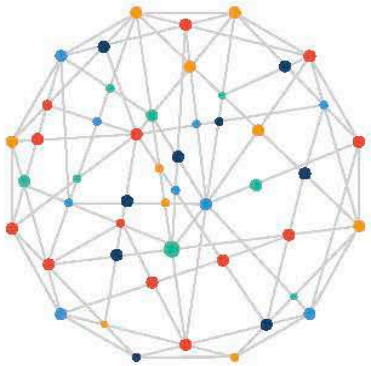
IERE Technology Foresight



Emerging Technologies for the 2020s Outline

2017

FROST & SULLIVAN

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IERE Technology Foresight activities

The social environment surrounding the electric power industry is changing drastically, and the related technical fields are expanding rapidly. IERE, an international platform comprised of major utilities around the world related to electric power technologies, has started the Technology Foresight activities in 2015, in which important technical issues are examined and discussed based on IERE members' own needs and foresights, both globally and locally.

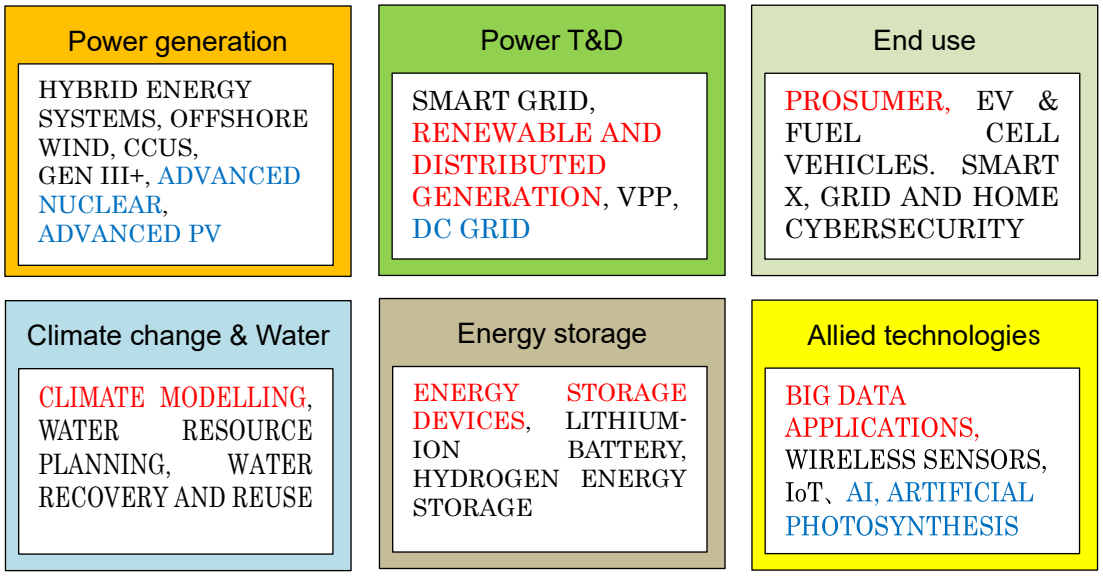
The IERE Technology Foresight 2017 report (TF2017) was compiled with the cooperation of a consultant in the period from 2016 to 2017. The technologies selected in TF2017 were based on the questionnaire survey of IERE members. The consultant then compiled the report with close cooperation with the IERE appointed Technical Committee and the major findings and finally report presented at IERE meetings. The TF2017 report outlines and explains the outlook of the most important Emerging Technologies which are already commercialized, and Fringe (black swan) Technologies which may potentially have a large impact on the electric power business in the near future. This document reflects the key results of the TF2017 report and proposes how to proceed with IERE Technology Foresight activities.

1. Outline of the Technology Foresight Report (TF2017)

As part of the regular Technology Leader Meetings (TLM) initiated by IERE within its Board members, the TLM held in Berlin on November 10, 2015 first conducted a member-wide survey on identifying key technologies impacting the industry at large.

Subsequently, at the 30th Beijing IERE Board Meeting held on May 10, 2016, a Technology Foresight task sponsored by IERE was proposed and then approved by the Board, in which IERE members would collaborate to research and analyze the emerging technologies that will enable and/or force the industry to transform, and then share the results with all members. Soon, the Technical Committee within the IERE Board members was formed and the Committee eventually selected Frost & Sullivan as a consultancy entrusting them to compile the Technology Foresight (TF2017) report in 2016.

Based on the questionnaire survey of IERE members, IERE members selected 20 important Emerging Technologies and 5 Fringe Technologies from 6 different fields ranging from power generation to allied technologies, Figure 1 refers. In addition, the Technical Committee further selected the five most important technologies that have the highest "Potential for Market Transformation" within the electric power industry.



(Reds are the most important 5 Technologies, blues are the Fringe Technologies)

Notes:
Artificial Intelligence (AI): Artificial intelligence involves developing human-like cognitive capabilities such as learning, reasoning, problem solving, planning, and self-correction for machines.
Internet of Things (IoT): A global network infrastructure, where physical and virtual 'things' have identities, and are linked through a high degree of autonomous data capture, event transfer, network connectivity, and interoperability.
Carbon Capture, Utilization, and Storage (CCUS): Technologies to capture anthropogenic generated carbon emissions from power generation and then either utilize it or permanently store it underground.
Prosumer: Collection of technologies that enable end users to become both consumers and producers of energy.
Virtual Power Plant (VPP): A group of prosumers interacting with another group of prosumers for selling and buying electricity.

Fig. 1 Most Important Emerging and Fringe Technologies in the six fields

2. Features of TF2017

Technology Foresights related to power industry are energetically performed by many international organizations, governments and consultancies, and representative

examples include the International Energy Agency's Energy Outlook and Energy Technology Perspectives.

As indicated by the Paris Agreement, countermeasures against global warming are an urgent issue of the global energy industry and technological advancements in the energy sector play a key role. At the same time, large swells of changes in the business model of the energy industry such as electricity liberalization are occurring. The rapid development and deployment of new technologies such as transport electrification and distributed energy resources are also putting new players in the traditional landscape. The purpose of the Technology Foresight activities advanced by IERE is to examine various technologies under the global expertise of the IERE community, and perhaps more importantly how to identify and advance the right technologies to suit the local needs and global trends.

TF2017 investigated different attributes of individual technologies with the cooperation of IERE experts, e.g. its function, drivers, outline and development status of the technology, the potential for market transformation, economics, market trends and foresight, future outlook, alternatives, R&D objectives, key organizations, advantages and disadvantages, enablers and barriers etc.

3. Key Insights from TF2017

TF2017 identifies five most important Emerging Technologies:

1) **Prosumer Technologies**: Prosumer technologies will bring about huge transformations to the architecture of the energy market. They also act as a catalyst for 3 major transitions occurring within the energy landscape, namely a) the transformation of the pattern of relationships between producers and customers. Prosumer Technologies enable decentralized power grids which increase "energy ownership" among end users, in the form of an industrial, commercial, or residential prosumer; b) Prosumer Technologies will lead to energy democracy, which means both the management and ownership of energy generation is distributed widely and is governed by free market principles. The rise of blockchain can also potentially impact energy trading between prosumers because it can cope with the inherent real-time dynamism in electricity demand and supply, thus real-time return on investments can be realized; c) Prosumer Technology may also accelerate an off-grid, low-carbon energy system and self-

sufficiency among end users. In an area without grid access or where expansion of the electricity grid is not viable, Prosumer Technologies can improve energy reliability by establishing rural energy entrepreneurs, generating additional revenue while offering local energy benefits to the surrounding community. This will also lead to lesser need to invest in more large-scale power plants. Also, certain concepts can be realized with Prosumer Technologies, such as Virtual Power Plants (VPP) systems.

TF2017 points out the rapid advances in technology, particularly smart meters as the enabling factor (Enablers) for prosumers. Smart meter penetration will likely to double from 2015 levels by 2025, mainly driven by replacement of first generation meters that have only basic functionalities and a limited lifetime of 10 years especially in Europe and APAC. TF2017 also points out a barrier of prosumers is the aging infrastructure which cannot handle fragmented bidirectional power flows and related accounting functionalities.

2) **Energy Storage Systems (ESS)**: ESS can be employed at all levels, e.g. generation, distribution or at the end-user's meter. ESS provides power balancing and load leveling for renewable integrations; reactive power supports and voltage regulation, and investment deferral. Furthermore, with more electric vehicles in place, ESS also can provide a buffer for charging needs to ease the stress in certain distribution networks. Residential Energy Storage (RES) is likely to experience significant growth globally, with Germany, China, Australia, the United Kingdom, and the United States being the pioneers. It is predicted that the RES market will become a fragmented and highly competitive market because, aside from the major battery manufacturers, multiple smaller companies are beginning to offer the same service. Globally, RES is likely to reach a clearly established market structure by 2017.

Currently, the selling cost of a second life battery is 35% lower than that of a brand new one, which could decrease down to 66% by 2018 due to the establishment of dedicated facilities for battery repurposing, which could bring down the cost of repurposed batteries to $20/kWh.

3) **Big Data Analytics (BDA)**: BDA can positively affect the electricity marketplace by enabling power companies to detect energy theft. Today's highly sophisticated gas and steam turbines used by thermal power plants leaves very little margin for variation. The capture and analysis of massive amounts of data collected from

sensors at different plant equipment can detect and notify the engineers located remotely about any malfunctioning or breakdowns. Power companies' own equipment is worth millions if not billions of dollars, including cables, overhead lines, transformers, and controls. BDA will also help predict failure and prevent it through maintenance or scheduled replacement. Perhaps most importantly, BPA will enable electrical utilities to offer their customers new incentives and pricing structures that can generate new revenue for end users. This is achieved by using BDA to measure and reward their customers' responses to enable more interactions.

Availability of advanced computational technologies such as in-memory computing (due to significant reduction in cost for memory in the last few years) is becoming an important enabler for Big Data adoption across sectors. Also, increasing adoption of Internet of Energy Things (IoT) powered by smart grids, smart meters, and smart home applications is a key enabling factor that will drive the use of BDA. On the other hand, Data quality, privacy and integration risks with existing infrastructure are considered as barriers of the technology.

4) **Renewables and Distributed Generation**: Distributed Generation (DG) has the potential to change the existing power scenario through greater adoption of renewables and the powering of remote locations globally. The rapid adoption of DG is currently empowering the energy market in many countries such as Africa and India. This is considered the beginning of a new global trend and could be used in tandem with solar photovoltaic (PV) and energy storage solutions to power many communities who are seeking to increase energy reliability and independence from the electricity grid. The addition of DG solutions will also reduce the dependence on conventional fossil fuel sources such as coal and gas for power generation, thereby improving the emission scenario. To remain competitive in the changing energy landscape, utilities will need to devise innovative business models to embrace both renewables and distributed generation.

Major barrier is how to effectively integrate modular and isolated systems into larger centralized grids over the long term. Potential risks include introducing greater volatility into energy networks, leading to possible large-scale and wide-area grid failures.

5) **Climate Modeling**: Meteorological variability often causes irregularity in the

power sector, especially for renewable power sources. Changes in climate conditions such as changes in temperature, precipitation, sea level, and frequency and severity of extreme events affect how much energy is produced, delivered, and consumed. Climate change's most worrisome change is on temperature and heat waves because the impact is felt across the value chain of power generation, either in generation, transmission, distribution or storage. For example, in July 2012, India was hit with a large blackout affecting more than 300 million people because of a surge in demand from an unexpected sector, which came from farmers. Due to draught conditions, farmers were using more electricity to pump water from deeper boreholes for agriculture purposes. The cumulative effects from a surge in the demand for air-conditioning and pumping power subsequently led to the massive blackout. Climate models give information about what changes have occurred, how well past and present climates have been understood, and what changes lie ahead. From the power utilities perspective, climate modeling contributes in four ways, which are: a) Prediction of temperature increases and heatwaves; b) Prediction of extreme events; c) Prediction of climate change impacts on coastal areas; and d) Prediction of renewable generation.

In addition, TF2017 is presenting the present state of technology development of each technology (Fig. 2). Various technological developments are considered necessary for practical applications of the Fringe Technologies.

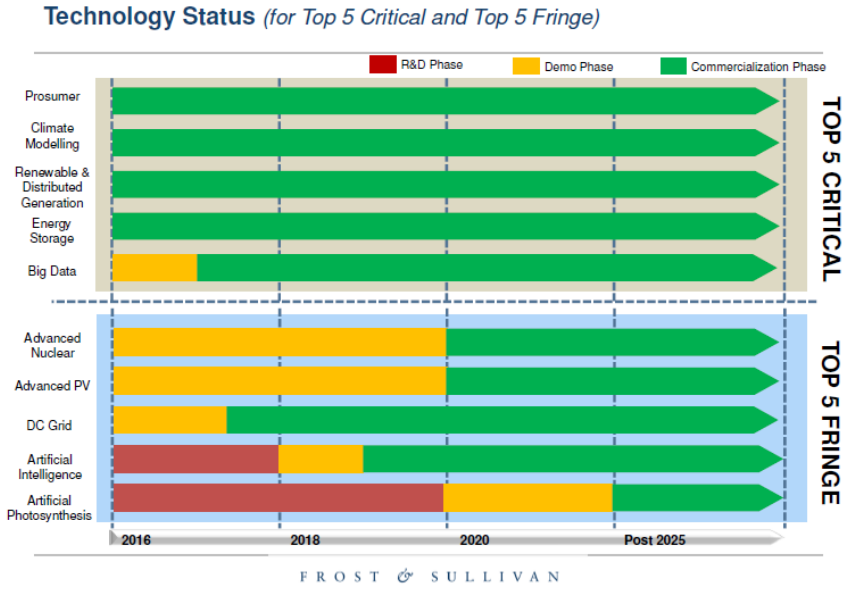


Fig. 2 Present state of technology development of each technology

4. Future IERE technology foresight activities

As mentioned above, the rapid progress in technologies significantly impacts the way energy is converted, transmitted and used. Thus, the business of energy companies is as much changing as the related R&D has to shift priorities. IERE's Technology Foresight provides an expert review on these developments. With its global outreach and, most importantly, with specific focus on R&D needs it will support utilities around the world in their preparations for the changes ahead. TF2017 has been established by IERE to launch a global platform for the evaluation of emerging and fringe technologies. On a regular basis industry players, not limited to the researchers only but also including the management and policy makers shall be informed to better understand the latest development of relevant energy technologies.

Individual technology developments and their adoption in markets depend on global trends as well as regionally different needs and political/ regulatory priorities. IERE, an international exchange platform for electric power technology research, helps to match technology foresight with insights on global trends and regional needs.

IERE's technology foresight activities are not only providing valuable support to IERE members to select, evaluate and analyze important technologies, but is also providing

opportunities to build a global community that shares knowledge and experiences amongst the IERE members. Our technology foresight activities will stimulate further individual or joint discussion amongst IERE members and external partners to foster outward orientation and an un-biased view to the benefit of all parties involved.

TF2017 has been officially released to all IERE members in 2017. Based on their feedback our future Technology Foresight activities will be shaped according to the member's needs. A more in depth analysis of selected topics is planned and an update of the current report including latest developments shall be provided on a regular basis (e.g. every 2-5 years).

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