QUANTA TECHNOLOGY

OAK RIDGE National Laboratory

Distribution System Synchronized Measurement Technology Deployment Industry Roadmap

Project team

- SDG&E
- ORNL
- Quanta Technology

Presentation Objectives

- Present update on project status

  - Follow up presentation to NASPI Virtual Work Group Meeting (April 15)

- Request feedback from NASPI Distribution Task Team to project draft report and presentation

  - Documents to be distributed after presentation

  - Please provide consolidated feedback (comments, track changes) by **August 27, 2021,** to Dan Brancaccio dbrancaccio@quanta-technology.com

- Please focus on applicability of roadmap to overall industry and specifically to current and future distribution needs and challenges

Overall Project Objectives and Approach

- Provide high-level guidance for development and investment synchronized measurement technology on distribution circuits, while looking at technical requirements and challenges vs. industry and customer needs.

- The roadmap shows the activities required for successfully deploying synchronized measurement technology and critical applications on the distribution systems of SDG&E and of other utilities in other regions with different needs.

- Helps DOE develop programs that can help the industry accelerate the grid modernization process by incorporating synchronized measurements and systems.

Roadmap for and Benefits of Deploying Sensor Technology for Distribution Network Modernization

- Identify and summarize major business drivers and needs.

- Industry outreach, including NASPI.

- Revise and update use cases and link them to key business drivers and needs.

- Identify system and product requirements and costs.

- Develop example budgetary cost estimates for typical deployment scenarios .

- Develop example roadmaps to help utilities accelerate the process - *Applications, Infrastructure, and Processes.*

Pilot programs

- Identify pilot programs for selected applications.

- Develop benefit-cost analysis for those pilots.

Roadmap Development Tasks
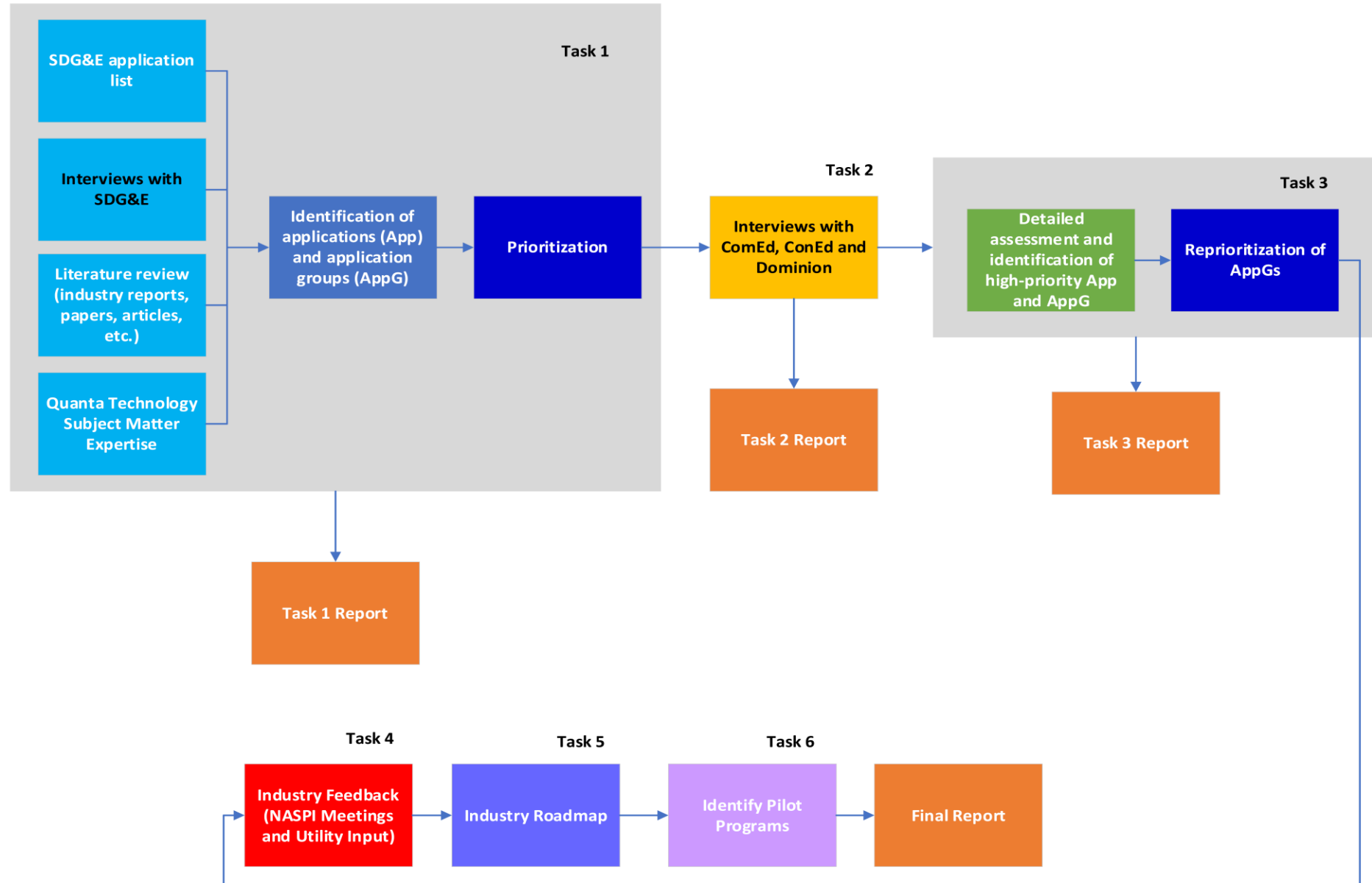
Summary of Industry Interviews

#	Questions	Utility (SDG&E)	ConEd	Dominion	ComEd
1	**Drivers and needs**				
	NERC compliance				■
	Risk management of major events	■			■
	Enhance transmission operation	■			
	Grid modernization/transformation			■	■
	DER integration	■			■
	Grid evolution				■
	Power quality for major customers				■
	Holistic T&D planning and operations	■			
	Real-time analytics				■
	Equipment failure and asset health management		■		
	Resilience improvement	■	■		
	Public Safety				
2	**Sensing technology benefits**				
	NERC compliance				■
	Risk management of major events				■
	Enhance transmission operation			■	
	Distribution reliability improvement	■			
	Grid evolution			■	
	Enhance distribution operation			■	■
	Real-time situational awareness	■		■	
	Improve DER integration				
3	**Utility needs and gaps**				
	Safety	■	■	■	
	Risk management	■	■		
	DER management		■		■
	Energy storage utilization		■		
	Electrification		■	■	
	T&D system planning			■	
	T&D system modeling and analysis			■	
	Asset management		■		
	Reliability & resilience			■	
	Power quality	■			
	Monitoring, protection, automation and control			■	
	PAC architecture		■		
	Grid analytics	■		■	■
	Grid evolution				■

#	Questions	Utility (SDG&E)	ConEd	Dominion	ComEd
4	**Existing synchronized measurement applications**				
	Linear distribution state estimation				■
	Microgrid operation				
	Falling conductor protection	■			
	System reconfiguration (phase angle monitoring)	■	■		
5	**Planned initiatives or vision**				
	Microgrid monitoring				■
	Critical customer monitoring				
	Real-time situational awareness	■		■	■
	System reconfiguration (phase angle monitoring)		■		
	Fault detection and protection				
	Power quality			■	
6	**Barriers and gaps for adoption**				
	Technology/application maturity				
	Telecommunications requirements	■			■
	Data management/storage needs	■			
	Cost	■	■		
	Business case development				
7	**Solutions to facilitate adoption**				
	Validation of business cases				
8	**Experience with synchronized measurement technology**				
	Positive experience				■
	Need for data quality verification				
9	**What can the industry do to faciliate adoption**				
	Demonstration of use cases				
	Large pilot programs			■	
	Foster innovation before standardization			■	
10	**Other technologies being explored and experience**				
	Power quality meters	■	■		■
	Advanced line sensors	■			
11	**Most valuable information from technology roadmap**				
	Implementing existing roadmap				■

Proposed Use Case and Application Grouping (1)

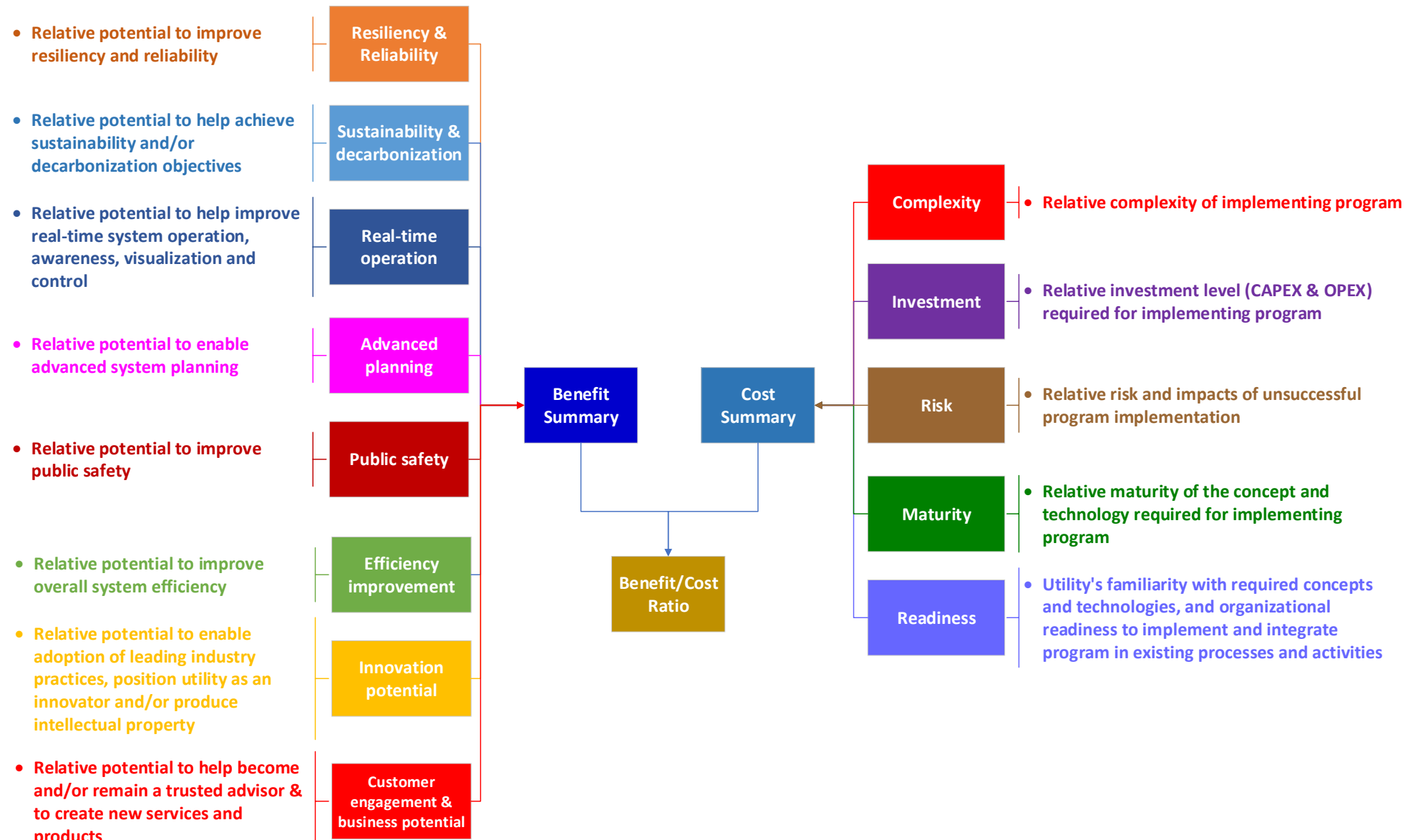| ORIGINAL SDG&E PROGRAM AREA (2012)	ORIGINAL SDG&E USE CASE NUMBER (2012)	PROPOSED GROUP NUMBER	PROPOSED APPLICATION GROUP DESCRIPTION	PROPOSED USE CASE NUMBER	NEW USE CASE DESCRIPTION
Monitoring	M-1		Advanced Volt-VAR Control (AVVC)	A1	Conservation Voltage Reduction (CVR)
Control & Optimization	C-1	AG1	Advanced Volt-VAR Control (AVVC)	A2	Volt-VAR Control (VVC) of distribution systems
Control & Optimization	C-8		Advanced Volt-VAR Control (AVVC)	A3	Volt-Var Optimization (VVO)
Monitoring	M-3		Advanced monitoring of distribution grid	A4	Active and reactive power flow monitoring
Monitoring	M-5		Advanced monitoring of distribution grid	A5	Voltage profile monitoring
Monitoring	M-11		Advanced monitoring of distribution grid	A6	Monitoring of communications system/equipment performance with management metrics
Monitoring	M-12	AG2	Advanced monitoring of distribution grid	A7	Frequency monitoring
Monitoring	M-14		Advanced monitoring of distribution grid	A8	Near real-time event monitoring (physical)
New	New		Advanced monitoring of distribution grid	A9	Near real-time event monitoring (cyber)
Monitoring	M-2		Advanced monitoring of distribution grid	A10	Phase angle monitoring for voltages and currents
Monitoring	M-6		Asset management of critical infrastructure	A11	Power apparatus asset management
New	New		Asset management of critical infrastructure	A12	Power apparatus functional monitoring
Control & Optimization	C-10	AG3	Asset management of critical infrastructure	A13	Monitoring and control of critical infrastructure and large customers
New	New		Asset management of critical infrastructure	A14	Underground secondary/spot network monitoring and analysis
Assessment	A-2		Asset management of critical infrastructure	A15	Dynamic rating of distribution assets
Monitoring	M-8		Wide area visualization	A16	Circuit status dashboards
Monitoring	M-13	AG4	Wide area visualization	A17	Integration of customer site FNET information
Monitoring	M-15		Wide area visualization	A18	Improved wide area situational awareness (T&D)
Model Validation	V-6		Wide area visualization	A19	Visualization of dynamic system response
Monitoring	M-4		DER integration	A20	Monitoring of intermittent DER
Assessment	A-1		DER integration	A21	Voltage impact assessment and mitigation due to high penetration of intermittent energy resources
Scheme Development	S-7	AG5	DER integration	A22	Active and reactive reverse power flow management
Control & Optimization	C-2		DER integration	A23	Customer/smart inverter control
Control & Optimization	C-7		DER integration	A24	DER management and energy balancing with energy storage
New	New		DER integration	A25	Load unmasking (behind-the-meter DER)
Assessment	A-6		Real-time distribution system operation	A26	Distribution state estimation
Control & Optimization	C-6	AG6	Real-time distribution system operation	A27	Closed-loop circuit operation
New	New		Real-time distribution system operation	A28	DERMS implementation
New	New		Real-time distribution system operation	A29	Improved demand response

Proposed Use Case and Application Grouping (2)

|					
Assessment	A-4	AG7	Enhanced reliability and resilience analysis	A30	Improved distribution reliability analysis
Assessment	A-5		Enhanced reliability and resilience analysis	A31	Post-mortem analysis
Monitoring	M-7	AG8	Advanced distribution system planning	A32	Phase identification
Model Validation	V-1		Advanced distribution system planning	A33	Distribution system computational model validation
Model Validation	V-2		Advanced distribution system planning	A34	Short circuit study validation
Model Validation	V-5	AG9	Distribution load, DER, and EV forecasting	A35	Load characterization, load modeling and load forecasting
New	New		Distribution load, DER, and EV forecasting	A36	DER forecasting
New	New		Distribution load, DER, and EV forecasting	A37	EV Forecasting
Assessment	A-7	AG10	Improved stability management	A38	Voltage stability monitoring and control
Scheme Development	S-15		Improved stability management	A39	Control instability, hunting, or oscillation detection - voltage, var, switching
New	New		Improved stability management	A40	Transient stability monitoring and control
New	New		Improved stability management	A41	Fault Induced Delayed Voltage Recovery (FIDVR) detection
Scheme Development	S-1	AG11	High-accuracy fault detection and location	A42	Faulted circuit indication
Scheme Development	S-4		High-accuracy fault detection and location	A43	Incipient fault & failure detection
Scheme Development	S-9		High-accuracy fault detection and location	A44	High accuracy fault location
Scheme Development	S-10		High-accuracy fault detection and location	A45	Communications failure location for maintenance dispatch
Scheme Development	S-12		High-accuracy fault detection and location	A46	High impedance fault location
Scheme Development	S-13		High-accuracy fault detection and location	A47	Open conductor fault detection
Scheme Development	S-2		High-accuracy fault detection and location	A48	Falling conductor protection
Scheme Development	S-8	AG12	Advanced distribution protection and control	A49	Reclosing assistance for fast circuit recovery after fault
New	New		Advanced distribution protection and control	A50	Current differential protection of feeder sections
New	New		Advanced distribution protection and control	A51	Adaptive protection of distribution systems
Control & Optimization	C-3	AG13	Advanced microgrid applications and operation	A52	Planned islanding and restoration of microgrids
New	New		Advanced microgrid applications and operation	A53	Advanced protection of microgrids
New	New		Advanced microgrid applications and operation	A54	Advanced distribution system topology, automation and control (holonic grids)
Scheme Development	S-3		Advanced microgrid applications and operation	A55	Islanding detection for distributed generation (anti-islanding scheme)
Scheme Development	S-5	AG14	Improved load shedding schemes	A56	Improved load shedding schemes - frequency
Scheme Development	S-6		Improved load shedding schemes	A57	Improved load shedding schemes - voltage
New	New		Improved load shedding schemes	A58	Improved load shedding schemes - load flow based
Control & Optimization	C-4		Improved load shedding schemes	A59	Load shedding real time compensative arming to balance 1547 compliant PV
Scheme Development	S-11	AG15	Advanced distribution automation	A60	Load transfer and load balancing
Control & Optimization	C-5		Advanced distribution automation	A61	Self-healing and enhanced FLISR operation

Proposed Use Case and Application Grouping (3)

Assessment	A-3		Technical and commercial loss reduction	A62	Circuit loss minimization
Scheme Development	S-14	AG16	Technical and commercial loss reduction	A63	Energy accounting
New	New		Technical and commercial loss reduction	A64	Techical and commercial loss identification, calculation and reduction
New	New		Monitoring and control of electric transportation infrastructure	A65	Monitoring and control of electric transportation infrastructure
New	New	AG17	Monitoring and control of electric transportation infrastructure	A66	Vehicle-to-Grid (V2G) monitoring and control
Control & Optimization	C-9		Integrated resource, transmission and distribution system planning and analysis	A67	Running sub-transmission (69 kV) and distribution in parallel
New	New	AG18	Integrated resource, transmission and distribution system planning and analysis	A68	Integrated resource, transmission and distribution system planning and analysis
Monitoring	M-9		Power quality assessment and analysis	A69	Harmonics measurement
New	New		Power quality assessment and analysis	A70	Voltage sag and swell measurement
New	New		Power quality assessment and analysis	A71	Flicker measurement
New	New	AG19	Power quality assessment and analysis	A72	Voltage and current imbalance measurement
New	New		Power quality assessment and analysis	A73	Short-duration interruption measurement
New	New		Power quality assessment and analysis	A74	Harmonic state estimation/diagnosis
New	New		Power quality assessment and analysis	A75	Primary meter customer (e.g major customer monitoring -power quality)

Prioritization: Benefit – Cost Ratio Calculation

- Relative potential to improve resiliency and reliability

Resiliency & Reliability

- Relative potential to help achieve sustainability and/or decarbonization objectives

Sustainability & decarbonization

- Relative potential to help improve real-time system operation, awareness, visualization and control

Real-time operation

- Relative potential to enable advanced system planning

Advanced planning

- Relative potential to improve public safety

Public safety

- Relative potential to improve overall system efficiency

Efficiency improvement

- Relative potential to enable adoption of leading industry practices, position utility as an innovator and/or produce intellectual property

Innovation potential

- Relative potential to help become and/or remain a trusted advisor & to create new services and products

Customer engagement & business potential

Benefit Summary

Cost Summary

Benefit/Cost Ratio

Complexity
- Relative complexity of implementing program

Investment
- Relative investment level (CAPEX & OPEX) required for implementing program

Risk
- Relative risk and impacts of unsuccessful program implementation

Maturity
- Relative maturity of the concept and technology required for implementing program

Readiness
- Utility's familiarity with required concepts and technologies, and organizational readiness to implement and integrate program in existing processes and activities
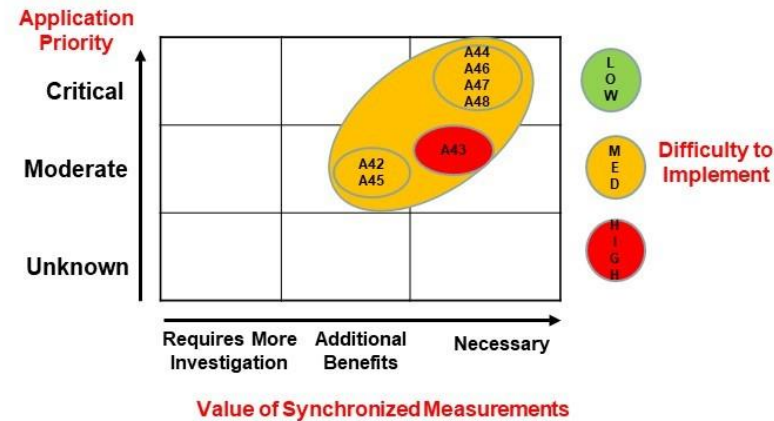
Example – Value of Synchronized Measurements for AG4, AG11, and AG13

Value of Synchronized Measurements for Wide Area Visualization (AG4)
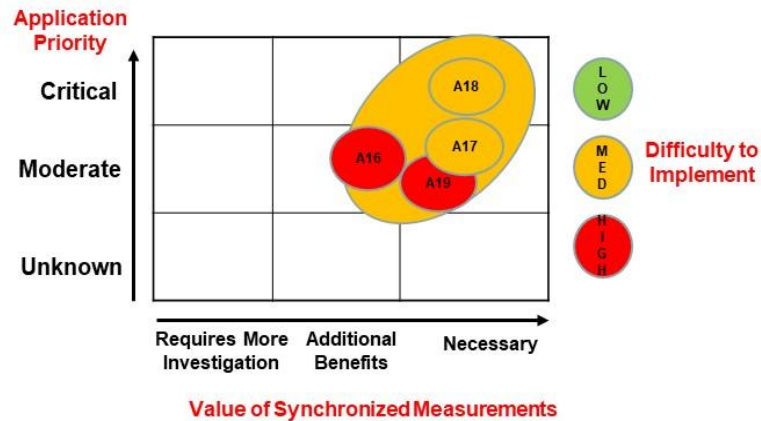

A16: Circuit status dashboard
A17: Integration of customer FNET information
A18: Improved wide area situational awareness
A19: Visualization of dynamic system response

High-Accuracy Fault Detection and Location (AG11)

A42: Faulted circuit indication
A43: Incipient fault and failure detection
A44: High accuracy fault location
A45:Communications failure location for maintenance dispatch
A46: High impedance fault location
A47: Open-conductor fault detection
A48: Falling conductor protection

Advanced Microgrid Applications and Operation (AG13)
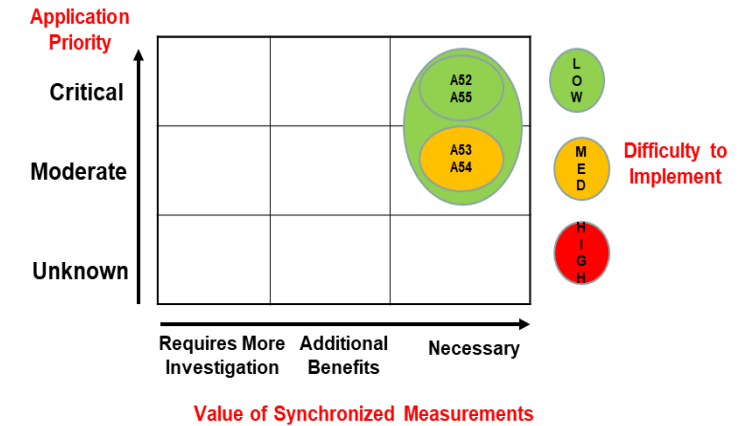
A52: Planned islanding and restoration of microgrids
A53: Advanced protection of microgrids
A54: Advanced distribution system topology, automation, and control
A55: Anti-islanding detection for distributed energy resources (anti-islanding scheme)

Results from Benefits Analysis (Relative Benefits by Initiative)

Application Number	Application Description	Relative Benefit								Benefit Summary	Benefit Summary Numerical
		Resilience & Reliability	Sustainability & Decarbonization	Real-Time Operation	Advanced Planning & Asset Mgmt.	Public Safety	Efficiency Improvement	Innovation Potential	Customer Engagement & Bus. Potential		
AG1	AVVC	4	5	5	5	3	6	4	6	MEDIUM	4.54
AG2	Advanced monitoring of distribution grid	7	6	8	6	6	8	6	5	HIGH	6.64
AG3	Asset management of critical infrastructure	7	4	5	7	6	7	7	5	MEDIUM	5.94
AG4	Wide-area visualization	8	6	9	6	7	5	6	7	HIGH	7.00
AG5	DER integration and control	7	9	7	7	4	6	8	7	HIGH	6.62
AG6	Real-time distribution system operation	8	5	9	4	7	7	6	5	HIGH	6.70
AG7	Enhanced reliability and resilience analysis	6	4	3	6	4	4	6	5	MEDIUM	4.58
AG8	Advanced distribution system planning	6	5	2	7	2	6	6	4	MEDIUM	4.42
AG9	Distribution load, DER and EV forecasting	6	7	5	7	2	6	5	6	MEDIUM	5.26
AG10	Improved stability management	7	4	9	3	4	4	7	3	MEDIUM	5.28
AG11	High-accuracy fault detection and location	8	4	8	6	9	8	7	7	HIGH	7.30
AG12	Advanced distribution protection and control	8	7	8	2	9	4	7	5	HIGH	6.72
AG13	Advanced microgrid applications and operation	8	8	7	4	5	4	7	7	HIGH	6.26
AG14	Improved load shedding schemes	7	4	7	4	4	6	6	6	MEDIUM	5.42
AG15	Advanced distribution automation	7	4	6	3	6	6	6	4	MEDIUM	5.42
AG16	Technical and commercial loss reduction	2	5	4	5	3	7	5	6	MEDIUM	4.16
AG17	Monitoring and control of electric transportation infrastructure	5	7	5	7	3	5	7	6	MEDIUM	5.26
AG18	Integrated resource, T&D system planning and analysis	6	6	4	7	3	7	6	4	MEDIUM	5.18
AG19	PQ measurement	6	5	5	6	2	5	6	7	MEDIUM	4.86

Results from Cost Analysis (Relative Costs by Initiative)

| Application Number	Application Description	Relative Cost					Cost Summary	Cost Summary Numerical
		Complexity	Investment (CapEx & OpEx)	Maturity	Risk	Readiness		
AG1	AVVC	4	6	7	3	7	MEDIUM	4.65
AG2	Advanced monitoring of distribution grid	4	7	6	3	7	MEDIUM	5.35
AG3	Asset management of critical infrastructure	8	8	6	4	5	HIGH	6.65
AG4	Wide-area visualization	6	7	6	3	6	MEDIUM	5.70
AG5	DER integration and control	7	7	6	5	5	HIGH	6.10
AG6	Real-time distribution system operation	7	7	6	5	7	HIGH	6.00
AG7	Enhanced reliability and resilience analysis	5	5	5	5	6	MEDIUM	4.95
AG8	Advanced distribution system planning	4	4	5	5	5	LOW	4.35
AG9	Distribution load, DER and EV forecasting	7	7	4	5	4	HIGH	6.55
AG10	Improved stability management	5	5	5	5	5	MEDIUM	5.00
AG11	High-accuracy fault detection and location	4	7	6	4	5	MEDIUM	5.55
AG12	Advanced distribution protection and control	7	7	5	5	5	HIGH	6.30
AG13	Advanced microgrid applications and operation	5	5	7	5	5	LOW	4.60
AG14	Improved load shedding schemes	5	5	7	3	5	LOW	4.40
AG15	Advanced distribution automation	6	7	6	6	6	HIGH	6.00
AG16	Technical and commercial loss reduction	5	4	6	3	6	LOW	4.05
AG17	Monitoring and control of electric transportation infrastructure	6	6	3	4	3	HIGH	6.05
AG18	Integrated resource, T&D system planning and analysis	8	8	3	4	2	HIGH	7.40
AG19	PQ measurement	5	6	7	2	5	MEDIUM	4.80

Prioritization Results

Prioritization results were used along with potential interdependencies among AGs to develop a proposed timeframe for implementation and overall roadmap

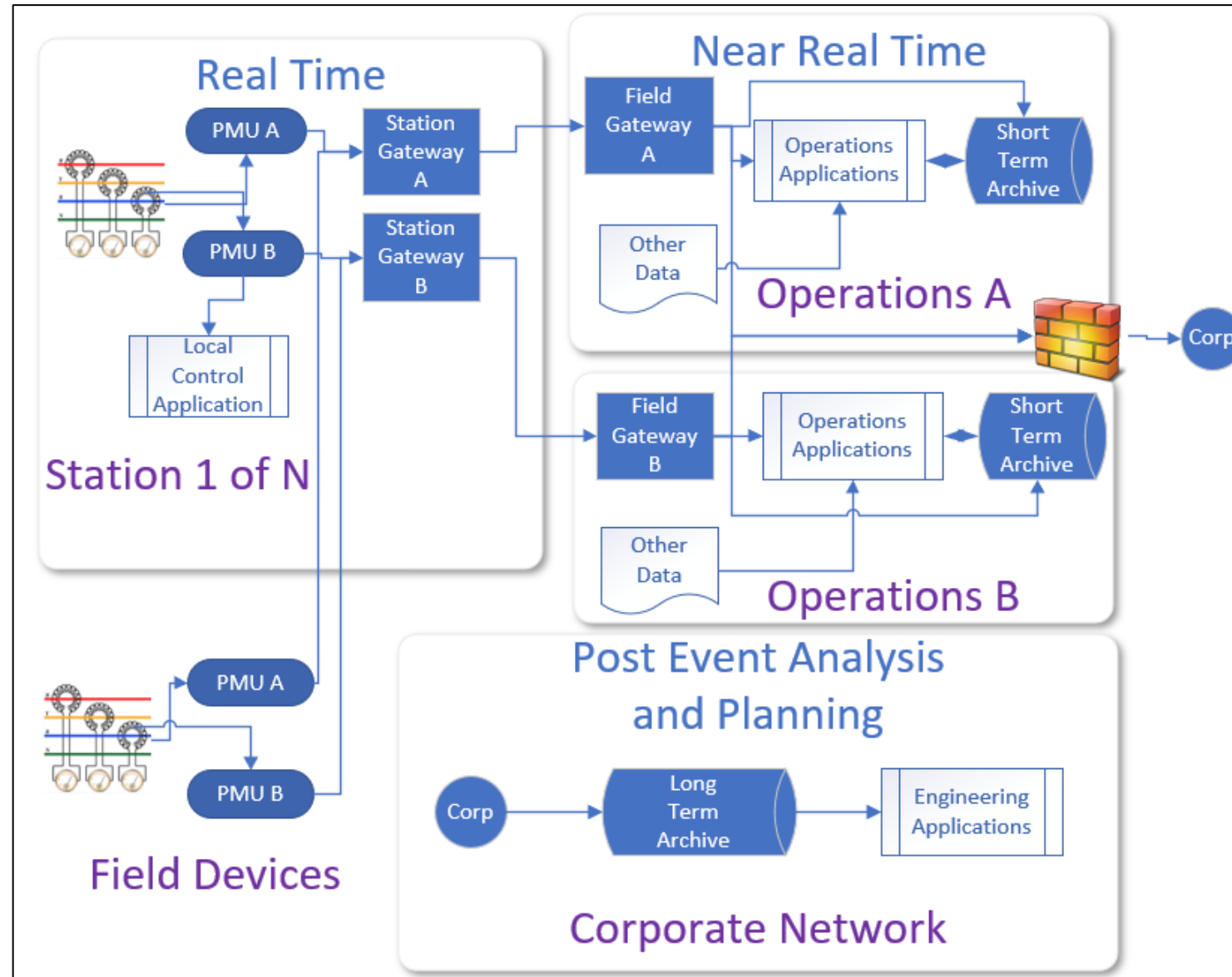| Application Number	Application Description	BCR_i	BCR_i Numerical
AG13	Advanced microgrid applications and operation	HIGH	1.36
AG11	High-accuracy fault detection and location	HIGH	1.32
AG2	Advanced monitoring of distribution grid	HIGH	1.24
AG14	Improved load shedding schemes	HIGH	1.23
AG4	Wide area visualization	HIGH	1.23
AG6	Real-time distribution system operation	MEDIUM	1.12
AG5	DER integration and control	MEDIUM	1.09
AG12	Advanced distribution protection and control	MEDIUM	1.07
AG10	Improved stability management	MEDIUM	1.06
AG16	Technical and commercial loss reduction	MEDIUM	1.03
AG8	Advanced distribution system planning	MEDIUM	1.02
AG19	Power quality measurement	MEDIUM	1.01
AG1	Advanced Volt-VAR Control (VVC)	MEDIUM	0.98
AG7	Enhanced reliability and resilience analysis	MEDIUM	0.93
AG15	Advanced distribution automation	MEDIUM	0.90
AG3	Asset management of critical infrastructure	MEDIUM	0.89
AG17	Monitoring and control of electric transportation infrastructure	MEDIUM	0.87
AG9	Distribution load, DER and EV forecasting	MEDIUM	0.80
AG18	Integrated resource, transmission and distribution system planning and analysis	LOW	0.70

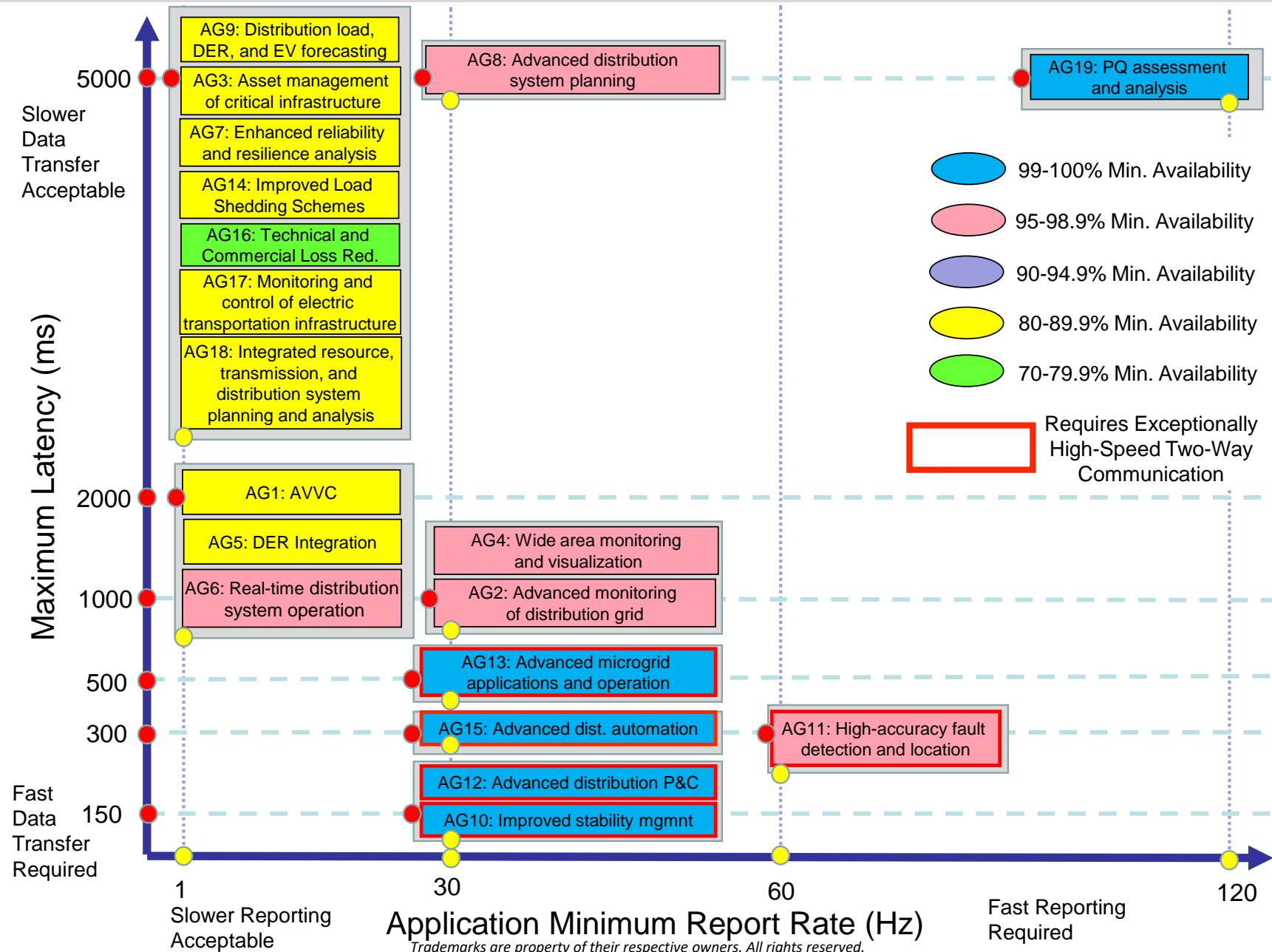# Prioritization Results – Application Benefit-Cost Ratio

APPLICATION BENEFIT-COST RATIO

Advanced microgrid applications and operations (highest benefit-cost ratio)

Integrated resource, transmission and distribution system planning and analysis (lowest benefit-cost ratio)
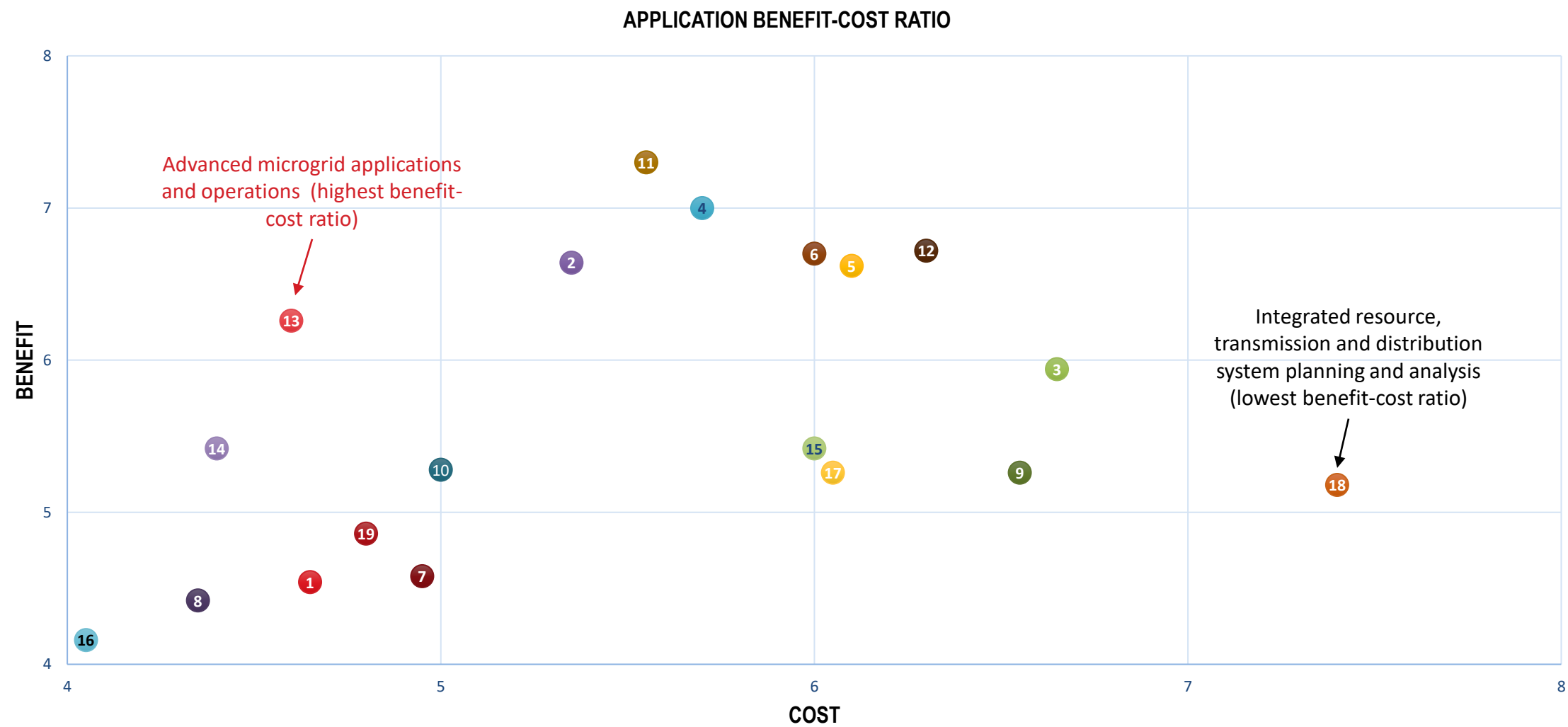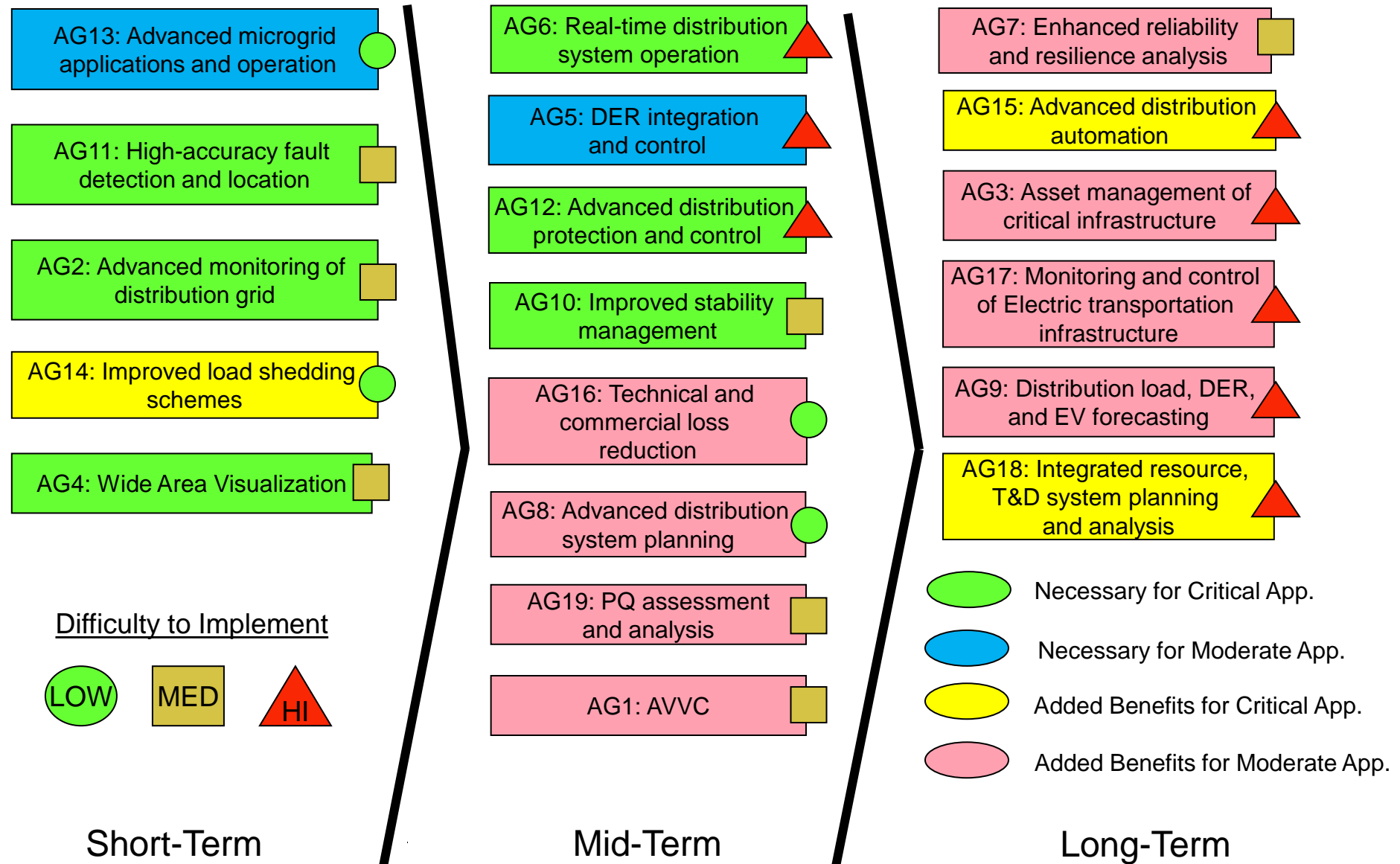
High Level System Architecture

Infrastructure and Process Requirements

Conclusions (1)

- **The 5 priority application groups from the overall industry perspective are:**
  - Advanced microgrid applications and operation
  - High-accuracy fault detection and location
  - Advanced monitoring of distribution grid
  - Improved load shedding schemes
  - Wide area visualization

- **These are all use cases with high benefits, that fully leverage the availability of synchronized measurements, and with only medium costs to implement.**

- **There are other applications where synchronized measurements will be greatly beneficial for improving the operations of the distribution system**
  - They include advanced distribution protection and control, real time distribution system operation, and DER integration and control.
  - The implementation of synchronized measurements for these specific applications is relatively complex or relatively immature in terms of algorithm, tools, or processes, so these high benefit applications will likely be a mid-term implementation priority.

- **Numerous viable applications using synchronized measurements can be adopted on the distribution system.**

  - This requires a strategic investment in infrastructure, system architecture, and processes—essentially, a great deal of change management.

  - These applications are based on acquiring large amounts of time-critical data that require significant bandwidth and are from numerous points on the distribution system.

- **Significant thought/planning should be given to system architecture, including availability requirements, accuracy requirements, and data archiving needs.**

  - This architecture requires a communication infrastructure that is more robust and capable than what is likely to exist for the distribution system.

- **Adoption requires a plan, organizational structure, tools, and training to implement, maintain, and enhance the applications and systems.**

  - This plan should define an organizational structure to support these applications and indicate the operating groups and roles responsible and accountable for application design, communications infrastructure, and data archiving and storage.

  - It should cover necessary maintenance, repair, support, and diagnostics tools, processes, and training for successful deployment.