

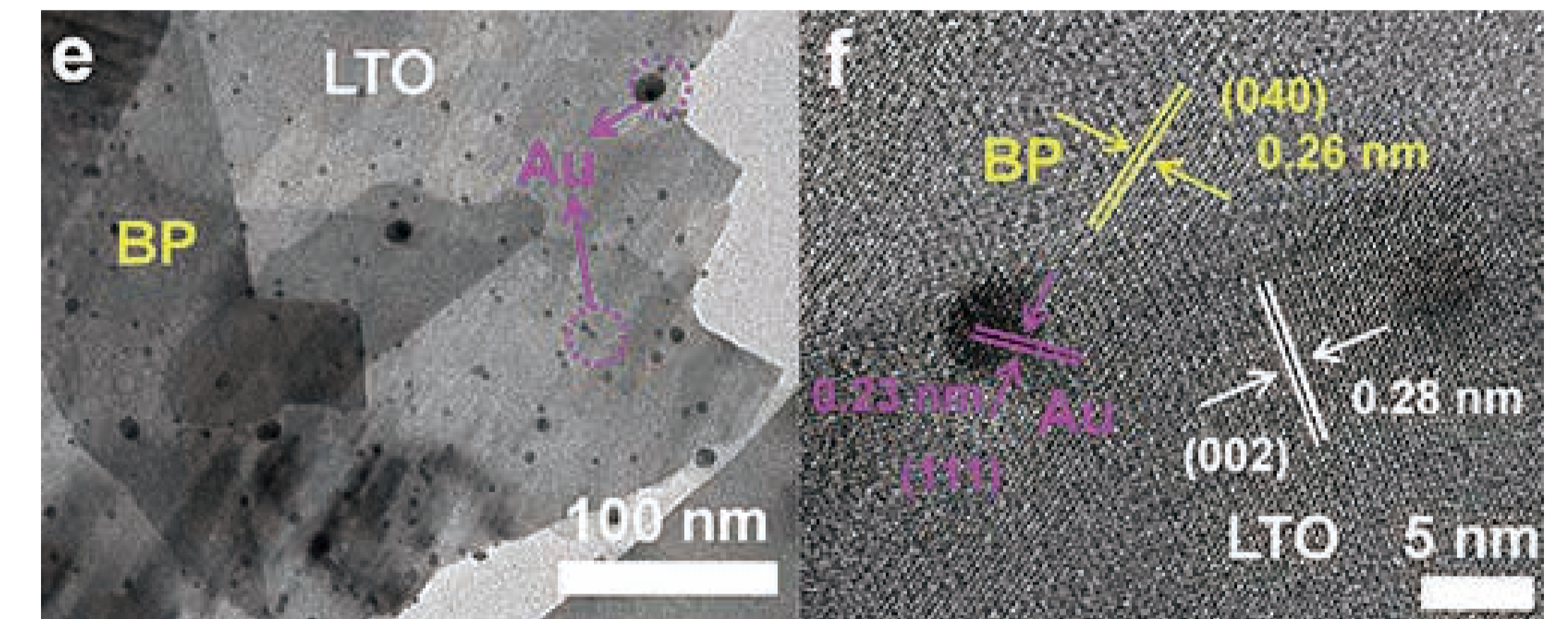
Title

# New materials for photocatalysts to produce hydrogen

Organization

**Osaka University**

A compound consisting of gold, lanthanum, titanium and oxygen, ( $\text{Au/La}_2\text{Ti}_2\text{O}_7$ ) sensitized with black phosphorus is developed as a photocatalyst for  $\text{H}_2$  production. Currently, only ultraviolet (UV) region of solar light (which only consists about 3 – 4 % of total solar energy) can be harvested by catalysts to produce hydrogen, resulting in a very low rate of conversion (only a few percentage points). **With this catalyst, a broad range of solar light including not only UV but also visible light and near-infrared (NIR) region can be harvested for energy to produce hydrogen.** This technology could be one significant step towards direct conversion of sunlight into hydrogen, which would complement or replace other processes such as thermolysis and electrolysis from zero-emissions sources of hydrogen to be used for e.g. fuel cells, and direct combustion in power plants.



**Electron microscope image of black phosphorous, lanthanum titanate, gold nanoparticles**

**Source** © The Institute of Scientific and Industrial Research, Osaka University ([http://www.sanken.osaka-u.ac.jp/en/e\\_toppage/e\\_hot\\_topics/topics\\_20170530/](http://www.sanken.osaka-u.ac.jp/en/e_toppage/e_hot_topics/topics_20170530/))

## CO<sub>2</sub> emissions reduction potential

If scaled up, this technology could provide a key to massive production of hydrogen at affordable cost, which can be used in fuel cells, direct combustion or energy carriers.

## Innovativeness

The technology is highly innovative due to its novel combination of elements enabling use of visible light and NIR, which together consists more than 90% of solar energy.

Title

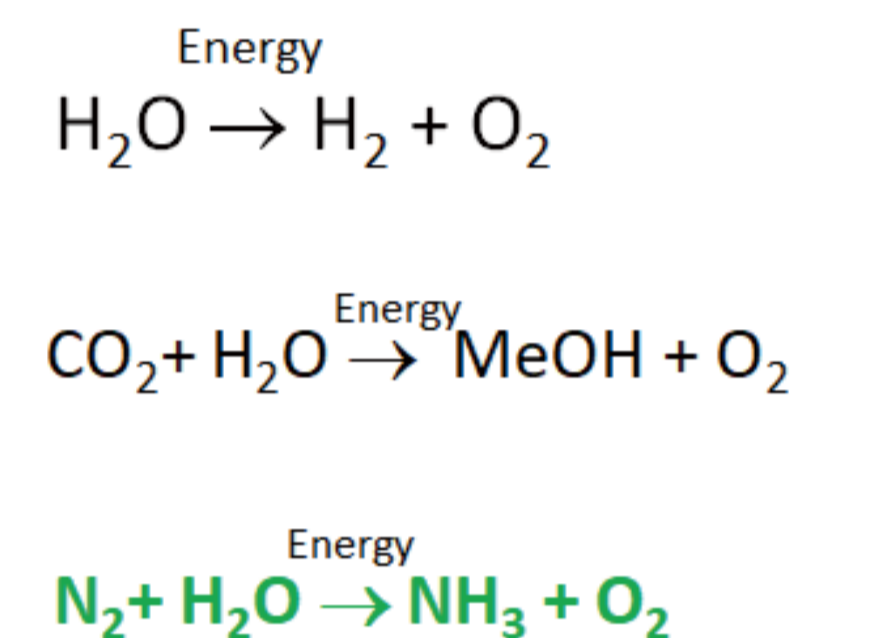
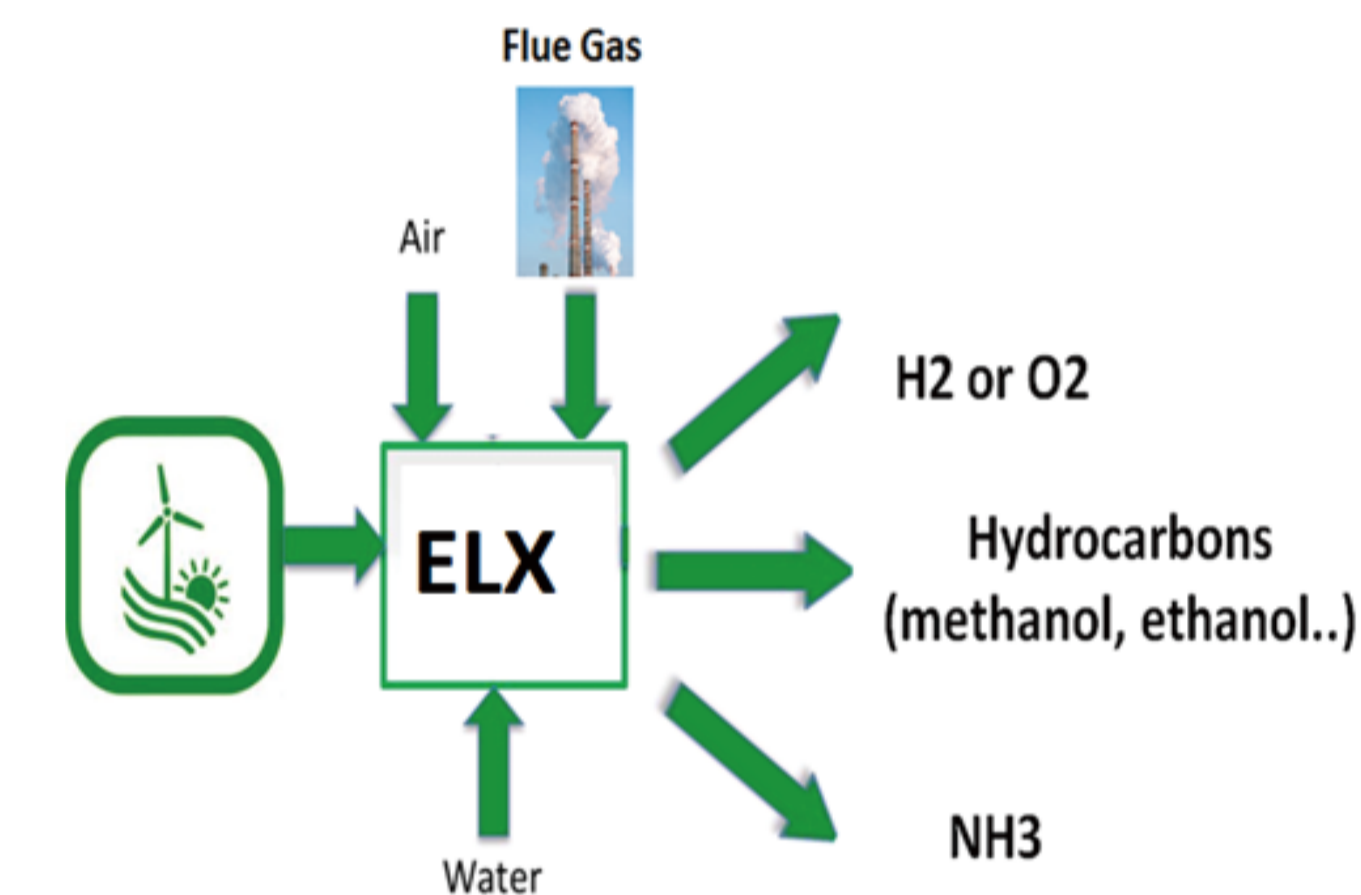
# High efficiency ammonia synthesis from water and nitrogen

Organization

## Giner Inc., Newton, MA

Ammonia, key element for nitrogen fertilizers, are produced today by Haber-Bosch method, requiring hydrogen whose production is both energy and emissions-intensive since it uses natural gas, whose carbon is eventually released as CO<sub>2</sub> at a rate of about 1.7t-CO<sub>2</sub>/t-NH<sub>3</sub>. A group of advanced membrane / catalyst components are being developed, **enabling ammonia to be produced by water, nitrogen and renewable electricity**. The components will be integrated into the existing water electrolysis platform to maximize the overall system efficiency.

There are two merits for this innovation. The first is that the temperature and pressure are much lower than conventional methods, leading to improved overall energy efficiency. The second merit of innovation is the opportunity to utilize renewable electricity, allowing for reduced CO<sub>2</sub> emission.



**Schematic diagram of the technology**

**Source** © Giner Inc., Newton, MA

**Acknowledgment**

This work was funded in part by the Advanced Research Projects Agency - Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR000814.

### CO<sub>2</sub> emissions reduction potential

Ammonia production emits c. 250 Mt-CO<sub>2</sub> worldwide, but is essential for fertilizer and is a potentially useful medium of electricity storage enabling transport of hydrogen. Therefore, alternative production of ammonia is highly sought after.

### Innovativeness

The technology is highly innovative, since it combines innovation in both membrane and catalytic components.

- Highly selective catalysts have been developed to boost nitrogen reduction while inhibiting side reactions.
- Advanced high temperature alkaline membranes have been explored to facilitate ammonia synthesis and separation.
- Ammonia synthesis proceeds at intermediate temperature and ambient pressure that can improve energy efficiency.

Title

# Advanced small modular reactor (aSMR)

Organization

## Advanced Reactor Concepts, LLC.

An advanced small module reactor (aSMR) will soon be deployed in a Canadian province pursuing the establishment of a center of excellence becoming a manufacturing hub for advanced SMR products based on its technology. The project is also expected to provide a nuclear supply chain created in the region.

The aSMR named ARC-100 is a 100 MWe sodium-cooled, fast flux, pool-type reactor with metallic fuel that builds upon the 30-year operation of the EBR-II reactor. What is notable is that **waste created by light-water reactors suffices as viable fuel**, offering a solution to the problem of nuclear waste.

Among other features, its **passive safety system prevents meltdowns of the reactor**, the most crucial element for nuclear applications, even in the case of a complete loss of power. Overall, a project using this reactor backed by matured technology might shed light on a holistic solution to the nuclear problem, though on a limited scale.

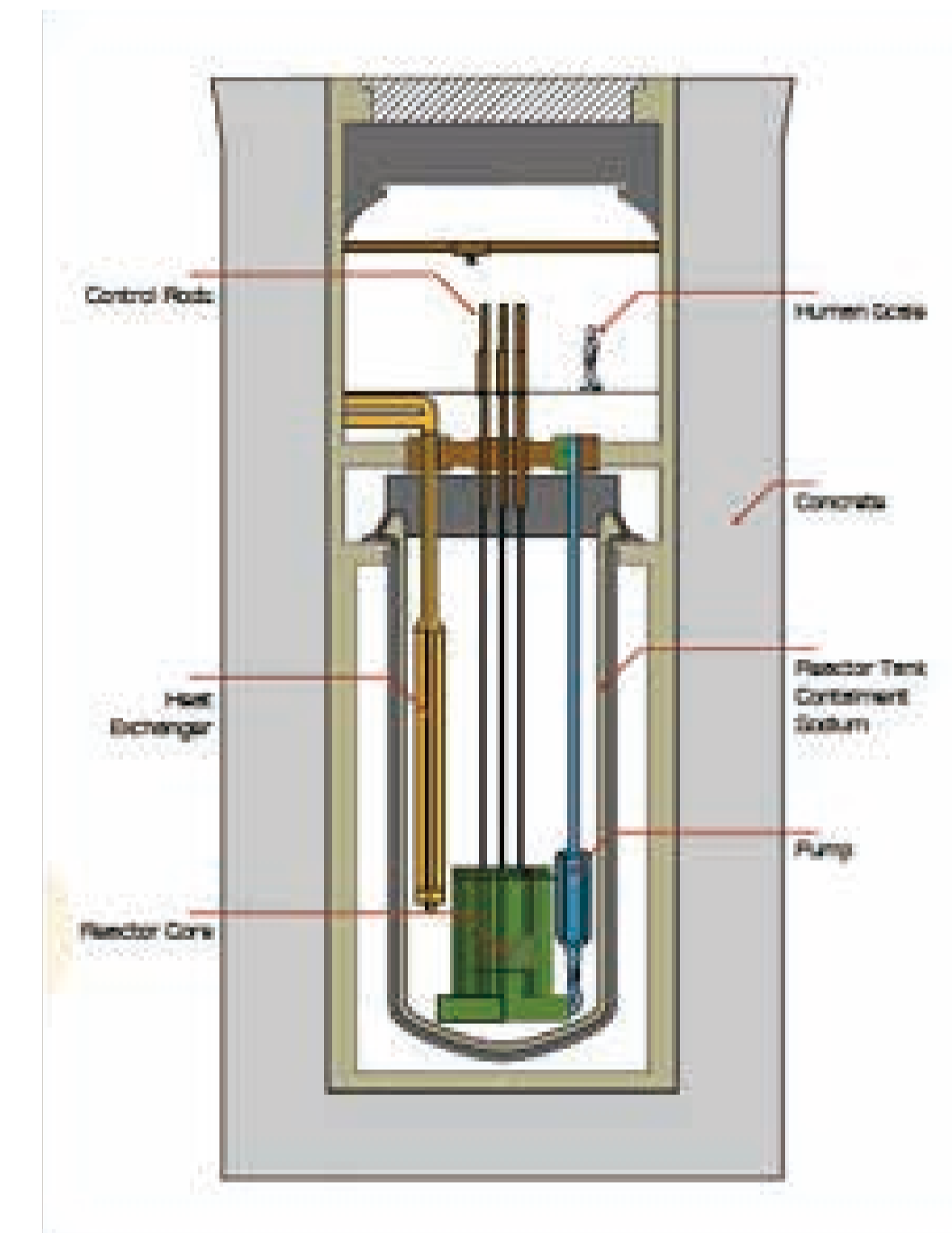


Diagram of ARC-100 reactor

Source © Advanced Reactor Concepts, LLC.  
 "A Sustainable, Cost-Effective Energy Solution for the 21st Century"  
 (<http://www.arcnuclear.com/uploads/File/arc-100-product-brochure.pdf>)

### CO<sub>2</sub> emissions reduction potential

As nuclear power itself is neutral with respect to GHG emissions, replacement of fossil fuel power plants with ones of this type should be a priority.

### Innovativeness

Economization has been achieved through compactness while safety is ensured.

Title

# Capture and conversion of atmospheric CO<sub>2</sub> into carbon nanotubes

Organization

**C2CNT LLC**

The synthesis method invented by researchers at George Washington University is not only used for conducting carbon sequestration from stack emissions or by direct air carbon capture but also produces a valuable product called carbon nanotube (CNT). Its strength, conductivity, flexibility and durability are expected to have far-reaching applications including capacitors, Li-ion batteries, lighter-weight structural materials, and among others.

Hindered by high production costs, however, the versatile material has not yet come into wide use. It is hence worth underscoring that, thanks to this novel technology, a researcher's laboratory running on renewable energy could bring about promising products at lower costs than through conventional methods.

The use of CNT is limited to date, which means that producing CNTs inexpensively by C2CNT's proprietary new method can be a notable achievement.



Source © Dr. Stuart Licht, Professor of Chemistry, George Washington University at SL@C2CNT.com

## CO<sub>2</sub> emissions reduction potential

If the technology is sufficiently scalable, production using the technology should expand so that it reduces GHG substantially, due to two factors, namely, the widespread application of CNT and the price competitiveness in markets.

## Innovativeness

It is highly innovative in that captured GHG can be converted into cutting-edge materials.

Title

# Turning carbon dioxide into concrete

Organization

## University of California, Los Angeles (UCLA) and CO<sub>2</sub>Concrete, LLC

UCLA researchers have developed a technology that turns carbon dioxide (CO<sub>2</sub>) emissions into CO<sub>2</sub>Concrete™, a replacement for traditional concrete – although with a much lower CO<sub>2</sub> footprint.

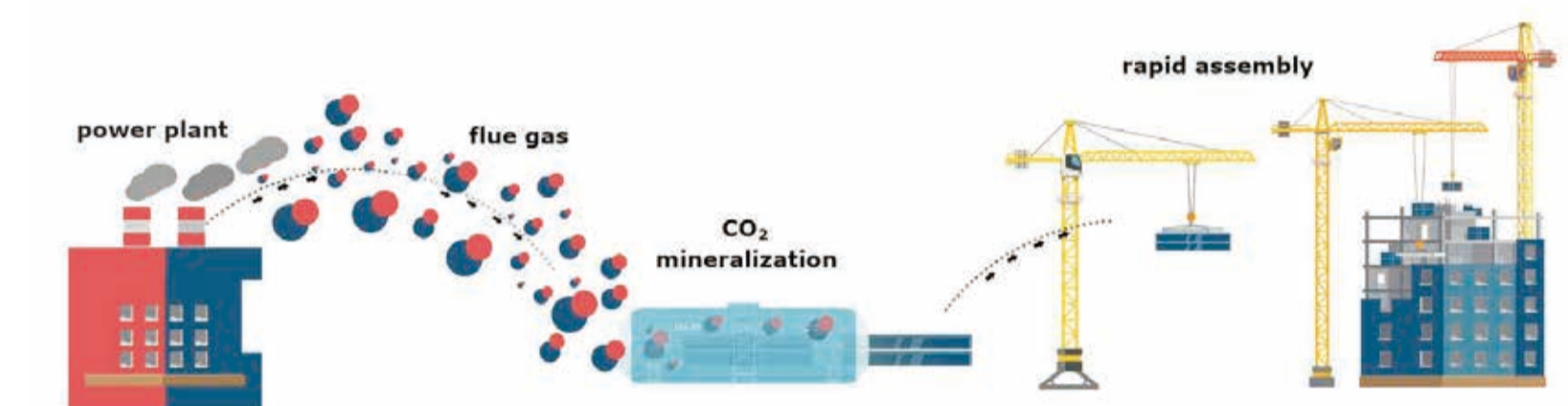
**The technology demonstrates energy efficiency and scalability** since (a) it directly utilizes CO<sub>2</sub> from flue gases without a need for carbon capture, (b) it operates at ambient temperature and pressure and does not need extrinsic energy, and, (c) it does not use ordinary portland cement (OPC), which is CO<sub>2</sub> and energy intensive. The core technology is cost-effective because it makes use of low cost and abundant materials as feedstocks that take up CO<sub>2</sub> including hydrated lime and coal combustion residuals. These materials fix CO<sub>2</sub> forming stable carbonates via a (patent-pending) CO<sub>2</sub> mineralization process, realizing a **carbon-neutral concrete since the CO<sub>2</sub> released during CaO formation is eventually absorbed**. The process can use CO<sub>2</sub> directly from dilute flue gas streams. A key advantage of this innovation involves creation of unique material formulations which are optimized for rapid CO<sub>2</sub> uptake.

### CO<sub>2</sub> emissions reduction potential

The technology can avoid emissions in excess of 1 billion tonnes CO<sub>2</sub> annually, due to reduced need for cement, reducing both energy and process-related emissions.

### Innovativeness

The technology is deemed to be superior in terms of CO<sub>2</sub> uptake, lower additional cost of integration to existing equipments, and energy efficiency.



## Turning CO<sub>2</sub> into CO<sub>2</sub>Concrete

Prepared by: Gaurav N. Sant, Ph.D.

Prepared for: Innovation for Cool Earth Forum  
Tokyo, Japan: October 10-12, 2018

CO<sub>2</sub>Concrete, LLC

Turning carbon dioxide into concrete

Source © CO<sub>2</sub> Concrete, LLC.

Title

# Development of a new, low combustible electrolyte for lithium ion batteries

Organization

## Hitachi and the Institute of Multidisciplinary Research for Advanced Materials of Tohoku University

Hitachi and the Institute of Multidisciplinary Research for Advanced Materials (IMRAM) of Tohoku University have jointly developed **a new electrolyte for lithium-ion batteries that have low combustibility** (with a flash point about 100 °C higher than conventional organic electrolyte solutions, whose flash point is about 20 °C). In addition, **it was calculated that conventional lithium ion conductivity is expected to increase fourfold.**

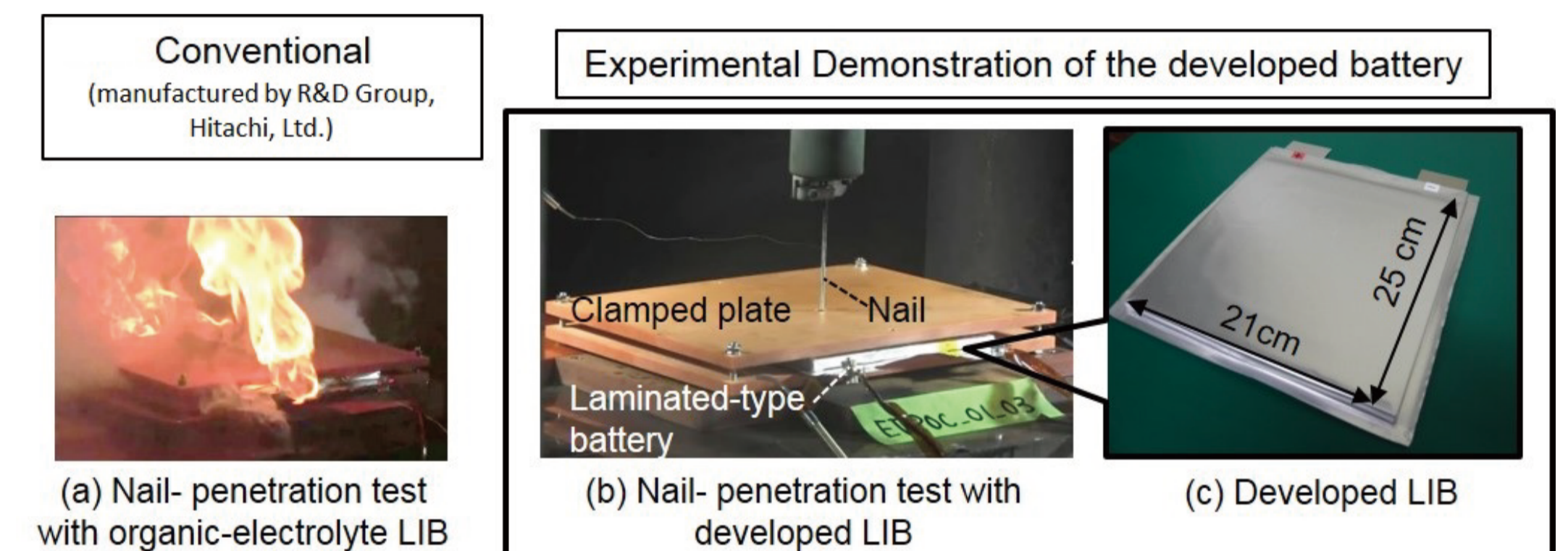
It is expected that the safety of lithium-ion batteries is increased significantly, while also increasing capacity and energy density. This is an important development for expanding the use of lithium ion batteries in stationary (e.g. homes) and mobile applications. **Additional benefit would be reduced reinforcements and cooling mechanisms to address safety, which can drive down the price.**

### CO<sub>2</sub> emissions reduction potential

Storage technology by itself does not reduce emissions, but is a key component of net-zero emissions society where the bulk of electricity is produced by renewables, and electrification is expected.

### Innovativeness

The technology is highly innovative due to its benefits which address multiple weaknesses of batteries: energy density and safety.



**Nail penetration test to confirm the properties of the new electrolyte**

Source © Hitachi, Ltd.

Title

# The world's first 100 kW class demonstration test of ocean current power generation

Organization

## NEDO and IHI Corporation

A 100 kW-class prototype subsea floating-type ocean-current power generation system has been developed. In 2017, **the world's first 100 kW class ocean-current power generation demonstration was conducted**. The demonstration test was carried out using the Kuroshio Current in the waters off the coast of Kuchinoshima, Toshima, Kagoshima Prefecture.

NEDO expects ocean-current energy to be a new renewable energy resource that **provides a large amount of energy with few fluctuations**. NEDO hopes for practical applications of the technology, especially on isolated islands, in addition to its potential contribution to energy security.

Using the results of this demonstration test, IHI Corporation will evaluate generation performances and control systems, with the goal of practical application of the subsea floating-type ocean-current power generation system, that effectively and economically utilizes ocean current energy after the year 2020.

### CO<sub>2</sub> emissions reduction potential

Ocean Energy Systems (OES) envisions that there is the potential to develop 337 GW of ocean energy by 2050 worldwide.

### Innovativeness

This project is world's first 100 kW class ocean-current power generation demonstration at actual sea.



Subsea Floating type ocean current power generation system; installation image

Source © New Energy and Industrial Technology Development Organization ([http://www.nedo.go.jp/english/news/AA5en\\_100295.html](http://www.nedo.go.jp/english/news/AA5en_100295.html))

Title

# Converting waste heat into electricity

Organization

## Climeon

Climeon, a Swedish company, provides technology that **converts low temperature waste heat from industries and geothermal heat into electricity**. It uses the temperature difference between hot and cold water (or the heat exchange of gas or steam) to produce clean electricity. The heat source is typically 70–120 °C and the cold source is 0–35 °C.

The system operates at low pressure (below 2 bar pressure), which enables a more compact and modular design. Each module generates 150 kW with a small footprint, is 2x2x2 meters in size, and requires only three connections including a hot source, a cold source and a power connection. These modules can be connected in a way that scales the system from 150 kW to 50 MW although the required number of connections remains at three.

**The efficiency of the system can be as much as twice as that of other low temperature solutions available today.** By using geothermal heat, the system is not affected by weather conditions, different from other renewable energy sources including wind or solar power.

### Market impact potential

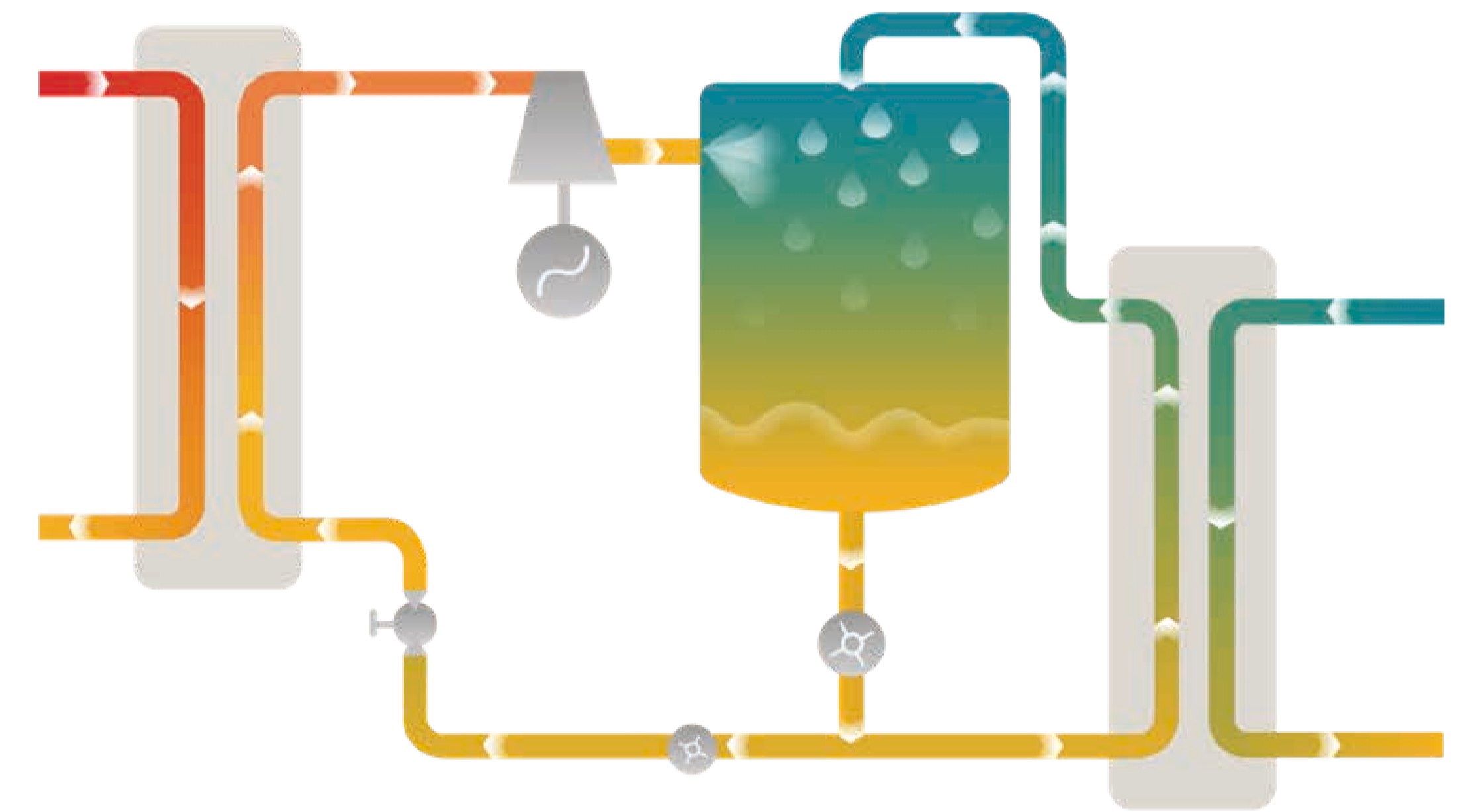
The efficiency of the system can be up to twice as much as that of other low temperature solutions available today.

### Uniqueness

The systems generate clean electricity from low temperature waste heat.

### Completeness

The technology has reached the commercialization stage and the system has already been released to the market.



Simplified Image of a Climeon Heat Power module

Source © Climeon  
(<https://climeon.com/ja/how-it-works-japan/>)



Title

# Delivering 100MW storage within 100 days

Organization

**Tesla, Inc.**

In 2016, South Australia experienced a statewide blackout. In March, 2017, Tesla CEO Elon Musk placed a wager to install a **100 MW battery system within 100 days** to solve South Australia's power crisis, or the system would be free (the total system cost is reported to be USD38 million). The 100 MW (129 MWh) Powerpack system was to be connected to a 309 MW wind farm. The race against the deadline began with the signing of the contract at the end of September. **The battery system was installed well ahead of schedule**, and was activated on December 1.

The system will deliver electricity during peak hours to prevent blackouts and increase grid reliability that will **accelerate the expansion of renewable energy**. Furthermore, it enabled Neoen, the owner of the wind farm, to **take advantage of the fluctuation in energy prices of the region and to maximize its profits**. The company is reported to have made USD800,000 in a matter of days. There are plans to build an even larger battery in South Australia.



View of the battery system and wind turbines

Source © Tesla, Inc.

## Market impact potential

The project can be a forerunner of large scale renewable / battery combination, which could change the game in enhancing profitability of renewable projects.

## Uniqueness

The project was far larger than previous battery system (30 MW), completed in record time.

## Completeness

The project takes advantage of an energy market with large price fluctuations. Its profitability is a testament to the viability of the business model.

Title

# The world's first hydrogen-powered train

Organization

## Alstom

The Coradia iLint from Alstom, **the world's first passenger train driven based on a hydrogen fuel cell**, has completed all test and homologation processes and has entered commercial operation in Germany. Three innovative energy functions are integrated into the design: clean energy conversion, flexible energy storage in batteries, and smart management of traction power. The vehicle generates low levels of noise and no emissions, exhausting only steam and condensed water.

The hydrogen fuel is derived as a by-product of an industrial process. In the future, Alstom aims to support hydrogen production from renewable energy such as wind power. **Having been approved for commercial operation by the German Railway Office for passenger service, the first two trains entered passenger service** in September 2018.

Once a large amount of renewable energy is installed in the power system, some part of the energy produced may need to be curtailed to balance the grid. Hydrogen will be one of promising technologies to convert such electricity. The use of hydrogen as train fuel is seen as a viable entry point for hydrogen fuel in the transportation sector. The Coradia iLint innovation represents a major step towards cleaner mobility, particularly for secondary lines where overhead lines are uneconomic or unavailable.

### Market impact potential

The vehicle can reduce carbon emissions in the transportation sector and help introduce renewable energy on a larger scale.

### Uniqueness

The train is the world's first to run on hydrogen.

### Completeness

The technology has successfully passed all test runs, received certifications from standardization bodies, and entered commercial operation in Germany.



**The world's first hydrogen-powered train**

Source © Alstom / Rene Frampe

(<https://www.partners.alstom.com/Assets/View/92a183b6-b12a-4561-b356-76a587d0de4e>)