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White Paper

Global Innovations from the Energy Sector 2010-2020

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Contents

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Introduction

Lin BoQiang
Chair of International Energy Community, China

Much progress has been made by the energy industry to accelerate sustainable energy innovation[1] during the past decade.

Driven by China, the wind and solar photovoltaic (PV) industries have demonstrated their ability to lower energy costs in the past 10 years. The global benchmark price for solar has dropped 84% and for wind by over 50% since 2010.[2] Wind and solar have started – on a global average – to outperform newly built fossil fuel-based electricity generation in terms of cost. In many parts of the world, the cost of energy from wind and solar PV is now lower than new coal and gas plants. Innovation across the supply chain, within the manufacturing plants, as well as module efficiency and blade-size innovations contributed to these reductions.[3]

Meanwhile, the price of lithium-ion battery storage has dropped by approximately 85% since 2012. The fact that the three scientists responsible for the development of lithium-ion batteries, starting back in the 1970s, won the Nobel Prize in Chemistry in 2019, highlights how important this energy source has become over the past decade.[4]

In parallel, innovations in hydraulic fracturing and horizonal drilling (or fracking) have resulted in a technological revolution in natural gas and oil extraction. In the past three to four years, the United States, which led many of the developments in this area, became an energy-producing superpower as a result.

In 2019, the World Economic Forum's International Energy Community in China decided to launch a competition to highlight examples of disruptive innovations coming from the energy sector over the past decade. Between September and December 2019, the submissions were evaluated by a panel of experts from China, the US, Europe and Africa.

This paper showcases a selection of the submissions judged to be novel, beneficial to society and contributing to accelerating the energy transition. The successful submissions are grouped into six chapters: Critical Infrastructure; Emission Reductions; Energy Efficiency; Systemic Efficiency; Renewables Integration; and Access to Electricity. Each chapter is drafted by experts from the organizations responsible for the selected innovations.

I hope you enjoy the result.

1 Critical Infrastructure

Transmission and distribution grids are the backbone of the entire electricity network. Innovative grid technologies play a key role in addressing energy transition-related opportunities and challenges. Three significant examples of innovation in this space are highlighted below.

Contributors

Harmeet Bawa
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Hartmut Huang
Head of Power Electronics, Power Transmission Solutions, Siemens Energy

Michael Walsh
Managing Director Europe, Smart Wires.

Balancing the growing need for electricity with minimal environmental impact

Despite an expected 6% reduction in energy demand in 2020 due to the COVID-19 pandemic, the global need for energy is likely to continue to rise, with electricity demand growing at an even faster pace.[5] The ways in which electricity is generated, distributed and consumed have changed, driven by increasing pressure to reduce environmental impact, resulting in new complexities and leading to an unprecedented transformation of the power sector.

On the supply side, there has been a significant influx of renewables (often remotely located and non-dispatchable) into the energy mix to reduce dependence on fossil fuels. In the past decade, renewables (excluding hydro) have grown from 3% to 10% of the global electricity mix. From a demand perspective, there are new “loads” such as electric vehicles and data centres that also need to be factored in. These radical changes require our critical electricity infrastructure to be more flexible and agile than ever before, without compromising on power security, reliability, efficiency or affordability.

Shaping the future of energy with a technology that changed the world

High-voltage direct current (HVDC) power transmission allows high volumes of power to be transported across large distances. A HVDC transmission link includes a converter station, converting AC voltage into DC voltage, a transmission line and another converter station at the other end of the line, converting DC voltage back into AC voltage.

Following its breakthrough innovation of HVDC in 1954, in 1997 ABB introduced HVDC Light™, a new voltage-sourced converter (VSC) solution, using power electronics for greater controllability and making smaller HVDC systems economically viable. HVDC Light™ enabled the transmission of large amounts of power, underground, underwater and on overhead lines and was ideal for applications like city in-feeds and interconnectors.

As we renew our push for a clean energy transition post COVID-19, this will be a key enabling technology for integrating bulk renewables, offshore wind connections and interconnections.

In the past decade, HVDC Light™ has seen many advances. Power capacity was boosted from 50 to over 3,000 megawatts (MW), enough to power millions of households. Voltage levels increased from 80 to 640 kV, increasing distance capability to 2,000 km and bringing transmission losses down to less than 1%, while advances in control and protection systems continued to provide greater efficiency and reliability. This latest generation of HVDC Light™ is significantly more compact, a big benefit in applications like cross-border interconnections.

The world's first commercial HVDC transmission system, the Gotland HVDC link, built by ABB in 1954

"In 1954, ABB introduced HVDC – a technology that changed the world. Today, HVDC is the technology of choice for integrating large-scale renewables, connecting offshore wind farms, building interconnectors and efficiently and reliably transmitting clean energy across vast distances to hundreds of millions of consumers around the world. Continuous innovations have helped keep our pioneering technology heritage alive and reinforced our commitment of enabling a stronger, smarter and greener grid."

Claudio Facchin
President, ABB Power Grids

Grid access for offshore wind parks

While HVDC technology has been developed and applied mainly for bulk power transmission over long distances, the access and the integration of renewable energy, particularly offshore wind, have become essential for the electrical power supply now and in the future.

However, grid access for remote offshore wind parks also brings new technology challenges; e.g. mandatory AC/DC power converters, black-start capabilities, compatibility with a low-inertia offshore grid. A newly developed power electronic converter – modular multilevel converter (MMC) – addresses these challenges.

MMC technology was commissioned for the first time in 2015 to connect a North Sea offshore wind project, Borwin2, to the grid. There are currently nine DC links in service or under construction in the North Sea based on MMC technology and delivered by big market players including Siemens, ABB and GE.

The successful grid access of offshore wind parks in the North Sea using this technology accelerates significantly the development of offshore wind in other regions as well; e.g. the US and China. It can also be used to supply high power consuming onshore and offshore industries such as oil and gas installations with renewables-based energy, helping these industries reduce their CO2 emissions.

"Energy transition needs innovative technologies to address technical challenges associated with renewables. Advanced power electronics provide the necessary technical features and solutions. The successful application of MMC technology for grid access of large offshore wind parks is a technological breakthrough and a great contribution to the energy transition."

Beatrix Natter
Executive Vice-President and Chief Executive Officer, Transmission Division, Siemens Energy

MMC is a new converter topology with excellent power-quality characteristics using the modern semiconductor device IGBT as switching elements. Using MMC for AC/DC conversion improves the dynamic performance necessary for weak or passive networks combined with low-footprint and high-energy efficiency. Application of MMC for AC and DC transmission was pioneered by Siemens introducing HVDC PLUS™ and SVC PLUS™ in 2010. During the past decade, MMC technology has been gaining increasing importance in power transmission and particularly for connecting offshore wind parks.

HVDC converter station in front of an offshore wind park

Increased utilization of existing infrastructure

Meanwhile, back on land, the new clean energy being generated from renewables-based sources needs to find pathways to the homes and businesses that need it. As adding or changing traditional onshore grid infrastructure can have a large financial, community and environmental impact, it is crucial that we also identify new ways to make more power flow through the existing grid.

Globally, technology companies such as Smart Wires, are helping grid operators meet the increased demands on critical infrastructure by using power flow control technology to solve congestion problems. These physical solutions can be deployed quickly and come in a modular format so that installations can be added to or removed as grid needs change, providing valuable flexibility and reducing congestion. The technology also allows real-time digital control of power flows, which allows the grid network itself to be dispatched in response to the real-time needs of society.

"It's remarkable how much spare capacity exists on today's grid. We regularly find projects where we can release several GWs of capacity in under a year without disturbing communities or the environment. This is causing leading utilities across Europe, Australia and the Americas to change the way they think about future investments in critical infrastructure."

Gregg Rotenberg
Chief Executive Officer, Smart Wires

In 2019, United Kingdom Power Networks (UKPN) installed Smart Wires power flow control technology on two circuits in a constrained region of its grid. An advanced algorithm runs to determine the amount of power flow control needed to balance flows across multiple circuits in real-time. This project allowed UKPN to increase capacity for local, distributed renewable resources while minimizing the impact of new infrastructure on communities.

Power flow control technology by Smart Wires

2 Energy Efficiency

Now, more than ever, organizations and governments are struggling to realize the tremendous potential of the world's cleanest energy – the energy which is not consumed. Yet, according to the International Energy Agency (IEA), global energy efficiency improvements have been slowing down each year since 2015.

This section highlights two significant energy sector specific innovations addressing energy efficiency introduced during the past decade.

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The power of the drive

Today, approximately one-third of global electricity is converted into motion by electric motors, with the number of motors in the world expected to grow. Approximately 50% of motors are connected to a pump or fan. The motors that power these applications are often set to run continuously at full speed when they don't always need to, wasting energy in the process. Variable speed drives can control the speed of the motor, so it uses the precise amount of energy required to perform the task, cutting waste. Even a small reduction in motor speed can result in significant energy savings.

ABB's installed base of variable speed drives reportedly saved 515 terawatt hours of energy in 2017, comparable to approximately eight days of global electricity consumption.[6]

Industrial pumping applications are a prime target for energy savings

In 2011, ABB launched a highly efficient synchronous reluctance motor (SynRM IE4) that offered the performance advantages of permanent magnet technology without the use of rare earth magnets. Case studies in industrial installations have demonstrated energy savings of up to 25%, depending on the application. Additional benefits of this motor technology include lower bearing and winding temperatures for enhanced reliability and long life. The design also creates less motor noise for a better working environment. SynRM motors now meet the new IE5 ultra-premium energy efficiency class defined by the International Electrotechnical Commission (IEC). These motors offer up to 50% lower energy losses and significantly lower energy consumption when compared with commonly used IE2 induction motors. SynRM motors are controlled by a variable speed drives to further maximize energy savings.

"A global consensus on climate change is driving industrial demand for solutions that increase energy efficiency. Our SynRM motor innovation is just one example of our commitment to develop technology that will help drive the low-carbon future for industries, cities, infrastructure and transportation. At Motion, our mission is to keep the world turning, while saving energy every day."

Morten Wierod
President, ABB Motion

Reducing consumption in oil refineries

Heat exchangers are used to transfer heat between fluids. They are commonly used for space heating and air conditioning but also in industrial processes such as power stations and oil refineries.

Fouling, or dirtying, of the heat exchangers is a common phenomenon in oil refineries, which results in the consumption of between 2%-3% more energy, equal to 0.25% of the GDP of industrialized countries.[7] Fouling mitigation techniques can reduce energy usage and therefore GHG emissions in the main refinery units by 3%-10%.[8] In 2010, Repsol found a solution to this challenge.

repHEN (Repsol Heat Exchanger Network) is an easy-to-use monitoring tool used by energy efficiency technicians at refineries to select the best cleaning schedule for heat exchangers to avoid increasing furnace fuel consumption through fouling. The initial prototype was tested in 2010 and has now been implemented in all Repsol's main heat exchanger networks. It also calculates costs and emissions associated with fouling and their evolution over time, helping Repsol's specialists to adopt new preventive measures, such as process or equipment redesign.

Boosting energy efficiency across Repsol's heat-exchanger networks

"At Repsol, we are steadily advancing on the road to the energy transition, deploying ambitious programmes to improve the energy efficiency of our operations."

Josu Jon Imaz
Chief Executive Officer, Repsol

3 Renewables Integration

According to projections,[9] costs of solar PV energy will decrease by 50%, while onshore and offshore wind energy costs will fall by 25% and 50% respectively by 2030, driven by technological improvements and economies of scale. In recent years, the integration of renewable energy has required a rethinking of energy systems, policy interventions and interactions with consumers. Here are some examples of innovation in this area over the past decade.

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Renewables integration through smart grids

A smart grid is an energy distribution system that combines three elements: traditional electrical equipment; electronic meters; and information and communications systems. The latest generation of smart grids are flexible, secure, efficient and sustainable, and the digitization of the grid makes it easier to manage the ongoing mass integration of renewables and the future mass integration of electric vehicles.

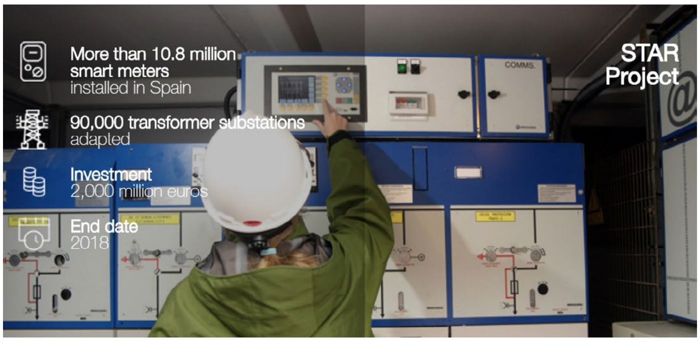
In 2010, European Union directives were encouraging utilities to modernize their distribution grids to be able to handle the influx of decentralized renewable projects being planned and constructed. Iberdrola saw this as a huge opportunity to contribute to the decarbonization of the economy, to improve the efficiency of the network, to optimize demand management and, most importantly, to promote the integration of large quantities of renewable energy.

Over the past decade, Iberdrola's STAR project has had a significant impact on smart grid development and the integration of renewables in Spain, the UK, the US and Brazil. With an investment of €2 billion, Iberdrola has digitized its distribution network in Spain, installed over 10.8 million digital meters and provided remote management, supervision and automation capabilities to over 90,000 sub-stations. In addition, Iberdrola's networks and retail subsidiaries have contributed to configuring some of the most advanced smart grids in the world:

- In the US, 1,000,000 smart meters have been installed in Maine, Connecticut and Ithaca
- In Brazil, over 220,000 smart meters have been installed in the states of Grande do Norte River, Bahia and Pernambuco
- In the UK, Iberdrola's commercial subsidiary has installed more than 1,080,000 smart meters with the Smart Meters project

"Thanks to our €2 billion STAR project, we have a fully digitized network, from our substations to the meters of our 11 million distribution customers at their home. As a result, the company can operate the network instantaneously, automatically and remotely, improving our capacity of response to incidents, which are now solved with greater speed and efficiency"

Ignacio S. Galán
Chief Executive Officer
and Chairman, Iberdrola



Policy frameworks to support renewables integration

Stable long-term policy frameworks designed around the integration of renewables are required to provide clear signals for investors. The European Bank for Reconstruction and Development (EBRD) has been working on some practical examples in Kosovo and Kazakhstan.

Kazakhstan suffers extremely cold winters with temperatures below -40°C. The country has traditionally relied on abundant and cheap coal reserves to produce heat and electricity at affordable low prices.

In 2008, the EBRD started a cooperation with the Government of Kazakhstan, resulting in the development of a renewable energy law, the introduction of a feed-in tariff system and the agreement of a National Concept for the Transition to a Green Economy in 2013. This laid the ground for the deployment of large-scale renewable power projects in the country with the first ever utility-scale solar farm, with capacity of 50 MW, financed by EBRD, commissioned in 2015. Over the past five years, 672 MW of renewable projects have been financed with support from EBRD. Currently, the EBRD is actively supporting the country in the transition to competitive tendering of renewable projects.

100 MW Saran solar power plant, Karaganda region, Kazakhstan

In Kosovo during the winter period when demand for electricity is highest, businesses are regularly disconnected from the grid and KESCO, the local utility, has to import significant quantities of electricity at short notice.

The EBRD worked closely with the Energy Regulatory Office to structure a balancing mechanism in Kosovo (in the absence of a liquid balancing market). This balancing mechanism ensures that renewable producers actively participate in balancing the system by requiring that they absorb 25% of the imbalance cost caused, up to a maximum of 5% of the project’s annual revenue. This has already led to renewable producers investing in weather forecast services and software to improve their performance on the system.

“The future of energy will look very different from today but the wholesale transition from old to new is already underway. In Kazakhstan and Kosovo, for example, we see countries that have relied for generations on coal-fired power moving at speed to green, reliable and affordable renewable energy. In Kazakhstan, we have already financed 672 MW of renewable capacity in just five years while in Kosovo we financed in 2019 two wind farms that will together provide more than 10% of the installed generating capacity. We are on the cusp of a revolution in energy, and we need to think innovatively and invest in large-scale renewable energy and associated facilities to ensure that we leave a sustainable future and a cleaner planet to future generations.”

Nandita Parshad
Managing Director, Sustainable Infrastructure Group, EBRD

Shared value cooperatives

Approaches such as socially responsible investing and environmental, social and governance screening have increased in relevance during the past decade. However, examples where treating social and environmental issues as integral to a company's core strategic positioning have resulted in growth, profitability and competitive advantage remain elusive.

In the UK, Falck Renewables and Energy4All have pioneered a shared value model between local communities and renewable energy plants. Local communities in the vicinity of a proposed renewable project are encouraged to set up financial cooperatives whose members participate in the funding of the project.

Through creating a sense of ownership and a financial reward for the community, the model contributes to the "social acceptance" of the project in a territory.

"This disruptive model of shared value creation allows local communities to experience the presence of renewable plants as a true upside for their territory. We intend to export the benefits of this approach to all the countries where we operate, adapting it to the different local specificities we encounter."

Toni Volpe
Chief Executive Officer, Falck Renewables

So far, seven cooperatives have been created from 2005 to 2019, involving more than 3,500 members who have raised over £10.7 million and paid share interest of around £6 million. The model has become a benchmark in the renewable energy sector and helps Falck Renewables to receive a consistent degree of acceptance in all the countries where the company operates.

Ben Aketil Wind Farm Cooperative on the Isle of Skye, Scotland

Digital technologies – blockchain

The Energy Web Foundation (EWF) was created in 2017, co-founded by Rocky Mountain Institute and Grid Singularity. EWF quickly built out the energy web chain, a blockchain platform designed specifically for the energy sectors to build and run blockchain-based apps.

The tracing of renewable origin of energy is an ever-increasing demand, associated with the growth of the corporate contracting market for green energy, and is one of the use cases for blockchain technologies which has been led by renewables companies such as Acciona. In recent years, projects have been deployed to guarantee 100% renewable origin of energy supplied to customers, and it is particularly important in those markets that lack existing renewable energy certification schemes.

"GREENCHAIN® is not only a platform to trace the 100% renewable origin of our energy, it is also an approach to involve clients in our commitment to sustainability. Furthermore, with this innovative project we prove that a blockchain-based solution can be commercially viable on a large scale."

José Manuel Entrecanales
Chairman and Chief Executive Officer, Acciona

Acciona's GREENCHAIN® application, based on blockchain technology, enables clients to check – in real time and from any location in the world – that 100% of the electricity they consume is clean. The advantages of the system lie in the simplicity of its integration with data systems, both of Acciona and the end client: ease of access, scalability and the complete security and privacy of data that blockchain ensures. Customers can check the specific renewable plant that is generating the electricity, as well as past consumption statistics and other relevant data, such as CO2 avoidance or the social initiatives that Acciona is carrying out around the project that supplies them.

Acciona's GREENCHAIN® active in Mexico

4 Systemic Efficiency

Among all the primary energy used (~14,000 Mtoe for 2018) only 33% is converted into useful energy. The remaining 67% is lost due to inefficiencies in electricity generation, transport, heavy industry and buildings. These inefficiencies can be addressed through sector optimization (e.g. electrification, grid efficiency, building and industry energy efficiency), as well as cross-sector optimization (e.g. optimized usage of energy mix through better design at the intersection of sectors).

This section highlights select innovations coming from the energy sector during the past decade which address systemic efficiency.

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A Joint Venture of The Carlyle Group and Schneider Electric

Marco Gazzino
Head of Innovability, Enel X

Robert Denda
Head of Network Technology and Innovation, Enel

Maikel Bouricius
Marketing Manager, Asperitas

Harnessing the power of digital

Integrating digital technologies has become a necessity for energy companies to do business. While more understanding on how to best leverage digitalization is needed within the industry, there are some business models that have emerged to use digital technologies to optimize efficiencies and effectiveness within the energy sector. Enel's Network Digital Twin® is one digital technology innovation from the past decade that stands out.

Network Digital Twin virtual reality user experience

Enel's Network Digital Twin® is a digital platform that creates an up-to-date and accurate virtual replica of the physical power network, its components and system dynamics. This technological disruption relies on pervasive digitalization combined with the use of new disruptive technologies: sensors, 3D modelling, artificial intelligence, and augmented and virtual reality. By creating a comprehensive view of what happens and simulating what might happen in the power networks, this technology supports system operation, network design, integration of distributed energy resources and workforce management, while at the same time fostering new forms of engagement and interaction with municipalities, technology partners, customers and other stakeholders.

"Electricity grids are among the most important infrastructures. Their digitalization through the Network Digital Twin® enhances the capability of managing unforeseen events, such as those related to extreme weather, which are becoming increasingly frequent and intense due to climate change. Beyond contributing to systemic efficiency and resilient infrastructures, Enel's solution also creates a digital urban platform connecting institutions, utilities and citizens within an ecosystem for sustainable living in cities, the Urban Futurability."

Francesco Starace
Chief Executive Officer and General Manager, Enel

Meanwhile, Schneider Electric and the Carlyle Group formed a joint venture, AlphaStruxure, in early 2019 which can be described as both a technology and business model innovation, providing Energy as a Service (EaaS) to large energy users across the commercial, industrial and infrastructure sectors.

Building the Next Generation of Energy Infrastructure

Increasing energy costs, declining reliability of the electric grid and the urgent need to reduce greenhouse gas emissions all create an imperative for a new approach to energy and infrastructure. AlphaStruxure designs, builds, owns and operates decentralized energy systems that deliver sustainability, reliability, resilience and long-term savings for large energy users across the commercial, industrial and infrastructure sectors. AlphaStruxure provides an EaaS model that empowers customers to stabilize long-term energy costs and upgrade critical energy systems without capital investment. Among AlphaStruxure's projects is the new Terminal One at JFK International Airport, which will incorporate multiple microgrids to move the facility towards 100% renewable energy within the next decade.

"We need to decarbonize cities and infrastructure at scale and at pace. It is do-able with existing technologies and a new way of thinking. AlphaStruxure was launched to change the way infrastructures are designed and built for a more sustainable future. It is one step to create more modern airports, water systems, transportation systems and others that will support future demand and connect society."

Jean Pascal Tricoire
Chairman and Chief Executive Officer, Schneider Electric

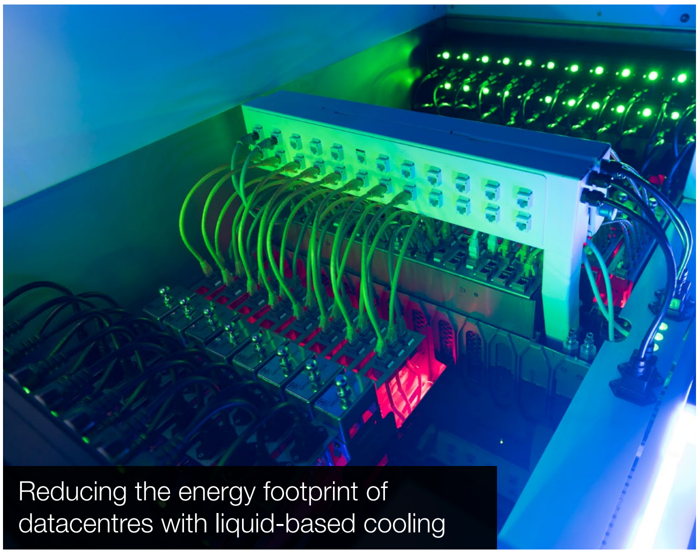
Cooling the data centres

The global data centre industry has been one of the fastest-growing energy-consuming industries, accounting for about 1% of global electricity demand in 2018 and projected to continue growing. A data centre cooling system is vital to maintain IT equipment working in a safe and reliable manner; inefficient systems can account for up to 40% of the centre's energy consumption.

Traditionally, there are two ways of cooling a data centre: air-based cooling and liquid-based cooling. However, in recent years new cooling solutions and technologies, such as fully immersed direct liquid-cooled systems, have gained momentum as they offer significant efficiency gains as the demands on equipment increase.[10] A partnership between Shell Research Limited and Asperitas provides a good example.

Asperitas uses Immersed Computing® to reduce the energy footprint of datacentres by up to 45%. It eliminates the need for air-cooling systems by submersing IT hardware in a fluid specifically designed by Shell for data server immersion cooling. The Shell Immersion Cooling Fluid is a synthetic, dielectric, single-phase immersion cooling fluid made from natural gas using Shell's GTL (Gas to Liquid) Technology.

A key benefit is that this solution is able to capture up to 98% of the energy put into the system as (waste) heat and reuse it to generate warm water of 55 degrees Celsius, effectively providing surrounding communities with ready-to-use residual heat for district and industry heating. The technology was introduced to the market in 2017 after an extensive R&D phase with the support of committed partners. The first commercial deployment has been running since 2018 and a variety of customers throughout Europe are already using this technology.


Reducing the energy footprint of datacentres with liquid-based cooling

"Cross-industry collaboration is fundamental to helping society reach net zero emissions. Industries in different sectors need to work together. We need to look at the whole system, then work out an approach by which each sector can decarbonize. Progress across all sectors will help society move towards meeting the goals of the Paris Agreement. At Shell we are committed to playing our part."

Harry Brekelmans
Projects and Technology Director, Shell

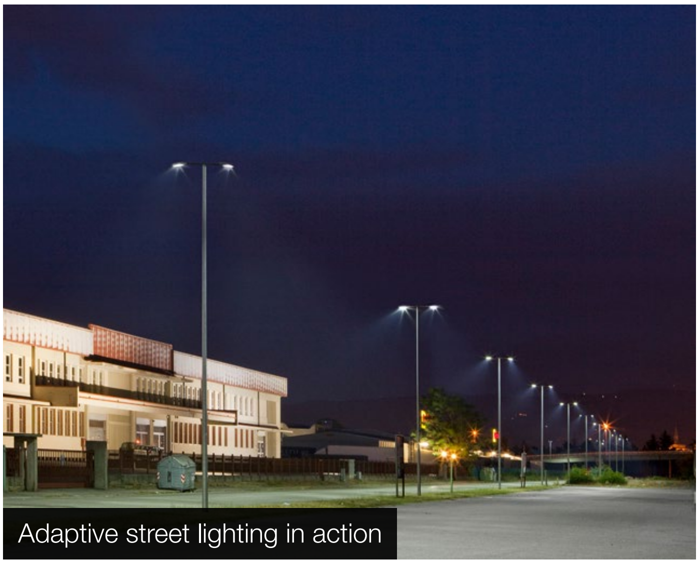
Smart lighting for smarter cities

United Nations projections indicate that 68% of the world's population will live in cities by 2050. Today, lighting services account for 15%-25% of energy spending in cities. In Italy, in 2017, public lighting consumed 6 TWh of electricity, costing about €1.7 billion and generating 1.9 million tons of CO2.

India's Domestic Efficient Lighting Programme, launched by the government in 2015, facilitated rapid scaling of the market for LED bulbs through competitive tenders. The first year of tenders saw LED prices fall by 55%, the sale of 60 million LEDs, and a reduction in nationwide electricity demand by nearly 2 GWh.[11]

Adaptive (or intelligent) street lighting allows street lighting to be modified to suit real traffic, weather and lighting conditions. Advantages include maximum possible energy savings and optimal street lighting. Enel's new adaptive lighting system can recognize specific local needs (e.g. traffic jams, car accidents) and boost lighting levels to 120% to improve safety.

In order to boost sustainability and economics of traditional lighting systems, Enel X launched a new adaptive lighting system, reaching 36% energy savings on top of the savings already achieved by traditional LED technologies with predefined power profiles. The integrated solution developed by Enel X focuses on street-light efficiency, ensuring maximum safety for citizens as well as electricity consumption optimization for local administrations. Enel X's adaptive lighting solution can achieve these results thanks to video analysis and neural network algorithms, enabling automatic dimming of streetlights based on real-time analysis of traffic, weather and luminance. The technology has been tested since April 2018 in two Italian cities and is one of Enel X's smart lighting flagship products.


Adaptive street lighting in action

"Urbanization and urban sustainability are two disruptive trends that are transforming cities and citizens' lives. These trends require advanced services to empower cities' resiliency and increase energy and lighting efficiency in urban environments. Enel X is collaborating with institutional stakeholders and customers to enable municipalities seizing these opportunities and deploying viable sustainable solutions."

Francesco Starace
Chief Executive Officer and General Manager, Enel

Systemic efficiency with health co-benefits

One of the positive side effects from approaching efficiency more systemically is the health co-benefits. Professor Khee Poh Lam of the National University of Singapore recently highlighted the need for green building design not only to address energy wastage but also to consider the impact of the indoor environment on occupants' health, comfort and productivity.

Meanwhile, Sinochem China has focused on the outdoor environment around its petrochemical plants, where research indicated that the impact of accidents was amplified by vehicle congestion near tank farms or chemical plants, often due to disorganized loading or unloading schedules and lack of information transparency.

In an interesting example of innovation transfer from the transport/logistics sector to the energy sector, in 2018 Sinochem launched the Vehicle Queuing Reservation System, a digital information system and safety-management tool combined. The system allows for remote querying of delivery plans, advance scheduling of loading and unloading, information on vehicles location and real-time tracking of vehicle queuing information. As a result, driver waiting time has been shortened from 3.22 hours to 1.18 hours, site-safety risks are reduced, land-resource usage is optimized and environmental pollution is reduced.

"In China, safety supervision of moving hazardous materials is our primary concern. I am delighted that we are taking our social responsibility. Our digital innovation of queuing system has reduced the safety risk of sites and improve driver and operating personnel well-being while saving lots of land resources from being occupied by parking. "

Sun Liming
Vice President of Sinochem
Energy High-Tech

5 Emission Reductions

Global energy-related carbon CO_2 emissions stopped growing in 2019 while the world economy expanded by 2.9%.[12] However, greenhouse gas emissions are not limited to CO_2 emissions and this section highlights some innovations from the past decade linked to emission reductions.

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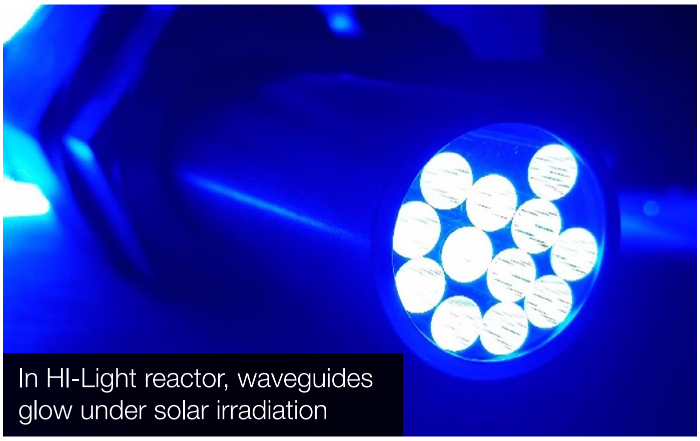
Emissions of carbon dioxide (CO2)

While carbon-capture technologies have yet to prove themselves commercially viable, much progress has been made in the past decade. Most planned/active CCS (carbon capture and storage) projects are currently in sectors where CO2 is readily available and can be captured at a relatively low cost.

On power generation, China Huaneng has recently equipped several of its coal-fired power plants with carbon capture systems; e.g. currently approximately 100,000 tonnes of CO2 are being captured per annum from one of Huaneng's coal power generation plants near Shanghai.

In recent years, carbon capture, utilization and storage (CCUS) has become a critical part of the industrial technology portfolio. Many industries, including chemicals and oil & gas, have begun developing technologies that transform CO2 from a waste material stored in different areas to a raw material that could be used in chemical processes or the food and drink industry.

As of 2019, there were 20 large-scale CCS facilities in operation, mostly linked to enhanced oil-recovery operations, and over 15 utilization facilities in places such as India, Canada, the US, China and Japan.[13]



In HI-Light reactor, waveguides glow under solar irradiation

Part of the solution to reduce CO2 emissions is to convert the pollutant into fuels and feedstocks that could serve as the building blocks for products that people use every day. Since 2016, researchers at Cornell University, together with a start-up called Dimensional Energy, developed a chemical reactor called HI-Light, which can convert CO2 into either syngas or methanol in an artificial photosynthesis process.

"It is our vision to reimagine CO2 as a useful resource rather than a waste. The 'HI-Light' reactor (developed by Cornell and commercialized by Dimensional Energy) is a solar-driven approach for converting CO2 into fuels. It ensures light availability and maximizes light scattering, and offers potential for upscaled CO2 conversion through efficient use of the sun's energy through artificial photosynthesis."

Xiangkun (Elvis) Cao
the Erickson Lab at Cornell University

Emissions of sulphur dioxide (SO_2), nitrogen oxides (NOx) and dust

Globally, intensive retro-fitting programmes on coal plants are resulting in increased efficiencies and a reduction in emissions of SO_2, NOx and particulate matter (or dust) emissions from coal plants.

Huaneng Yuhuan 4×1000MW Coal-fired Power Plant

From 2015-2018, China Huaneng invested a total of 16.9 billion yuan to renovate 112 GW of installed coal-generation capacity (representing 94.7% of its entire coal fleet) to ultra-low emission status. As a result, in 2018, China Huaneng's sulphur dioxide, nitrogen oxide and dust emissions reduced by 71%, 47%, 80% respectively compared to 2015.

Sulphur dioxide	Nitrogen oxide	Dust emissions
-71%	-47%	-80%

"The global energy transition is an irreversible trend. China Huaneng constantly accelerates structural changes and continuously increases the proportion of renewable energy. We also vigorously promote energy saving and emissions reduction and strive for high efficiency and ultra-low emissions of coal-fired power units, so as to contribute to the safe, clean, efficient and sustainable development of the global energy sector."

Yinbiao SHU, Chairman of China Huaneng Group

Emissions of SF6

More than 10,000 tons of SF6 gas (the most potent greenhouse gas in the atmosphere) are produced per annum, most of which (over 8,000 tons) are used as an effective electrical insulator and/or arc-quenching mechanism for circuit breakers, GIS and other switches (collectively known as switchgear) helping to prevent accidents and fires.

Global SF6 emissions from the electrical industry have been increasing due to loss of gas through poor gas-handling practices during equipment installation, maintenance and decommissioning, and leakage from SF6-containing equipment.

"In 2017, Siemens introduced Blue switchgear to the world – a technology that is completely environmentally friendly and is ideal to support decarbonization. Today, more than 1,150 bays around the world are transmitting power efficiently at the highest levels of safety and helping to reduce the ecological impact. Digital transformation (Sensgear® & Sensformer®) of conventional products through continuous innovations are strengthening our commitment to make transmission networks efficient, resilient, smarter and sustainable."

Beatrix Natter
Executive Vice-President and Chief Executive Officer, Transmission Division, Siemens Energy

Instead of SF6 gas, Blue switchgear comes with clean dry air insulation and a vacuum interrupter, which is completely environmentally friendly eliminating the impact of SF6 gas to the environment. It provides maintenance-free operation, high operational safety as well as utmost environment protection and ease of handling. Additionally, in 2019, Blue switchgear was enhanced to a digital product as Sensgear® to further improve productivity, performance and reduce unplanned downtime. Further, our digital power and distribution transformers, Sensformer® including high voltage components could be filled with Ester oil, which is fully biodegradable and safe for the environment.

Electrical switchgear shifting away from SF6 gas

Biofuels

The IEA reported that by 2018, more than 45 countries had policies in place to support the use of biofuels in the transport sector. Nonetheless, as of 2019, aviation contributed 2%-2.5% to worldwide CO2 emissions (the equivalent of Canada). As such, the reduction of aviation's emissions has been (and continues to be) a critical component of global climate mitigation action aimed at limiting warming to 1.5°C.

Solaris is a multi-purpose crop and defined as an ultra-low indirect land-use change (ILUC)[14] crop. Apart from the oil, the seed cake left after pressing is a high-protein feed and the biomass can be used as animal feed or to produce textiles. The leftover seed cake also decreases the dependence on African imports of soy cake.

While key alternatives to oil for aviation, such as clean hydrogen, advanced biodiesel and bio-kerosene are not yet available at commercial scale, 2016 saw South African Airways (SAA) perform Africa's first flight powered by sustainable aviation fuel produced from Sunchem's nicotine-free tobacco plant, Solaris. The fuel was refined by World Energy Fuels in the US, supplied by SkyNRG and the initiative was supported by Boeing.

"Solaris has proven to be a successful crop in South Africa for different biofuel markets such as the aviation market for which we delivered the first feedstock for Africa's first green flight and more recently the signing of Project Reya Fofa in which we will start producing biofuel locally for O.R. Tambo ground handling."

Hayo de Feijter
Executive Director, Sunchem BV

6 Access to Electricity

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The past decade

In 2010, about 1.2-1.4 billion people around the world lacked access to electricity, the majority living in sub-Saharan Africa or in rural areas. By 2019, according to IRENA et al,[15] that figure was approximately 840 million, with Kenya, Cambodia and Myanmar notable contributors to the electrification drive. Still, today, in Africa, over 600 million people do not have access to electricity.

One of the main developments in electricity access is the general acceptance of three credible methods for connecting households and industry to a reliable electricity supply – grid extensions, mini-grids and stand-alone systems. All three methods are being incorporated into many countries' national policies and strategies.

Grid extensions

Grid extensions, when available to households, are generally the lowest cost option for access to electricity.

Since 2013, Power Africa has been working with electricity transmission and distribution companies to improve planning of grids, operations and financial sustainability. Power Africa has helped to establish almost 900,000 new on-grid connections across Nigeria, Ethiopia and Uganda in the past seven years.

Electricity theft is more significant in Africa than in most other regions. Theft reduces revenues for already stretched utilities and lowers investment in the broader system, while increasing the cost of electricity for paying customers.

Between 2010 and 2015, a novel model by Tata Power Delhi Distribution Limited's (TPDDL) connected 175,000 new customers to the grid in 217 neighbourhoods near New Delhi. The approach reduced new connection charges, offered a 24-month payment plan, reduced proof of identification requirements and relaxed land-right formalities for potential customers. In the process, the utility doubled its customer base and increased its revenues fourfold.

The Kamata device, used by the Ugandan utility (Umeme), measures the current flowing through the mains cable and detects attempts to tamper with the meter. If it picks up interference, the device automatically cuts the power and sends details of the customer and location to the utility[16].

Stand-alone systems

In the past decade, off-grid solar photovoltaic systems have become the most economical source of entry-level electricity for over 33% of the African population living in more remote areas or far from distribution grids. These systems can be used by single households or businesses and come in a range of sizes, from small portable lights to solar home systems powering multiple appliances. In addition to cheaper systems, pay-as-you-go (PAYG) business models have emerged since 2010 which help lower-income families access the energy ladder.

The emergence of PAYG models has transformed this market. Some use "mobile money" payments, e.g. M-Kopa, others use scratch cards, e.g. Azuri Technologies. Some businesses operate on a rent-to-own basis, allowing the customer to eventually own the solar home system outright; others operate through monthly payments. Beyond making electricity affordable for families with often extremely limited budgets, consumer confidence is increased as the risk of faulty technology shifts to the supplier. These models have attracted over $600 million in funding in recent years, as well as interest from large corporate investors such as ENGIE and Total.

Mini-grids

Mini-Grids comprise a generator and a mini-distribution network supplying multiple users. As defined by SE4All, mini-grids can be unconnected to the main grid (i.e. off-grid) or connected to the main grid but able to operate independently. According to ESMAP , 47 million people around the world are connected to 19,000 mini-grids, mostly hydro- and diesel-powered. The number of hybrid solutions has also grown in the past decade to include renewable-diesel hybrids, solar-wind hybrids, solar-biomass hybrids. One of the leading mini-grid developers in this emerging space is PowerGen, with over 100 mini-grids in seven countries in Africa. In addition to being an economic solution to energy access now, mini-grids enable developing countries to "future-proof" their power networks with a more distributed, smart distribution network comparable to the one being built in more developed countries.

"As we get closer to 100% electrification, it becomes exponentially harder to reach the last mile because of their isolation. IoT and software are enabling local companies to bridge that gap and deliver 24/7 reliable power through remote monitoring and automation."

Afnan Hannan
Co-Founder and Chief Executive Officer, Okra

The automation space for mini-grids has grown in recent years. One example of an innovation in this space comes from Okra. Okra is a technology company active in Asia delivering an IoT solution to mesh solar PV systems into smart grids. While mini-grids provide power to an entire community, the power is delivered through a single generative point – which can introduce a risk. By using smart devices, Okra ensures that most power is used where it is generated at the solar PV installation on each house. Only when there is excess power generation or consumption does the network share power with neighbouring systems.


Electrifiying small businesses through smart devices

The key to solving energy access by 2030 while building the foundations of a clean, smart power system in Africa will depend on the ability of governments and international institutions to leverage the potential of all three of these solutions in an integrated and coordinated manner.

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