IERE Technology Foresight

Survey on IERE Members' Vision
Executive Summary

2021

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IERE Technology Foresight Activities 2021:

Survey on IERE Members' Vision

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Executive summary

The power industry must meet many missions received from society, such as decarbonization, energy efficiency, and cost reduction.

IERE started the Technology Foresight Activity in 2016. In this activity, IERE members selected 20 important Emerging Technologies and five Fringe Technologies and summarized these technologies in the “IERE Technology Foresight 2020 (TF2020)” report and distributed it to members in May 2017.

Since then, the social situation has changed significantly, and IERE has decided to issue a new version of the report before TF2020 becomes obsolete. Therefore, IERE has started a new Technology Foresight activity.

There are many analyses/opinions on energy and electric power industries reported by many organizations. From these analyses/opinions, the IERE Central Office extracted the following ten trending keyword sets:

- Electrification / Energy access
- Decarbonization / Environmental protection
- Energy efficiency
- Decentralization
- Intermittency / stable supply
- Prosumer
- Digitalization
- Resiliency / Flexibility
- Management rationalization
- Deregulation / Market trading

While referring to these trending keyword sets, the electric power industry was divided into three business sectors: **a. Generation**, **b. Transmission/Distribution (T/D) and Retail**, and **c. Strategic Management**. The IERE Central Office conducted a questionnaire (Appendix 1) survey among IERE members regarding the priority of related technologies, their implementation and planning status, and specific technologies and issues of interest in each related technology area.

In 2020, the global epidemic of COVID-19 caused lockdowns worldwide, which had a major impact on the electric power industry. Based on this, the impact of the COVID-19 pandemic was also assessed in the questionnaire. There were 28 answers to the questionnaire from the IERE members (Table 1).

Table 1 Number of responses by country and region

Zone	Country and region	Number of responses
Asia	Japan	14
	China	2
	Hong Kong SAR	1
	Taiwan	1
	Philippines	1
Europe	Germany	2
	France	1
	Czech Republic	1
	Norway	1
America	United State	2
Africa	South Africa	1
Others	-	1
Total		28

After and beyond the COVID-19 pandemic

First, the IERE Central Office sought opinions/expectations about the effects of the COVID-19 pandemic on the energy system and the technology development items necessary after and beyond the COVID-19 pandemic. The following opinions regarding the electricity demand and energy composition were collected. Here, the number in parentheses indicates the number of responses.

There are many opinions/expectations about the electricity demand: the electricity demand will decrease in the short term (18), medium- to long-term demand will return to the original level (6), demand will increase due to the conversion to electricity (3), and it will be difficult to determine (4). It was also noted that demand in the household sector had increased (6).

In addition, there are opinions on the progress of clean energy (10), stronger influence of the state (7), change in energy composition (6), new needs and social issues (3), reduction of R&D budgets (2), and regionalization/self-sufficiency.

There is a risk of not being able to maintain an electric power system sufficiently to prevent the spread of infection (2). It was also indicated that maintenance periods have been postponed and the separation of critical teams is necessary, such as control center operators.

In the necessary technology development items, many technical items were noted such as remote work, remote inspection/digitization (15), measures to increase telecommuting (11), power storage systems (7), digitization (7), and improvement of power supply reliability (4).

Directions of the technology development policy

While summarizing the results of the questionnaire regarding the direction of the power industry business, the Central Office organized the results by the number of times the ten trending keywords were mentioned. It was found that the members concentrated on one or two specific trend keywords related to each business

sector. These specific keywords are “Decarbonization/Environmental protection” and “Intermittency / Stable supply” (for **Generation**), “Intermittency / Stable supply” (for **T/D and Retail**), and “Digitization” (for **Strategic Management**) (Figure 2(a)). These keywords appear to indicate the directions that the IERE members are aiming to follow.

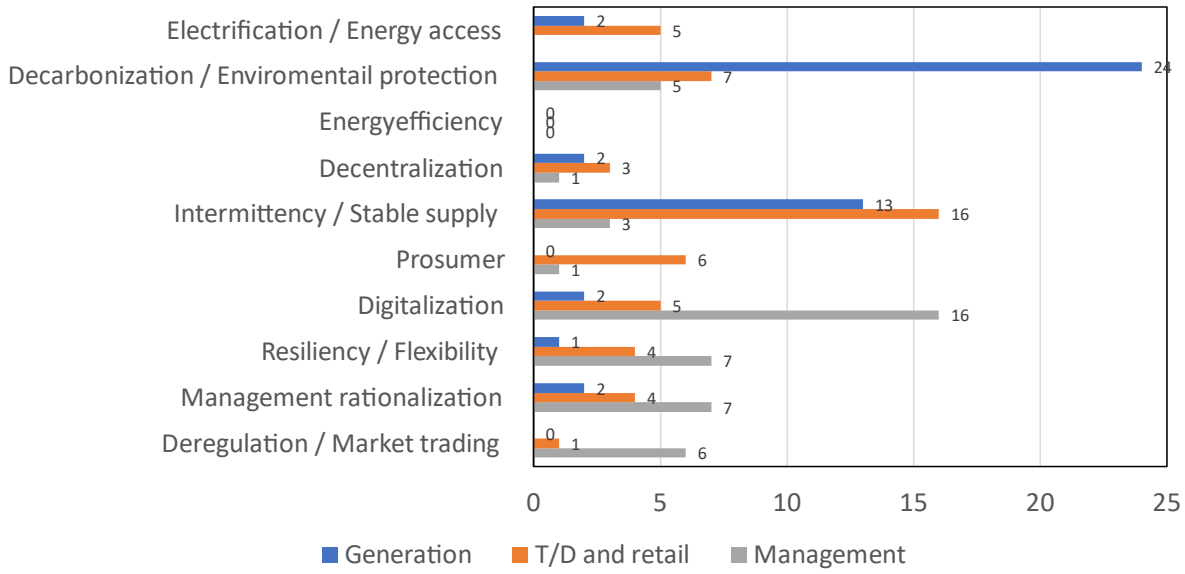

Figure 2(a) Cumulative number of related trending keywords extracted from responses (Q1-1, 2-1, 3-1)

In the present answers, it should be noted that the above directional trends, for example, decarbonization, do not show regional characteristics such as in Europe, America, and Asia, and these global trends are homogeneous among IERE members.

Priority of relevant technologies and technical items/issues

a. Generation

In the sector of “**Generation**,” the correlation between the priority of each related technology presented by the Central Office and the status of implementation is very strong. However, it is noteworthy that while PV, wind power, and hydropower have high priority, LNG, biomass, and nuclear power are more advanced in terms of the implementation status (Figure 3).

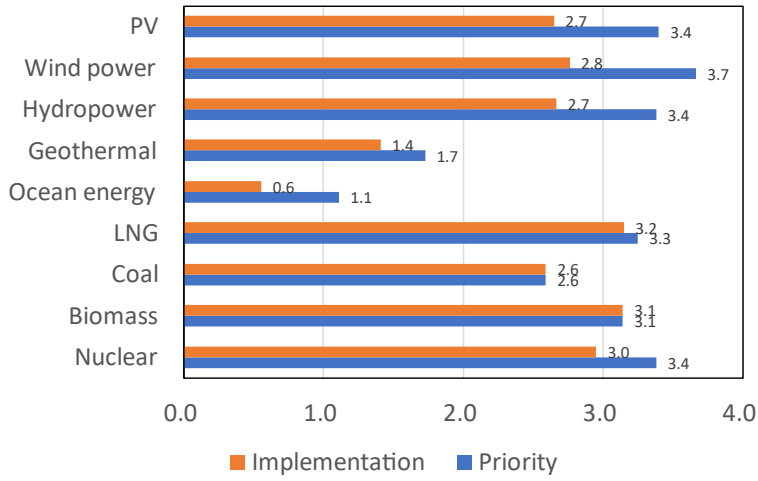

Figure 3 Priority and implementation level of relevant technologies (Q1-2, Generation sector)

As specific technical items/issues of interest in each related technology, floating offshore wind (in wind power-related technology), advanced hydropower operation using big data and AI (in hydropower-related technology), risk assessments for LNG (in LNG-related technology), co-firing for biomass (in coal-related technology), and nuclear SMR (small module reactor) (in nuclear-related technology) are attracting attention (Table 2).

Table 2 Technical items/issues of member's interests (Q1-2, Generation sector)

Relevant technology	Technical items/issues
PV	Use of aerial drones for plant inspection, Efficiency improvement. Output forecast, Agri-PV, Solar field, Land occupation
Wind power	Floating offshore wind turbine, Aerial drones for blade inspections, Output forecast, Frequency, High-altitude wind power, Localization (Domestic production)
Hydropower	Advanced maintenance (AI, etc.), Smart hydropower, Frequency control, PSH, EIS
Geothermal	Geophysical monitoring, Efficiency improvement, Environmental protection
Ocean energy	Tide power generation, Wave power generation, Cost reduction
LNG	High efficiency, O&M cost reduction, Environmental protection, Fire/explosion/risk studies on rail transport, Cold energy, AHAT
Coal	IGCC, IGFC, CCS/CCUS, SOFC, Environmental protection, Utilization of coal ash
Biomass	Biofuel with microalgae, Co-firing with coal, Environmental protection, Palletization
Nuclear	Output Control, SMR, Radioactive waste disposal, Severe accident response

Note: Shaded technical items/issues indicate the notable items/issues

Regarding decarbonization measures, there is a significant difference between Japan and other countries. Outside Japan, coal-fired power plants without CCUS are expected to be stopped and switched to renewable energy, while Japan seems to focus on improving the technologies (efficiency, CCUS, etc.) of coal-fired power plants. In addition, there is increasing global interest in nuclear power plants with highly safe SMRs, which is a countermeasure against global warming.

b. T/D and Retail

In the sector of "**T/D and Retail**," as the share of renewable energy in the overall energy production increases, measures in the "Intermittency / Stable supply" area will be crucial issues.

Compared to TF2020, digitization is progressing more rapidly. As measures in the "Intermittency / Stable supply" area, e-mobility connected to the grid is becoming widespread in addition to ESS and grid integration, and intelligence improvement via digital technology. Therefore, there is considerable interest in the impact on EV systems and society, such as EV charging stations.

In terms of the priority/implementation level of relevant technologies, there is a high interest in batteries, DSM/VPP, smart grids, and mini/micro grids (Figure 4).

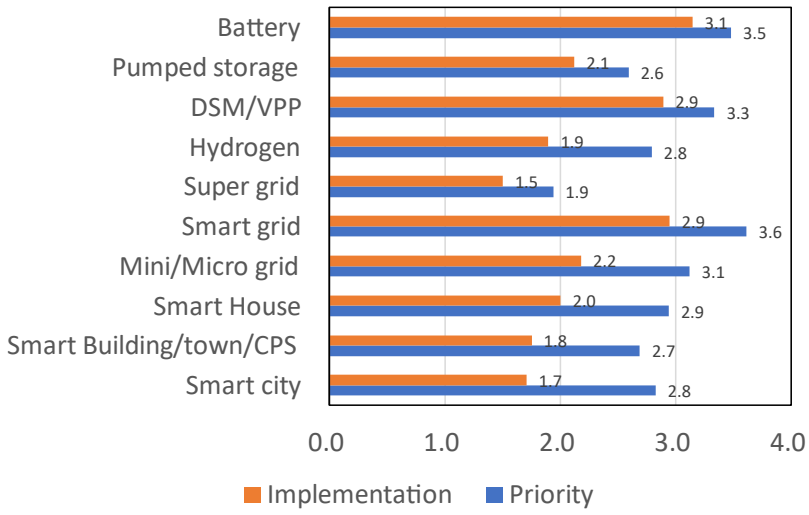

Figure 4 Priority and implementation level of relevant technologies (Q2-2, T/D and Retail sector)

Specific technical items/issues of interest in each related technology are V2G and reuse (in battery-related technology), DERMS (in DSM/VPP-related technology), and advanced metering infrastructure (AMI) and smart inverters (in smart grid-related technology). Mini/micro grids are highly useful/reliable for power supply during a disaster. There are also notable indications, such as zero emission houses/buildings (in smart house-related and smart building/town/CPS (cyber physical system)-related technology) (Table 4).

Table 4 Technical items/issues of member's interests (Q2-2, T/D and Retail sector)

Relevant technology	Technical items/issues
Battery	V2G, Reuse, Safety evaluation, All solid-state battery, Redox flow batteries
Pumped storage	Output/control frequency control, Frequency control, Underground storage
DSM/VPP	DERMS, Large-capacity charger/discharger, Energy management
Hydrogen	P2G, Hydrogen blending in pipelines, Compression, Combustion. SOFC, Utilization of NH3, Output control, Generation efficiency, resource application
Super grid	UHV, UHVDC, Dispatching automation
Smart grid	AMI, FACTS, Smart inverter, SCADA, ADMS, Cloud computing, Edge computing, Flexible DC grid, AI, IoT, Block chain, Digital twin, FLISR, IVVO
Mini/Micro grid	In-dependent operation, Power supply in the event of disaster, Flexible DC grid, New energy integration, New chemical energy storage technology, EMS, Inverter-based microgrid, IEC 61970
Smart house	HEMS, V2H, Zero emission house, Internet home appliance, Non-invasive measurement, 5G, Power line carrier communication, Eco cute (Heat Pump)
Smart building/town/CPS	Zero emission building, BEMS, VPP
Smart city	Compact city, 5G, Energy storage, Electric vehicle (EV), AI, Regional energy system rational transportation system, Compact city, Aggregator, xEMS

Note: Shaded technical items/issues indicate the notable items/issues

c. Strategic Management

In the sector of "**Strategic Management**," which was not investigated in the previous TF2020 survey, there are many new comments on asset management (facilities and equipment) and cybersecurity in the context of digitization and resilience, such as securing power supply during emergencies (Figure 5).

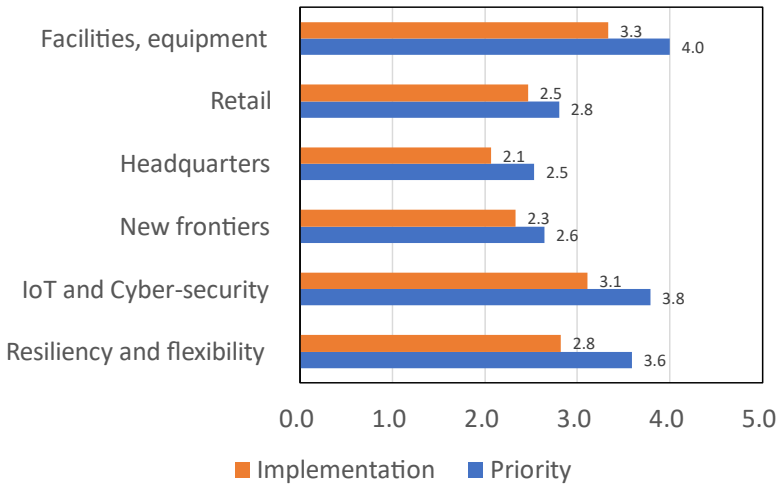

Figure 5 Priority and implementation level of relevant technologies (Q3-2, Strategic Management sector)

With regard to specific technical items/issues of interest in each relevant technology, there are relatively many indications, such as asset management (in generation and T/D facilities/equipment-related technology), agricultural electrification (in new frontiers-related technology), blockchain and privacy (in IoT and cybersecurity-related technology), and adaptation to climate change (in resiliency and flexibility-related technology). However, the technical items are scattered in each relevant technology. Defense in depth, as a cybersecurity measure, is remarkable (Table 6).

Table 6 Technical items/issues of member's interests (Q3-2, Strategic Management sector)

Relevant technology	Technical items/issues
Generation and T/D facilities, equipment	Asset management, Smart O&M (digitalization/AI diagnosis), Asset online monitor systems, Aging measures, Digital operations, Safety, Mobility solution
Retail	Digital commerce/marketing/operation, Energy services, Algo-Trading processes, Peer to peer trading, microgrids, Community engagement
Headquarters	Automated back-end processes, Utility 3.0, Electric power trading/data analysis (machine learning/deep learning), IRP models, Market design, FITS/Subsidy
New frontiers	Agricultural electrification, Industrial electrification, Smart farming, EV charging infrastructure and EV management, MAAS
IoT and cybersecurity	Block chain, AI Deep learning, Prosumers, various AI technology, Digital platforms for IoT integration across multiple stakeholders, Privacy, Data security, SCADA, Defense in depth
Resiliency and flexibility	Adaption for climate change, Automatically detecting and grasping the damage status of equipment, Black start technologies, LCP (life continuity plan), Earthquake countermeasures, RAMP

Note: Shaded technical items/issues indicate the notable items/issues

Technologies of high interest to members

Technologies of high interest to IERE members across all business sectors were examined based on the priority and implementation level of relevant technologies in **a. Generation**, **b. T/D and Retail**, and **c. Strategic Management**. Table 8 shows the ranking based on the total priority value and implementation level of relevant technologies. Table 8 indicates that the high-ranking technologies perceived by members are "Generation and T/D facilities, equipment" and "IoT and cybersecurity" in **Strategic Management**, "Battery" and "Smart grid" in **T/D and Retail**, and "Wind power" and "LNG" in **Generation**. It can be seen that the relevant technologies of high interest are widely dispersed in the three sectors.

Table 8 Ranking based on the total value of Priority and implementation level of relevant technologies

Electric power industry business sectors	Relevant technologies	Priority	Implemen-tation	Priority + Implemen-tation	Ranking
Generation	PV	3.40	2.65	6.05	**11**
	Wind power	3.67	2.76	6.43	**5**
	Hydropower	3.38	2.67	6.05	**12**
	Geothermal	1.73	1.41	3.14	**24**
	Ocean energy	1.11	0.56	1.67	**25**
	LNG	3.25	3.15	6.40	**7**
	Coal	2.59	2.59	5.18	**15**
	Biomass	3.14	3.14	6.29	**9**
	Nuclear	3.38	2.95	6.33	**8**
T/D and Retail	Battery	3.48	3.14	6.62	**3**
	Pumped storage	2.59	2.12	4.71	**18**
	DSM/VPP	3.33	2.89	6.22	**10**
	Hydrogen	2.79	1.89	4.68	**19**
	Super grid	1.94	1.50	3.44	**23**
	Smart grid	3.61	2.94	6.56	**4**
	Mini/Micro grid	3.12	2.18	5.29	**13**
	Smart house	2.94	2.00	4.94	**17**
	Smart building/town/CPS	2.69	1.75	4.44	**22**
	Smart city	2.82	1.71	4.53	**21**
Strategic Management	Generation and T/D facilities, equipment	4.00	3.33	7.33	**1**
	Retail	2.80	2.47	5.27	**14**
	Headquarters	2.53	2.07	4.60	**20**
	New frontiers	2.64	2.33	4.98	**16**
	IoT and cybersecurity	3.79	3.11	6.90	**2**
	Resiliency and flexibility	3.59	2.82	6.41	**6**

The technical items/issues of interest in the "Generation and T/D facilities, equipment" area include asset management, smart O&M (digitalization/AI diagnosis), asset online monitoring systems, digital operations, mobility solutions, and others, as listed in Table 6. It is believed that the rationalization of installation plans and O&M using advanced technologies such as digitalization/AI and online monitoring are being aimed at. The technical items/issues of interest in the "IoT and cybersecurity" area are blockchain, AI deep learning,

digital platforms for IoT integration across multiple stakeholders, data security, defense in depth, and others, as listed in Table 6. Upgradation and cost reduction of IoT and cybersecurity measures are urgent issues, and a clear vision, policy, process chart, and common recognition in the electric power industry are required. Technical items/issues of interest in the "Battery" area include V2G, reuse, all-solid-state batteries, and others, as listed in Table 4, and their use as a society is drawing attention along with technological development.

Compared with previous Technology Foresight activities "TF2020," interest in LNG and biomass, which were not choices in TF2020, is observed to be high. There is a growing interest in the use of LNG and biomass as measures in "Decarbonization" and "Intermittency / Stable supply."

Broadly examining the technical items/issues for each relevant technology, the following are listed as the other interesting technical items/issues from the perspective of their novelty and impact on society in addition to the technologies (shaded) specified in Tables 2, 4, and 6.

- Agri-PV
- Airborne wind energy systems (AWES)
- CCUS
- Compact city
- Coupled to compressed air energy storage (CAES)
- Digital twin
- Direct air capture (DAC)
- Edge computing
- E-mobility
- Flow battery
- Power to protein
- P2H (power to hydrogen)
- Sustainable catalysts as energy transition enablers
- Various xEMS services

Web conference

A web conference on the present Technology Foresight activity was held on March 16, 2021. Following the introduction of the outline of the survey results from the IERE Central Office, E.ON and EPRI introduced the impact of the COVID-19 pandemic on the electric power industry; SwRI, CEPRI, and CLP introduced the direction of technologies in the electric power industry, and discussions were held. Major trends related to the electric power industry discussed at the Technology Foresight Committee meeting were also introduced. Online polls for the next important technologies were conducted concurrently.

Future Directions

The technical items required in terms of decarbonization, intermittency and stable supply measures, and digitalization were identified. In the future, the IERE should discuss any technical issues that must be re-examined and the measures to be implemented, such as collaborative research by IERE members or

outsourcing the survey to a consulting firm.

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IERE

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