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ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

Smart Grid Case Studies

Smart Grid Drivers and Technologies by Country, Economies, and Continent

Analytical Report

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ISGAN Annex 2

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About ISGAN Analytical Reports

This analytical report has analyzed a survey among experts in 18 ISGAN member countries on smart grid drivers and associated technologies in 2020. The goal was to select the top 6 drivers and the top 5 technologies and comprehensively analyze the current status of each member country's economic levels by continents. The purpose of this survey was to help establish policies for promoting and deploying smart grids early and analyze statistically the status in each country to provide the reference data for identifying the temporal changes in drivers and technologies and the key promotion strategy in each country. This also reflects works in progress in the development of smart grids in the different regions of the world. Its aim is not to communicate a final outcome or to advise decision-makers, but rather to lay the ground work for further research and analysis.

Disclaimer

Foreword

The International Smart Grid Action Network (ISGAN) was launched at the first Clean Energy Ministerial (CEM) in 2010 and was subsequently organized as a task-shared International Energy Agency (IEA) Implementing Agreement for a Co-operative Programme on Smart Grids in 2011. The task-shared projects undertaken with ISGAN Participants' contributions are aimed toward multilateral government-to-government collaboration to advance the development and deployment of smarter electric grid technologies, practices, and systems. To date, ISGAN has established nine multilateral collaborative projects (or Annexes) to address the principal areas of smart grids where government collaborations can have the most impact.

Work in this report was conducted under ISGAN Annex 2: Smart Grid Case Studies. The report begins with a description of the development and application of a unified framework for assessment. This unified assessment framework ensures a common assessment methodology for use by each ISGAN Participant both to accomplish objective of identifying countries' specific motivating drivers for pursuing smart grids, and to allow groupings of countries' prioritized assessment results to unveil multinational assessment priorities of smart grid motivating drivers and technologies, such as by geographic regions or by the advanced state of countries' economies.

The national-level and multinational-level prioritized assessment results presented in this report are being used to guide further Annex 2 work toward fulfilling other objectives of Annex 2 for further in-depth case studies, in particular. Specifically, each ISGAN country is applying the national-level prioritized assessment results to identify smart grid activities underway that meet, address, or respond to its prioritized motivating drivers and technologies. The activities identified to meet multinational assessment priorities will then be featured in the ISGAN Smart Grid Project Webinar series, during which their information will be shared with all interested parties for lessons learned.

This report is the third edition of the assessment report of smart grid motivating drivers and technologies, and is based on analysis of the 2020 survey results. The second edition was published in September 2014 and is based on the survey results from that year. Comparison of driver and technology priorities analyzed from the two biennial sets of survey results are presented herein.

Abstract

The survey of ISGAN Participants on smart grid motivating drivers and technologies of priority was first conducted in 2012, 2014 and again in 2020. This report summarizes the unified assessment framework used in the 2020 survey, the analysis methodology, and the analysis results of smart grid motivating drivers and technologies at both the national level and multinational level. Building on the lists of smart grid motivating drivers and technologies that were used for the 2014 survey, the assessment framework in 2020 was developed with slight refinements to reflect review feedback from current ISGAN Participants. The refined framework (i.e., lists of drivers and technologies) was then programmed into an online survey tool for use by each Participant to complete the assessment. Each Participant's survey results were subjected to a validation process by that country's national coordinator for Annex 2. A clustering analysis methodology was developed and applied to derive the composite, national-level prioritized assessment results from survey results (those approved through validation, or completed but not yet validated) from multiple respondents for a country. The same methodology was further applied to groups of multiple Participants' prioritized assessment results to identify motivating drivers and technology priorities at a multinational level. Clustering analysis for the group of all ISGAN Participants, as well as of Participants grouped by economies (developed and developing) and by continent (Asia, Europe, Oceania and North America), was conducted; these multinational-level prioritized assessment results are provided herein.

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1.0 Introduction

The International Smart Grid Action Network (ISGAN), launched at the first Clean Energy Ministerial (CEM) in July 2010, creates a mechanism for multilateral collaboration to accelerate world-wide development and deployment of smarter electricity grids. ISGAN has launched key projects (known as Annexes) across its five principal areas of focus (Policies, Standards, and Regulation; Finance and Business Models; Technology and Systems Development; User and Consumer Engagement; and Workforce Skills and Knowledge). The Smart Grid Case Studies project, that is, Annex 2, has the objectives of identifying countries' specific motivating drivers for pursuing smart grids, cataloguing the wide range of smart grid activities underway, and collecting and organizing the wealth of experience currently being generated into a resource available first to ISGAN Participants and then to a broader, global audience. These objectives and the associated scope of activities are described in the ISGAN Annex 2 *Programme of Work*, Issue 10.0. This paper summarizes work completed for Task 4, Assessment of biennial survey on smart grid motivating drivers and technologies, under the Annex 2 *Programme of Work*.

The objective of Task 4 was to define the motivating drivers for smart grids and analyze the associated, contributing smart grid technologies. The Task involved developing and applying a unified ISGAN framework for assessing and prioritizing national-level smart grid motivating drivers and contributing smart grid technologies. It is expected that both ISGAN and non-ISGAN Participants will contribute data and information to this Annex. As of this report publication, 26 nations across the globe and the European Commission have signed on as ISGAN Participants (identified on the **ISGAN website**).

This paper documents the Annex 2 unified framework for assessment, prioritized assessment results by each Participant, purpose and methodology for multinational (or clustering) analysis, analysis results of common motivating drivers and driver-technology pairs of high priority at the national level as well as across all nations and to nations clustered by economies or by continent, and comparison of multinational prioritized assessment results between the 2014 and 2020 studies.

2.0 COMPARISON BETWEEN 2014 VERSUS 2020 SURVEY ANALYSES

The ISGAN assessment studies have been conducted to date, i.e., one in 2014 and this one in 2020. In between the two study periods, the roster of ISGAN Participants has grown from 25 to 26. New Participants and non-ISGAN Participants as observer introduce their own countries' prioritized assessment results for multinational-level analyses. In addition, the national-level smart grid motivating drivers and technology priorities have changed for the common Participants in both studies. Hence, assessment results in each study should be viewed as indicative of national-level and multinational-level priorities for that particular study period only and as dependent on the ISGAN Participants and non-ISGAN Participants in the survey; in other words, assessment priorities are expected to change over time. The survey participants and assessment results of the top-ranked smart grid motivating drivers and technologies are shown comparatively in Table 1 for the 2014 and 2020 studies.

Table 1. Comparison between 2014 vs. 2020 Survey Analyses

The items in bold letter refer to those that are common in the 2014 and 2020 analysis reports.

	2014 Survey	2020 Survey
Top 6 Drivers of Smart Grid	**System efficiency improvements**	Optimizing asset utilization
	Reliability improvements	**System efficiency improvements**
	Renewable energy standards or targets	Distribution adequacy
	Enabling new products, services, and markets	Decarbonization of energy systems
	Enabling customer choice and participation	**Enabling customer choice and participation**
	Reducing operating and maintenance costs	Transmission adequacy
Top 5 Technologies of Smart Grid	**Advanced Metering Infrastructure (AMI)**	**Advanced Metering Infrastructure (AMI)**
	Distributed Energy Resources(DER) integration	Advanced demand forecasting and load monitoring
	Information and communications technology	Big data management
	Distribution management systems and outage management systems	**Distributed Energy Resources (DER) integration**
	Smart homes	Transportation electrification

Table 1 also shows that the top-6 ranked drivers from the 2014 and 2020 assessment studies exhibit great commonality, as evidenced by two of the top-6 ranked drivers being the same, albeit in a slightly different priority order. However, it is worth noting that the top ranked driver has shifted from ‘System Efficiency Improvements’ to ‘Optimizing Asset Utilization’.

In regard to the top-5 ranked technologies, the 2014 and 2020 assessment results share two common technologies, i.e., ‘Advanced Metering Infrastructure (AMI)’ and ‘Distributed Energy Resources (DER) Integration’, with AMI being the top-ranked technology in both studies. One interesting point is that interest from each government is shifting toward demand forecasting and monitoring technology through the use of big data in recent years.

Some of the 2014 survey participants including China, Finland, Mexico, Russia, Singapore, South Africa, Switzerland, and United States did not provide input for the 2020 survey, while there were additionally new participants from ISGAN and non-ISGAN Participants, namely Austria, Belgium, France, Malaysia, Thailand, United Kingdom, and Vietnam.

Table 2. Survey participants in 2014 and 2020

2014 Survey Participants	2020 Survey Participants
Australia, Canada, China, Finland, Germany, India, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, Russia, Singapore, South Africa, Spain, Sweden, Switzerland, and United States	Australia, Austria*, Belgium*, Canada, France*, Germany, India, Ireland, Italy, Japan, Korea, Malaysia*, the Netherlands, Spain, Sweden, Thailand*, the United Kingdom*, and Vietnam*

** Countries newly participated in the survey*

3.0 MULTINATIONAL-LEVEL PRIORITIZED ASSESSMENT RESULTS

Clustering analyses at the multinational level were conducted for the following groupings:

- Economies: developed and developing
- Continent: Asia, Oceania, Europe, and North America

Table 3. Grouping of Participants for Multinational Clustering Analysis

Participating Countries	Economy		Continent			
	Developed Country	Developing Country	Asia	Oceania	Europe	North America
Australia	●			●		
Austria	●				●	
Canada	●					●
Germany	●				●	
India		●	●			
Ireland	●				●	
Italy	●				●	
Japan	●		●			
Korea	●		●			
Netherlands	●				●	
Spain	●				●	
Sweden	●				●	
United Kingdom	●				●	
France	●				●	
Belgium	●				●	
Malaysia*		●	●			
Thailand*		●	●			
Vietnam*		●	●			

** Non-ISGAN participating countries*

4.0 Multinational Analysis Results of All Participants with Validated Results

Figure 1 and 2 show the overall analysis results for the top-6 ranked drivers and the top-5 ranked technologies. More specifically, Figure 3 indicates the core technologies for each top-ranked driver, respectively.

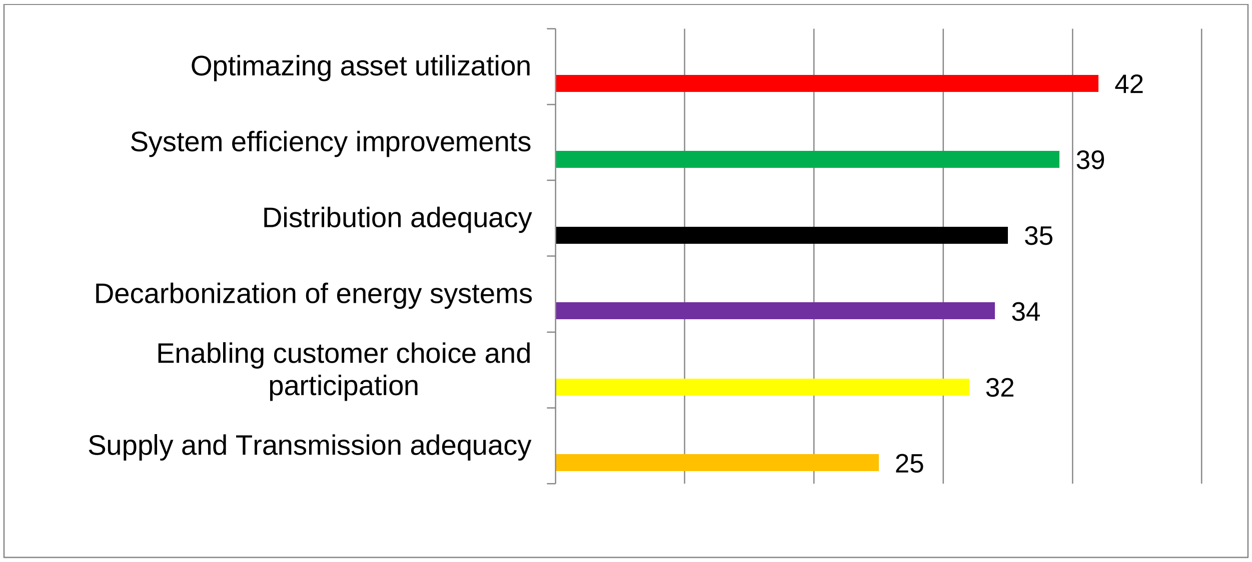

Figure 1. Top-6 Ranked Motivating Drivers from Clustering Analysis of the 18 National-Level Results

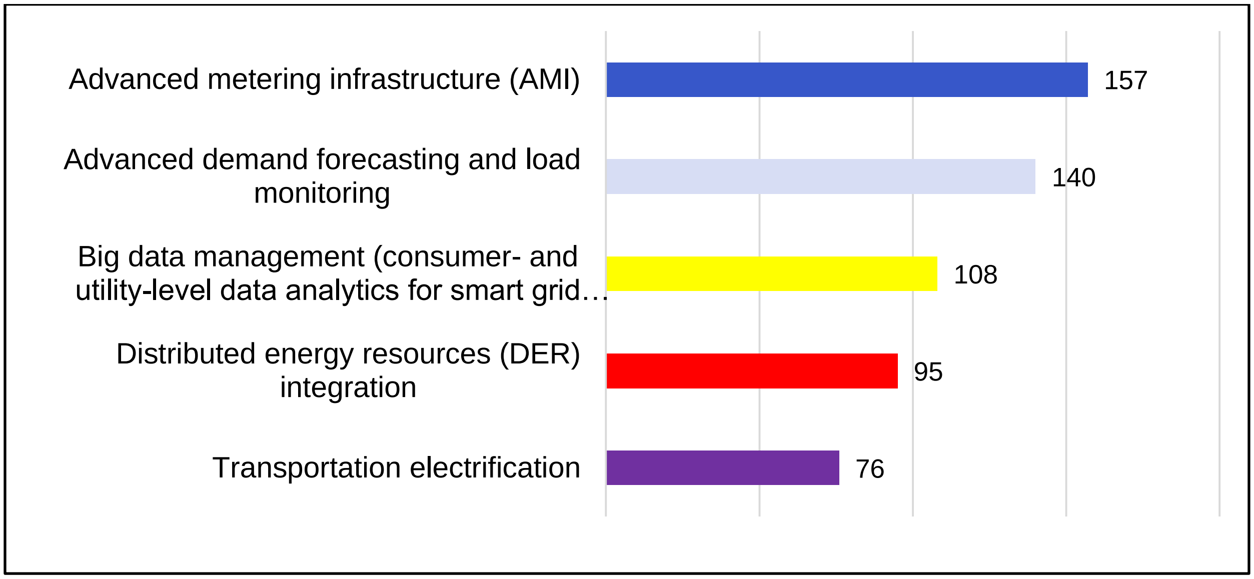

Figure 2. Technology Priorities across All Drivers from Analysis of the 18 National-Level Results

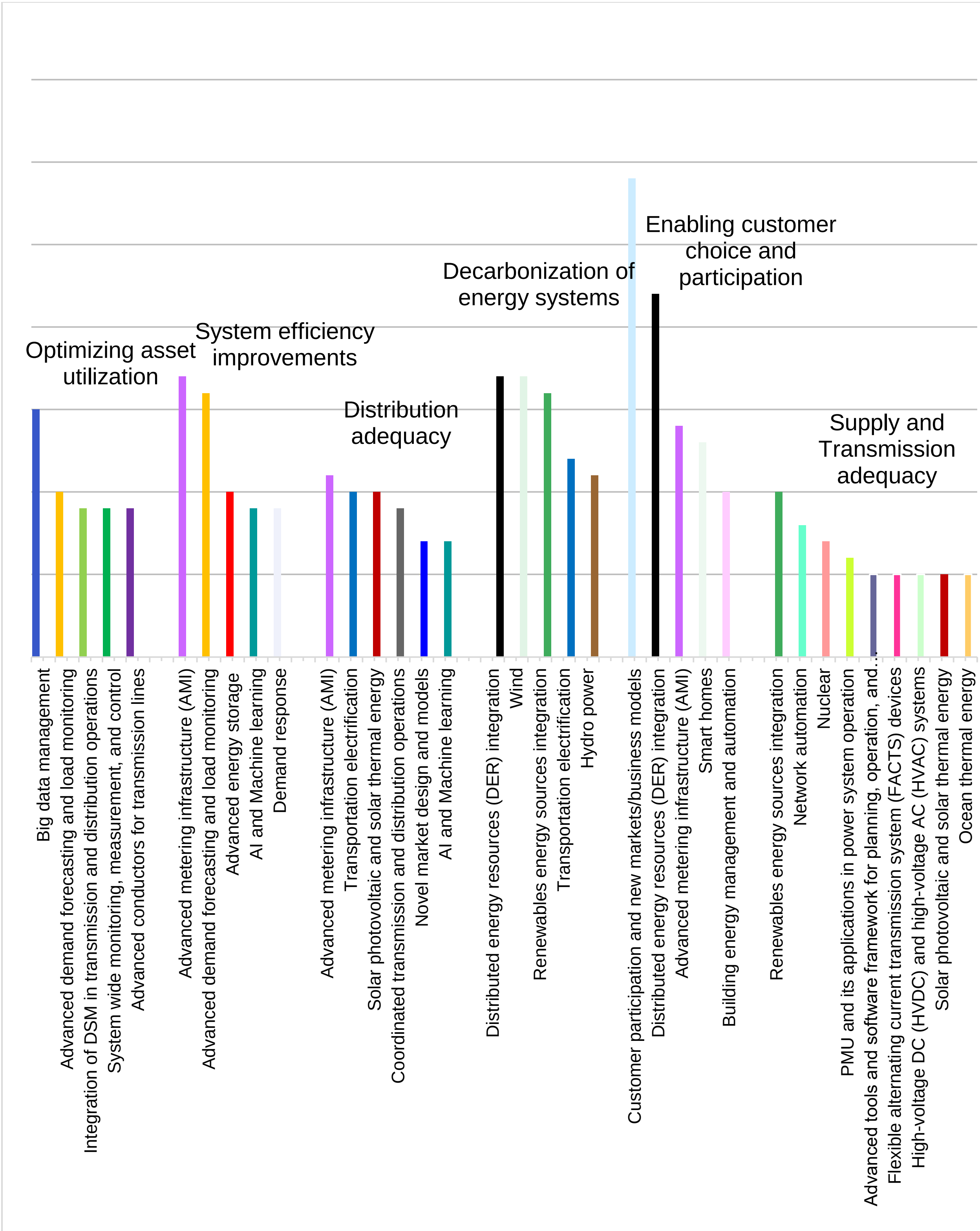

Figure 3. Top-5 Ranked Technologies for Each of the Top-6 Ranked Drivers (Shown in Figure 2)

It is shown that 'System efficiency improvements' and 'Enabling customer choice and participation' were both selected as one of the top drivers for smart grids in 2014 and 2020, indicating that the experts consider them very important. On the other hand, it is shown that the most top driver changed from 'System Efficiency Improvements' in 2014 to 'Optimizing asset utilization', indicating that experts' key interest changed from performance improvement such as system efficiency improvement to optimal operation of power systems.

In terms of associated technologies supporting the key smart grid drivers, 'Advanced Metering Structure (AMI)' is selected as the top technology in both 2014 and 2020, indicating that not only AMI has been steadily deployed in various countries but also is considered to be fully distributed in the years to come. It confirms that the AMI is the core technology for smart grids and the essential infrastructure that helps to create some potential business models. Moreover, 'DER integration technology' is also deemed necessary for the integrated management of distributed resources, which have rapidly expanded on a global scale due to the policy factor for increasing the rate of renewable energy in each country from 2014.

5.0 Multinational-Level Analysis Results by Economies

The top motivating drivers and the top technologies across all drivers for developed and developing economies from clustering analyses of multinational results are shown in Figure 4 and Figure 5, respectively. The Figure 4 shows clustering analyses of the 14 developed economies' national-level results, and the Figure 5 shows clustering analyses of the 4 developing economies' national-level results.

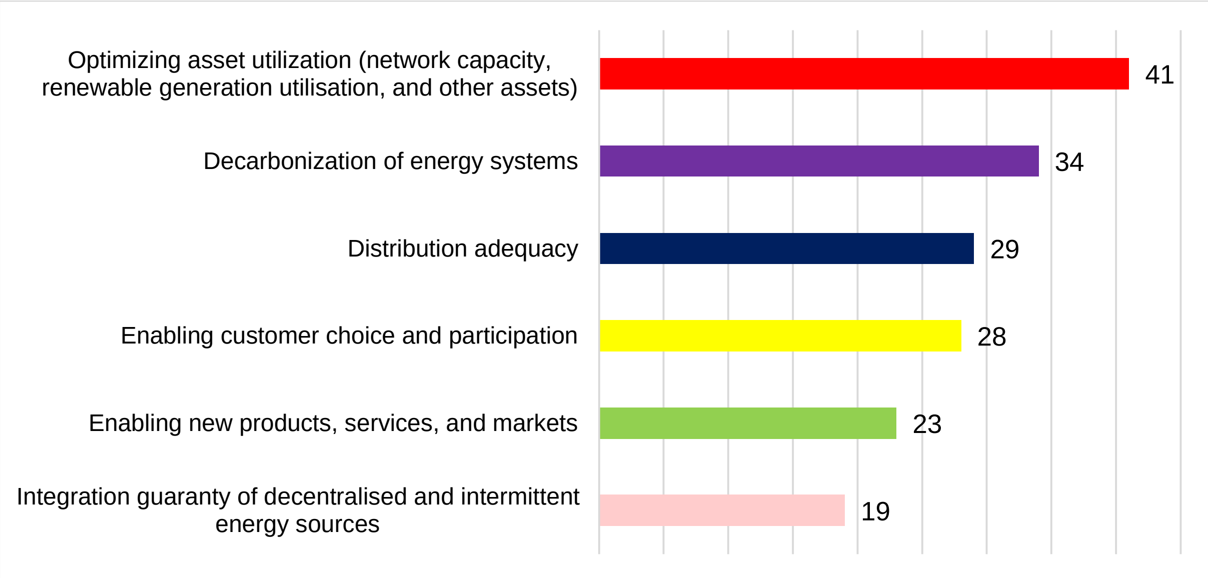

Figure 4. Top-6 Ranked Motivating Drivers from Clustering Analysis by Developed Economies

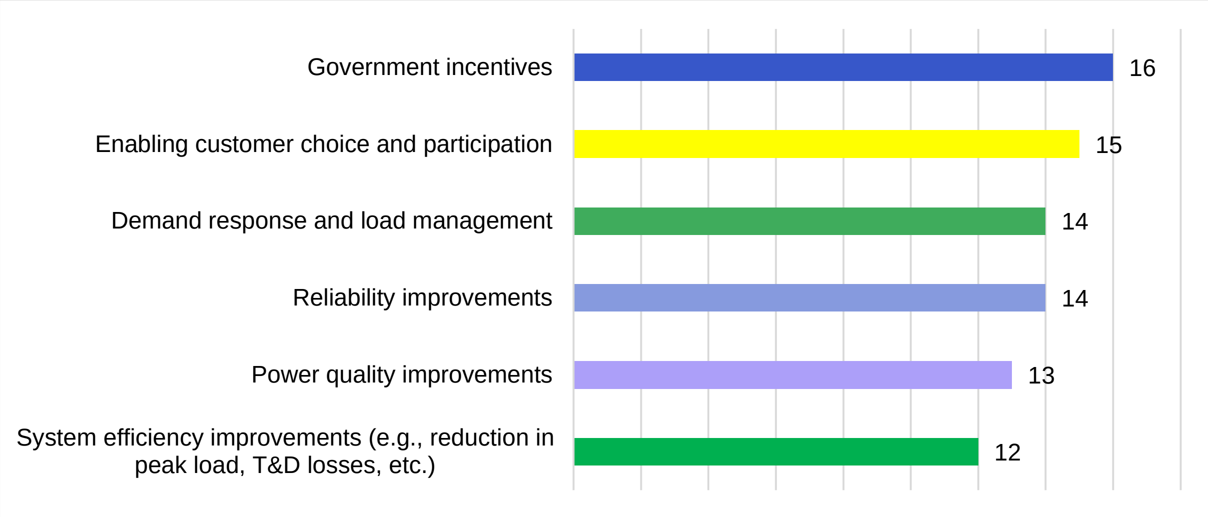

Figure 5. Top-6 Ranked Motivating Drivers from Clustering Analysis by Developing Economies

As can be seen from the results, it can be found that the major driving drivers of smart grids in developing countries and advanced countries are quite different.

Considering the fact that developed countries selected 'Optimizing asset utilization', 'Decarbonization of energy systems', 'Distribution adequacy', 'Enabling customer choice and participation', 'Enabling new products, services, and markets', and 'Integration guarantee of decentralized and intermittent energy source' as the top six drivers for smart grids, it is explained that they tend to put more weigh on the optimal management of power assets, participation of prosumers in the market, decarburization, GHG reduction, and decentralization and integrated management of resources.

On the other hand, developing countries selected 'Government incentives', 'Enabling customer choice and participation', 'Demand response and load management', 'Reliability improvements', and 'System efficiency improvements' (e.g., reduction in peak load, T&D losses, etc.) as the top six drivers for smart grids, indicating that they are more interested in government incentives, power system stability, power quality improvement, and decentralization of resources due to their limited power generation sources.

The clustered analysis economic scale shows that 'Enabling customer choice and participation' is the driver that both developed and developing countries consider important, indicating that customer participation is an essential factor in the spread and deployment of smart grids.

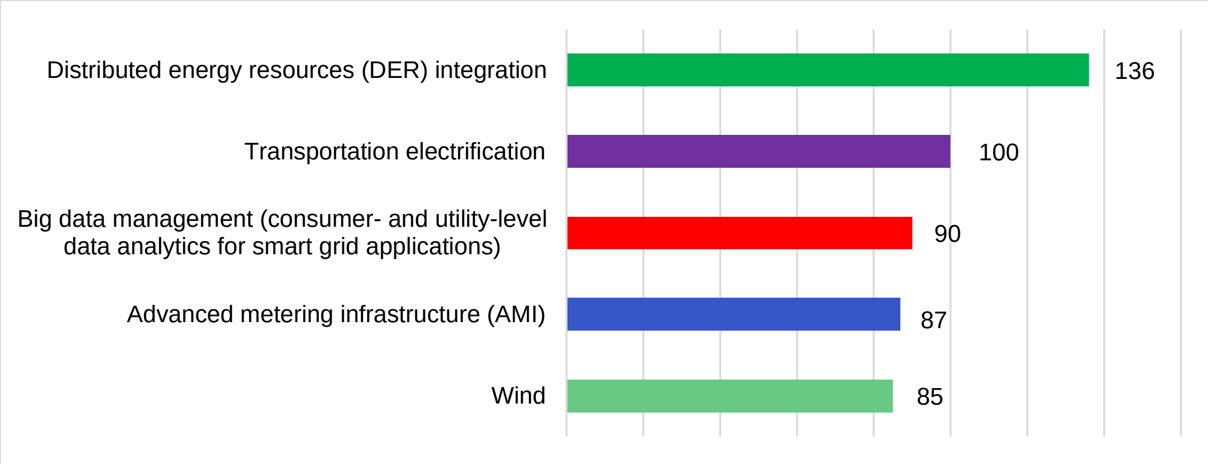

Figure 6. Technology Priorities across All Drivers from Analysis by Developed Economies

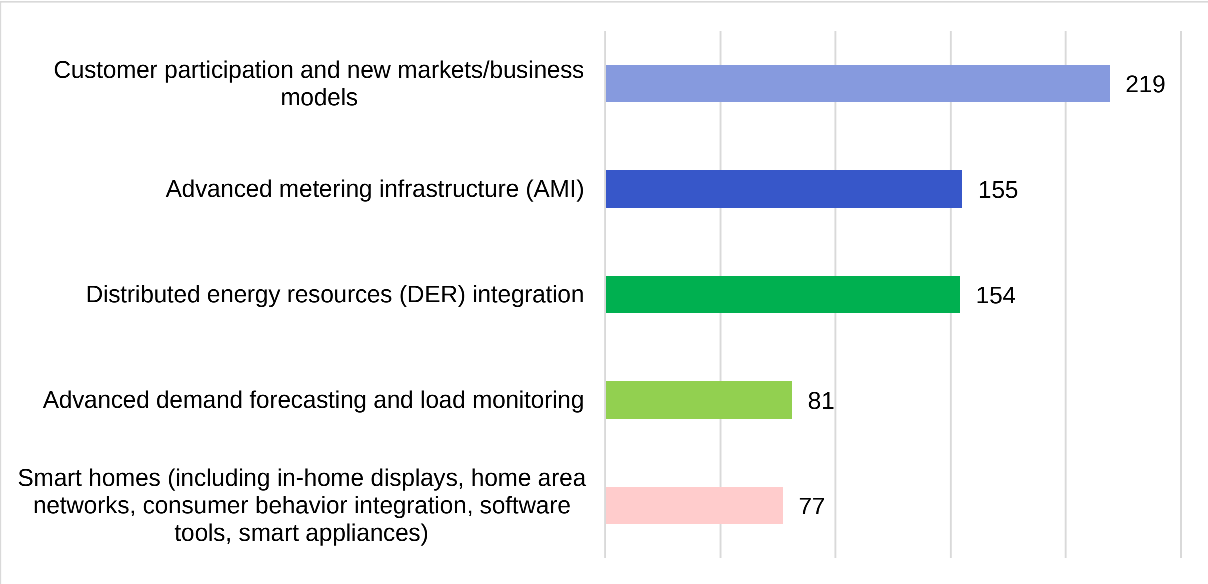

Figure 7. Technology Priorities across All Drivers from Analysis by Developing Economies

The analysis result shows that both developed and developing countries selected the following two technologies as one of the top five smart grid technologies:

- Advanced Metering Infrastructure (AMI)
- Distributed Energy Resources (DER) integration

Considering the fact that developed countries selected 'Distributed Energy Resources(DER) integration', 'Transportation electrification', 'Big data management', 'Advanced Metering Infrastructure (AMI)', and 'Wind' as the top five key smart grid technologies, they seem to have more interests in adopting new technologies such as renewable DER, electric vehicles, and big data.

On the other hand, developing countries selected 'Customer participation and new markets', 'business models', 'Advanced Metering Infrastructure (AMI)', 'Distributed Energy Resources (DER) integration', 'Advanced demand forecasting and load monitoring', and 'Smart homes'.

This indicates that they are keen on other technologies needed by the end-users that help generate the short-term profits rather than by power utility companies (suppliers).

6.0 Multinational-Level Analysis Results by Continent

Clustering analyses of multinational results show the top motivating drivers (Figure 8) and the top technologies across all drivers (Figure 9) for each of the four continents. The number of Participants in each continent is indicated as follows in parentheses: Asia (5); Oceania (1); Europe (10); and North America (1). The identity of Participants in each continent is shown in Table 3.

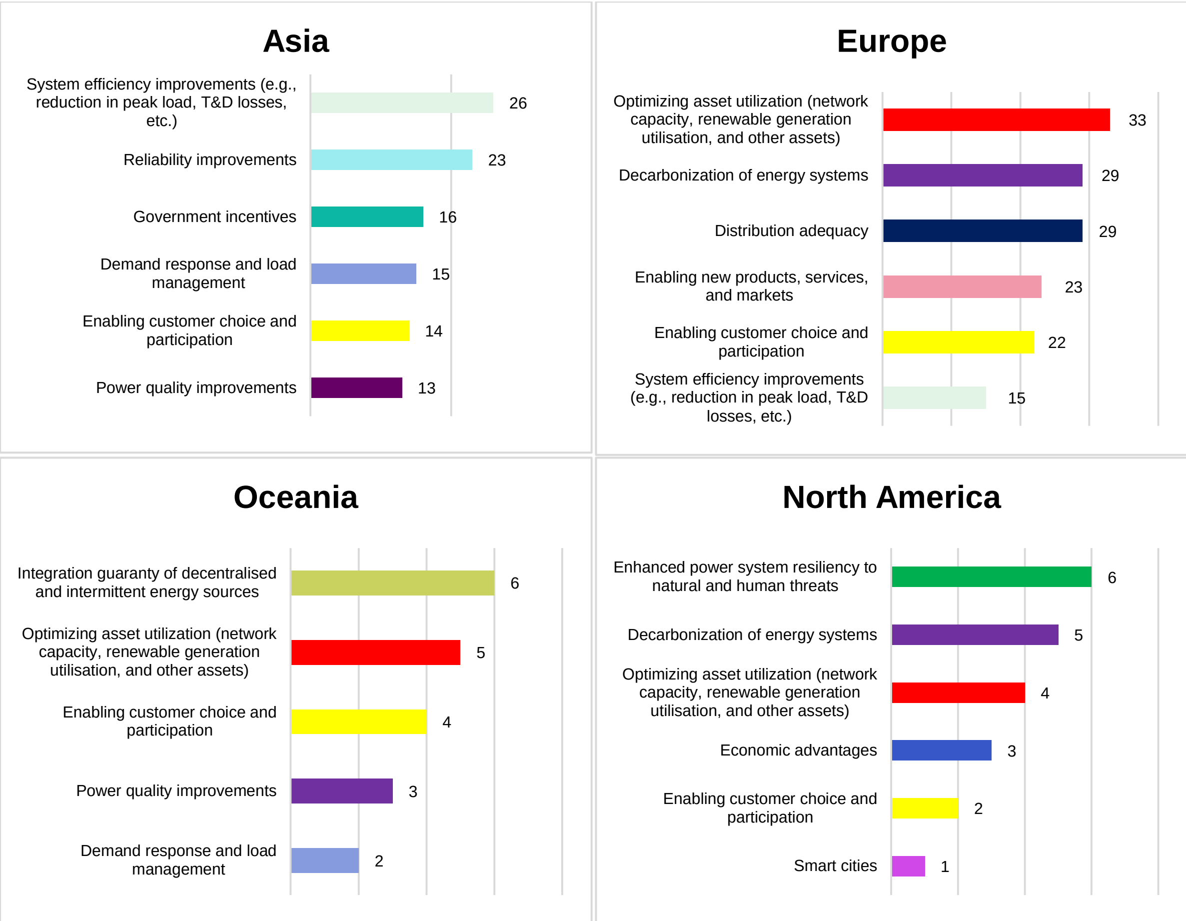

Figure 8. Top-6 Ranked Motivating Drivers from Clustering Analyses by Continent

Notably, drivers related to aspects of the system optimization including 'System efficiency improvements' or 'Optimizing asset utilization' were commonly selected as most the significant driver for smart grids by all continents.

In addition, although the main drivers for smart grids for each continent appear differently, all continents selected 'Enabling customer choice and participation' as one of the top six drivers for smart grids. It can be assumed that active consumer participation and empowerment is the most important factor in spreading the smart grid in all continents.

Figure 9. Top-5 Ranked Technology Priorities across All Drivers by Continent

The above analysis result shows that 'Distributed Energy Resources (DER) integration' was commonly selected as one of the top five technologies in all continents.

It appears that Europe is focusing on optimizing and managing the assets of power facilities, and it is analyzed that it has a lot of interest in integrated management of distributed resources of renewable energy including wind power.

In Asia, it appears that a lot of efforts are being made on the aspect of improving the efficiency of power facilities, and it is analyzed that they are very interested in load prediction and management that combines new technologies such as artificial intelligence (AI) with smart grids.

In North America, it appears that a lot of efforts are being made to build a power system that can be sustained in the face of natural disasters and various environmental variables, and in particular, there is an interest in active use of distributed resources such as improving the utilization of hydroelectric power.

In Oceania, it is understood that efforts are made to maximize regional decentralization and intermittent energy use by breaking away from the existing centralized power supply. It is also analyzed that they are interested in the development of simulation tools for smart grid design, operation and analysis through distributed resources.

7.0 Motivating Drivers and Technologies Identified as being of Priority to Two or More of the Continents

Common motivating drivers and technologies identified as being of priority to at least two of the four continents are presented in Table 4.

Table 4. Motivating Drivers and Technologies Identified as a Priority to Two or More Continents

Motivating Driver	Priority to Continents
Enabling Customer Choice and Participation	All
Optimizing Asset Utilization	Europe, Oceania, North America
System Efficiency Improvements	Asia, Europe
Decarbonization of Energy Systems	Europe, North America
Demand Response and Load Management	Asia, Oceania
Power Quality Improvements	Asia, Oceania

Technology	Priority to Continents
Distributed Energy Resources (DER) Integration	All
Advanced Metering Infrastructure (AMI)	Asia, Oceania
Advanced Demand Forecasting and Load Monitoring	Asia, Europe
Consumer Participation and New Markets/Business Models	Asia, Europe
System Wide Monitoring, Measurement, and Control	Oceania, North America

As shown, 'Enabling Customer Choice and Participation' is the only motivating driver of priority to all four continents; the next most common driver, i.e., of priority to four continents, is 'Optimizing Asset Utilization'.

In regard to the common technologies, 'Distributed Energy Resources (DER) Integration' is the commonly interested technology that has a high priority to all four continents.

The following table summarizes the top priority driver and the associated core technologies for each continent:

Table 5. Quick Glance at Core Technologies for the Top Priority Drivers by Continents

Continent	Top Priority Driver	Top Five Core Technologies
Asia	System Efficiency Improvements	1. Advanced Demand Forecasting and Load Monitoring 2. Advanced Metering Infrastructure (AMI) 3. Distributed Energy Resources (DER) Integration 4. AI and Machine Learning 5. Smart Homes
Europe	Optimizing Asset Utilization	1. Distributed Energy Resources (DER) Integration 2. Transportation Electrification 3. Customer Participation and New Markets/Business Models 4. Wind 5. Advanced Demand Forecasting and Load Monitoring
Oceania	Integration Guarantee of Decentralized and Intermittent Energy Sources	1. Distributed Energy Resources (DER) Integration 2. Advanced Tools and Software Framework for Planning, Operation, and Analysis 3. Advanced Metering Infrastructure (AMI) 4. System-wide Monitoring, Measurement, and Control 5. Standards and Conformance Testing
North America	Enhanced Power System	1. Distribution Management Systems 2. Hydro Power 3. Distribution Energy Resources (DER) Integration 4. System-wide Monitoring, Measuring, and Control 5. Renewable Energy Sources Integration

Appendix A. Survey Participating Countries

A total of 40 experts worldwide participated in the 2020 survey, but 12 of 40 questions were not analyzed because some participants did not finish the questionnaire.

The 28 survey responses collected from 18 countries, as highlighted in the table, were included in the analysis results and reflected to the priority evaluation results at the national and individual levels.

The numbers in parentheses refer to the number of participants in the country, and country listing is in order of completion of the survey.

Table 6. Status of Survey Completion and Validation by ISGAN/Non-ISGAN Participants

Survey Participation	ISGAN Member Countries	Non-**ISGAN Member Countries**
All 40 responses (19 countries)	Korea (2), United States (2), Germany (3), Netherlands, United Kingdom (2), France (3), Canada, Sweden (6), Japan, Italy, Spain (2), India (6), Ireland, Australia, Belgium (3), and Austria	Malaysia (2), Thailand, and Vietnam
Valid response are 28 responses among total 40 responses (18 countries)	Korea, Germany, Netherlands, United Kingdom (2), France, Sweden (4), Canada, Japan, Italy, Spain (2), Australia, India (6), Ireland, Belgium, and Austria	Malaysia, Thailand, and Vietnam

Appendix B. Parameters for motivating drivers and technologies for 2020 survey

Table 7. Parameters for Smart Grid Motivating Drivers for 2020 Survey

Reliability	Distribution adequacy Generation adequacy Power quality improvements Power restoration improvements Reliability improvements Transmission adequacy
Efficiency	System efficiency improvements (e.g., demand response and load management for reduction in peak load, T&D losses, etc.) Optimizing asset utilization (network capacity, renewable generation utilisation, and other assets) Energy efficiency improvements Enabling new products, services, and markets Enabling customer choice and participation Demand response and load management
Economic	Economic advantages Emerging business models Government incentives Reducing operating and maintenance costs Revenue collection and assurance improvements Smart regulations to incentivize investments social prosperity
Environmental	Renewable energy standards or targets Environmental advantages Regulatory compliance Decarbonization of energy systems
Security	National security concerns Enhanced power system resiliency to natural and human threats Integration guaranty of decentralized and intermittent energy sources
Crosscutting	Aging workforce concerns Aging infrastructure concerns Energy consumers Job creation Rural electrification Smart cities Sector-coupling, i.e. between electricity and heat, gas and transport sectors.
Policy	Regulatory (Experimental) Sandboxes Nuclear power phase-out

Table 8. Parameters for Smart Grid Technologies for 2020 Survey

Crosscutting	Advanced demand forecasting and load monitoring
	Ancillary services by distribution system operators
	Big data management (consumer- and utility-level data analytics for smart grid applications)
	Coordinated transmission and distribution operations
	Cyber security and Cyber physical security
	Electromagnetic compatibility
	Information and communications technology
	Integration of demand-side management (DSM) in transmission and distribution operations
	Network automation
	Novel market models
	Phasor measurement unit (PMU) based systems for enhanced grid observability and controllability
	Power electronics-based devices, including intelligent electronic devices (switches, relays, breakers, reclosers, transformers, capacitor banks), short-circuit current limiters, inverters & converters, regulators & circuit improvement
	Standards and conformance testing
	System wide monitoring, measurement, and control
	Advanced tools and software framework for planning and operation, and analysis
	Workforce training and education
	AI and Machine learning
	IOT (Internet of Things)
	Block-Chain
	Sector coupling (P2H, P2G,V2G)
	Drone technology
	Demand response
	Advanced energy storage (including Lithium-ion batteries, Vanadium flow batteries, sodium sulphur batteries and hot water storage) and energy storage integration
End Users	Building energy management and automation
	Distributed energy resources (DER) integration
	Microgrids, minigrids, and local sustainable energy
	Smart homes (including in-home displays, home area networks, consumer behavior integration, software tools, smart appliances)
	Costumer participation and new markets / business models
Distribution	Advanced metering infrastructure (AMI)
	Condition-based monitoring and maintenance
	Direct load control
	Distributed energy resources (DER) integration
	Distribution feeder circuit automation
	Distribution management systems (including situational awareness, state estimation, and outage management)
	Enterprise back office system – geographic information system (GIS), outage management system, customer information system, meter data management system
	Fault detection, identification, and restoration (FDIR)

	Power quality improvements Transportation electrification Capacitor automation Voltage & VAR control
Transmission and Substation	Advanced conductors for transmission lines Dynamic-thermal circuit rating Flexible alternating current transmission system (FACTS) devices High-voltage DC (HVDC) and high-voltage AC (HVAC) systems Market simulation tools (for balancing, congestion management, market integration) Renewables energy sources integration Resource planning, analysis, and forecasting tools High temperature superconducting devices (e.g. SFCL, cables etc.) Substation & transmission line sensors PMU – Phasor Measurement Units and its applications in power system operation
Generation	Biogas Biomass Hydro power Natural gas combined cycle Solar photovoltaic and solar thermal energy Tidal power Wave energy Wind Clean Coal, e.g., integrated gasification combined cycle (IGCC) Nuclear Ocean thermal energy Geothermal