L powders obtained over the course of multiple

metal 3D printing projects. The model helps predict how processable a powder is so that it can be optimized if needed. |



Marine PEYROT,
Project manager, Pulp&Fuel,
and scientist at CEA-Liten's reactors
and processes laboratory

WASTE-TO-ENERGY SOLUTION FOR PULP FACTORIES

The purpose of the EU Pulp&Fuel project, which CEA-Liten is coordinating, is to develop technologies to convert waste generated by paper pulp production processes into energy. Pulp factories mainly produce dry, tree-bark-type waste and a liquid residue from the wood burning stage called black liquor. Pyro-gasification and hydrothermal gasification processes currently being explored in laboratory conditions could be used on pulp factory waste. These processes effectively convert the waste into gas, which can then be converted into biofuels.

So far, we have shown the feasibility of converting wood bark powder and black liquor into recoverable gases. This project calls upon a broad range of disciplines and leverages all of the expertise available at our labs. It has been an incredible opportunity to work with top-notch biorefinery stakeholders from across Europe.” |

HYDROTHERMAL LIQUEFACTION PROVEN EFFECTIVE AT TREATING BIO-WASTE

The potential of Hydroliq, CEA-Liten's pilot synthetic biocrude plant, was recently demonstrated in the Waste2Road and Bitume 2.0 projects. The plant operated continuously for 30 hours, producing 10 kg and 5 kg of biocrude for the two projects. The biocrude can either be refined into biofuel or used in road resurfacing.

The hydrothermal liquefaction process used takes place at temperatures of up to 350 °C and pressures up to 200 bar. These conditions give water properties that help convert bio-resources into fuel. CEA-Liten would now like to acquire a 10-liter-per-hour test plant; the current plant produces 1- 2 liters per hour. |



10 KG OF BIOCRUDE
PRODUCED

HOT ISOSTATIC PRESSING TECHNOLOGY TRANSFERRED TO INDUSTRIAL PARTNER

CEA-Liten contributed its hot isostatic pressing know-how to a project that enabled ATMOSTAT to build a 1:1 scale nuclear reactor first-wall panel. The panels, which line the nuclear reactor, are made from three materials assembled by hot isostatic pressing around a complex cooling circuit designed to keep wall temperatures under 600 °C. The advance positioned ATMOSTAT, in partnership with ALSYOM (both ALCEN companies), to win a bid to supply the first-wall panels for the ITER nuclear fusion reactor in Cadarache, France. |

WOOD-POWDER GASIFICATION TESTED ON GIROFLÉ REACTOR

A wood-powder gasification test was completed on the GIROFLÉ entrained-flow test gasifier. The goal was to assess efficiency at moderate temperature (< 1,250 °C) and pressure (5 bar). Regardless of the temperature of the inside wall of the reactor (1,165 °C and 1,225 °C during the tests), the wood powder was virtually completely converted into gas. |

D I G I T A L A N D T E C H N O L O G I C A L P L A T F O R M S

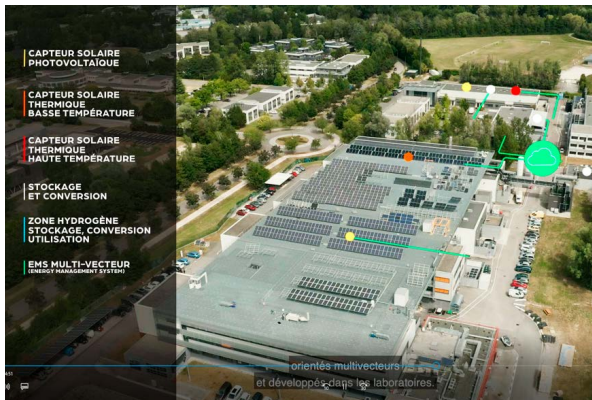
OUR DIGITAL AND TECHNOLOGICAL PLATFORMS COMBINE MEANS AND SKILLS, AND ALLOW TO INNOVATE BOTH IN PRODUCT AND PROCESS R&D. CONVINCED THAT COMPETITIVENESS REQUIRES, AMONG OTHER THINGS, THE DEVELOPMENT, TESTING AND VALIDATION OF INNOVATIONS ON PRE-INDUSTRIAL EQUIPMENT, LITEN CONTINUOUSLY INVESTS TO KEEP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



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.

Visit our website for a visual tour of our digital and lab tools for energy grid research and development.



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.

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.

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.

New equipment for organic PV R&D at the RESTAURE platform



Visit our website for more information about our platforms

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 hightemperature 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.

We recently added ECM GreenTech packaging benches to our high-temperature electrolyzer stack pilot production line. This new equipment is used to complete the final step in the production process: The stacks are operational and their performance can be tested



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.

A new solid-state battery dry-room area with a mixer, several extruders, a hot press, and fume hoods was set up to support our expanding research in this field. The goal is to develop new solid-state battery processes.



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.

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 about our platforms

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.

We added HP 5002 and HP Metal Binder Jet printers to our additive manufacturing toolbox.



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.

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.

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.



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.

The French Directorate General for Enterprise (DGE) selected CEA-Liten to conduct filtration tests on consumer-grade (non-medical) face masks.

Visit our website for more information about our platforms



www.liten.cea.fr/en/