



QUANTA
TECHNOLOGY



Distribution System Synchronized Measurement Technology Deployment – Industry Roadmap Development

Project team

- SDG&E
- ORNL
- Quanta Technology

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.

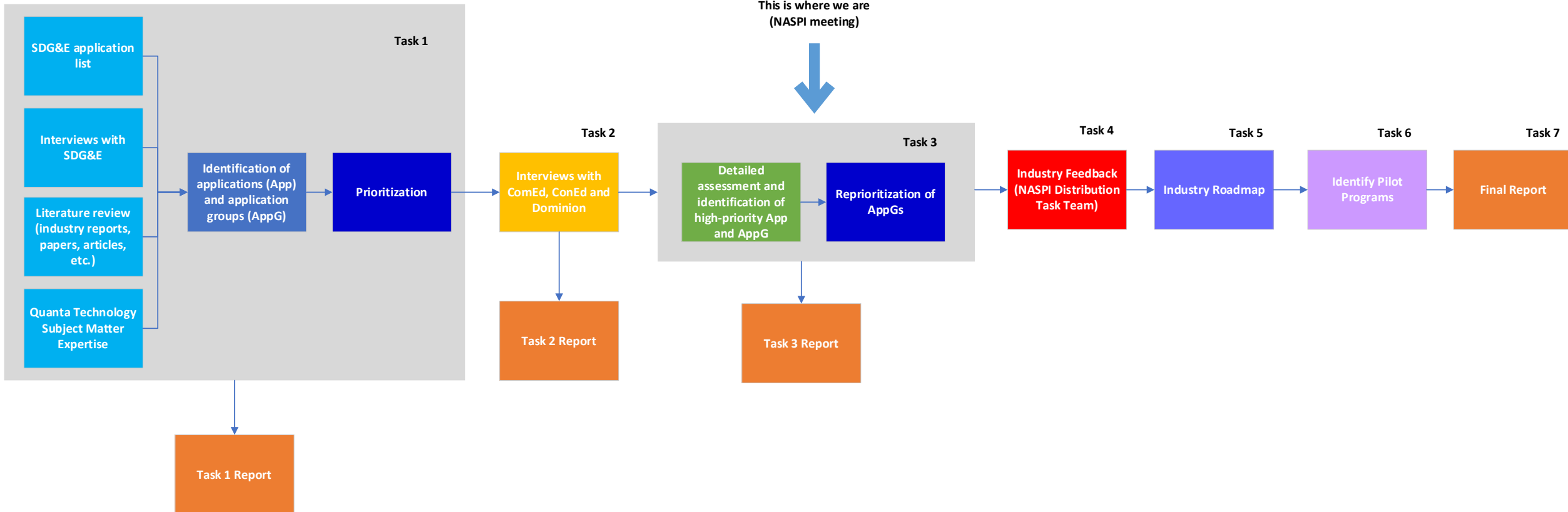
Roadmap for and Benefits of Deploying Sensor Technology for Distribution Network Modernization

- 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.

Project Tasks



Proposed Use Case and Application Grouping (1)

| PROPOSED GROUP NUMBER | PROPOSED APPLICATION GROUP DESCRIPTION | PROPOSED USE CASE NUMBER | NEW USE CASE DESCRIPTION |
|-----------------------|---|--------------------------|---|
| AG1 | Advanced Volt-VAR Control (AVVC) | A1 | Conservation Voltage Reduction (CVR) |
| | Advanced Volt-VAR Control (AVVC) | A2 | Volt-VAR Control (VVC) of distribution systems |
| | Advanced Volt-VAR Control (AVVC) | A3 | Volt-Var Optimization (VVO) |
| AG2 | Advanced monitoring of distribution grid | A4 | Active and reactive power flow monitoring |
| | Advanced monitoring of distribution grid | A5 | Voltage profile monitoring |
| | Advanced monitoring of distribution grid | A6 | Monitoring of communications system/equipment performance with management metrics |
| | Advanced monitoring of distribution grid | A7 | Frequency monitoring |
| | Advanced monitoring of distribution grid | A8 | Near real-time event monitoring (physical) |
| | Advanced monitoring of distribution grid | A9 | Near real-time event monitoring (cyber) |
| | Advanced monitoring of distribution grid | A10 | Phase angle monitoring for voltages and currents |
| AG3 | Asset management of critical infrastructure | A11 | Power apparatus asset management |
| | Asset management of critical infrastructure | A12 | Power apparatus functional monitoring |
| | Asset management of critical infrastructure | A13 | Monitoring and control of critical infrastructure and large customers |
| | Asset management of critical infrastructure | A14 | Underground secondary/spot network monitoring and analysis |
| | Asset management of critical infrastructure | A15 | Dynamic rating of distribution assets |
| AG4 | Wide area visualization | A16 | Circuit status dashboards |
| | Wide area visualization | A17 | Integration of customer site FNET information |
| | Wide area visualization | A18 | Improved wide area situational awareness (T&D) |
| | Wide area visualization | A19 | Visualization of dynamic system response |
| AG5 | DER integration | A20 | Monitoring of intermittent DER |
| | DER integration | A21 | Voltage impact assessment and mitigation due to high penetration of intermittent energy |
| | DER integration | A22 | Voltage impact mitigation for high penetration of intermittent DG |
| | DER integration | A23 | Active and reactive reverse power flow management |
| | DER integration | A24 | Customer/smart inverter control |
| | DER integration | A25 | DER management and energy balancing with energy storage |
| AG6 | Real-time distribution system operation | A26 | Load unmasking (behind-the-meter DER) |
| | Real-time distribution system operation | A27 | Distribution state estimation |
| | Real-time distribution system operation | A28 | Closed-loop circuit operation |
| | Real-time distribution system operation | A29 | DERMS implementation |
| | | A30 | Improved demand response |

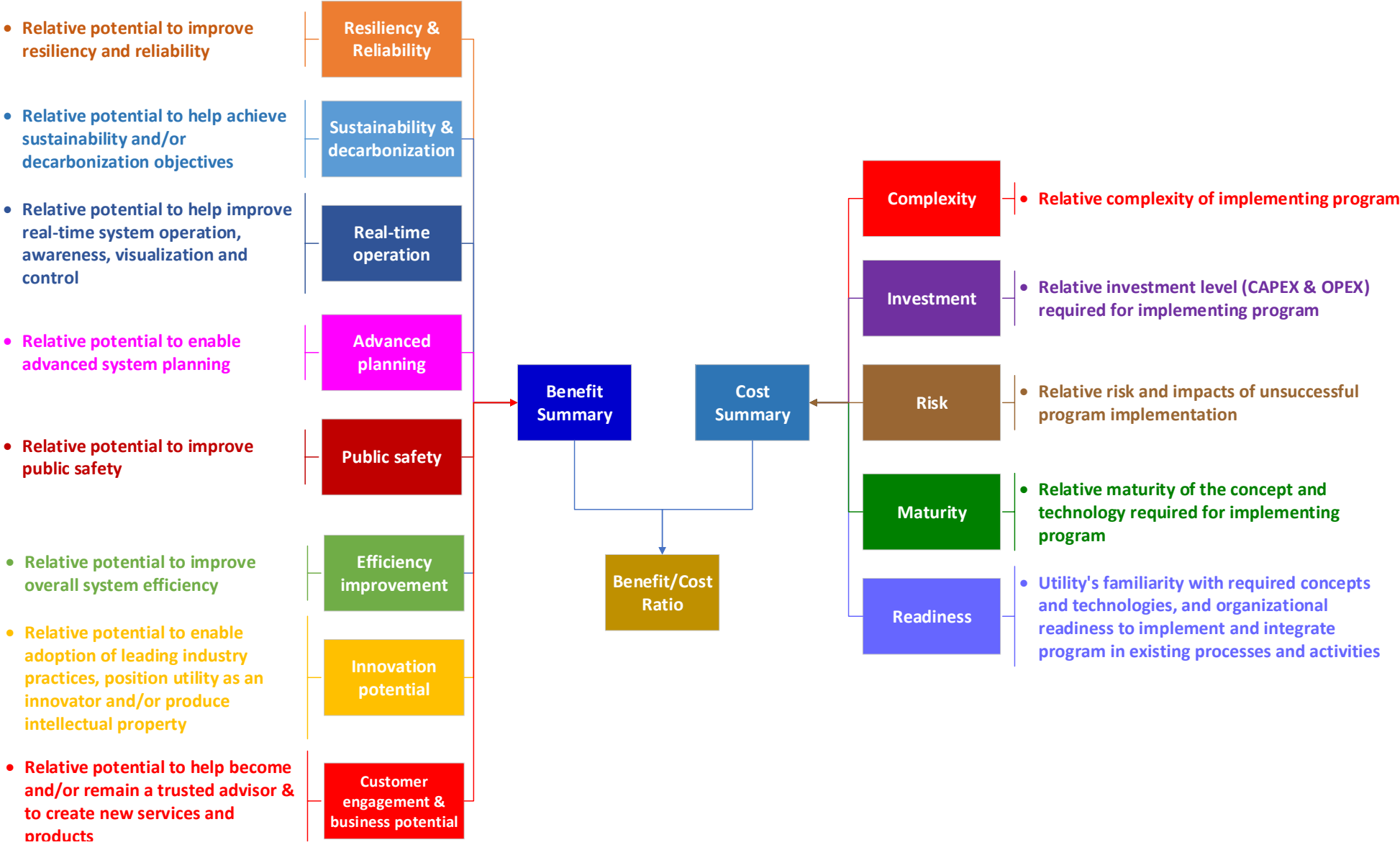
Proposed Use Case and Application Grouping (2)

| | | | |
|------|--|-----|--|
| AG7 | Enhanced reliability and resilience analysis | A31 | Improved distribution reliability analysis |
| | Enhanced reliability and resilience analysis | A32 | Post-mortem analysis |
| AG8 | Advanced distribution system planning | A33 | Phase identification |
| | Advanced distribution system planning | A34 | Distribution system computational model validation |
| | Advanced distribution system planning | A35 | Short circuit study validation |
| AG9 | Distribution load, DER, and EV forecasting | A36 | Load characterization, load modeling and load forecasting |
| | Distribution load, DER, and EV forecasting | A37 | DER forecasting |
| | Distribution load, DER, and EV forecasting | A38 | EV Forecasting |
| AG10 | Improved stability management | A39 | Voltage stability monitoring and control |
| | Improved stability management | A40 | Control instability, hunting, or oscillation detection - voltage, var, switching |
| | Improved stability management | A41 | Transient stability monitoring and control |
| | Improved stability management | A42 | Fault Induced Delayed Voltage Recovery (FIDVR) detection |
| AG11 | High-accuracy fault detection and location | A43 | Faulted circuit indication |
| | High-accuracy fault detection and location | A44 | Incipient fault & failure detection |
| | High-accuracy fault detection and location | A45 | High accuracy fault location |
| | High-accuracy fault detection and location | A46 | Communications failure location for maintenance dispatch |
| | High-accuracy fault detection and location | A47 | High impedance fault location |
| | High-accuracy fault detection and location | A48 | Open conductor fault detection |
| | High-accuracy fault detection and location | A49 | Falling conductor protection |
| AG12 | Advanced distribution protection and control | A50 | Reclosing assistance for fast circuit recovery after fault |
| | Advanced distribution protection and control | A51 | Current differential protection of feeder sections |
| | Advanced distribution protection and control | A52 | Adaptive protection of distribution systems |
| AG13 | Advanced microgrid applications and operatic | A53 | Planned islanding and restoration of microgrids |
| | Advanced microgrid applications and operatic | A54 | Advanced protection of microgrids |
| | Advanced microgrid applications and operatic | A55 | Advanced distribution system topology, automation and control (holonic grids) |
| | Advanced microgrid applications and operatic | A56 | Islanding detection for distributed generation (anti-islanding scheme) |
| AG14 | Improved load shedding schemes | A57 | Improved load shedding schemes - frequency |
| | Improved load shedding schemes | A58 | Improved load shedding schemes - voltage |
| | Improved load shedding schemes | A59 | Improved load shedding schemes - load flow based |
| | Improved load shedding schemes | A60 | Load shedding real time compensative arming to balance 1547 compliant PV |
| AG15 | Advanced distribution automation | A61 | Load transfer and load balancing |
| | Advanced distribution automation | A62 | Self-healing and enhanced FLISR operation |

Proposed Use Case and Application Grouping (3)

| | | | |
|------|---|-----|---|
| AG16 | Technical and commercial loss reduction Technical and commercial loss reduction Technical and commercial loss reduction | A63 | Circuit loss minimization |
| AG17 | Monitoring and control of electric transportation infrastructure Monitoring and control of electric transportation infrastructure | A64 | Energy accounting |
| AG18 | Integrated resource, transmission and distribution system planning and analysis Integrated resource, transmission and distribution system planning and analysis | A65 | Technical and commercial loss identification, calculation and reduction |
| AG19 | Power quality assessment and analysis Power quality assessment and analysis Power quality assessment and analysis Power quality assessment and analysis Power quality assessment and analysis Power quality assessment and analysis Power quality assessment and analysis | A66 | Monitoring and control of electric transportation infrastructure |
| | | A67 | Vehicle-to-Grid (V2G) monitoring and control |
| | | A68 | Running sub-transmission (69 kV) and distribution in parallel |
| | | A69 | Integrated resource, transmission and distribution system planning and analysis |
| | | A70 | Harmonics measurement |
| | | A71 | Voltage sag and swell measurement |
| | | A72 | Flicker measurement |
| | | A73 | Voltage and current imbalance measurement |
| | | A74 | Short-duration interruption measurement |
| | | A75 | Harmonic state estimation/diagnosis |
| | | A76 | Primary meter customer (e.g major customer monitoring -power quality) |

Prioritization: Benefit – Cost Ratio Calculation



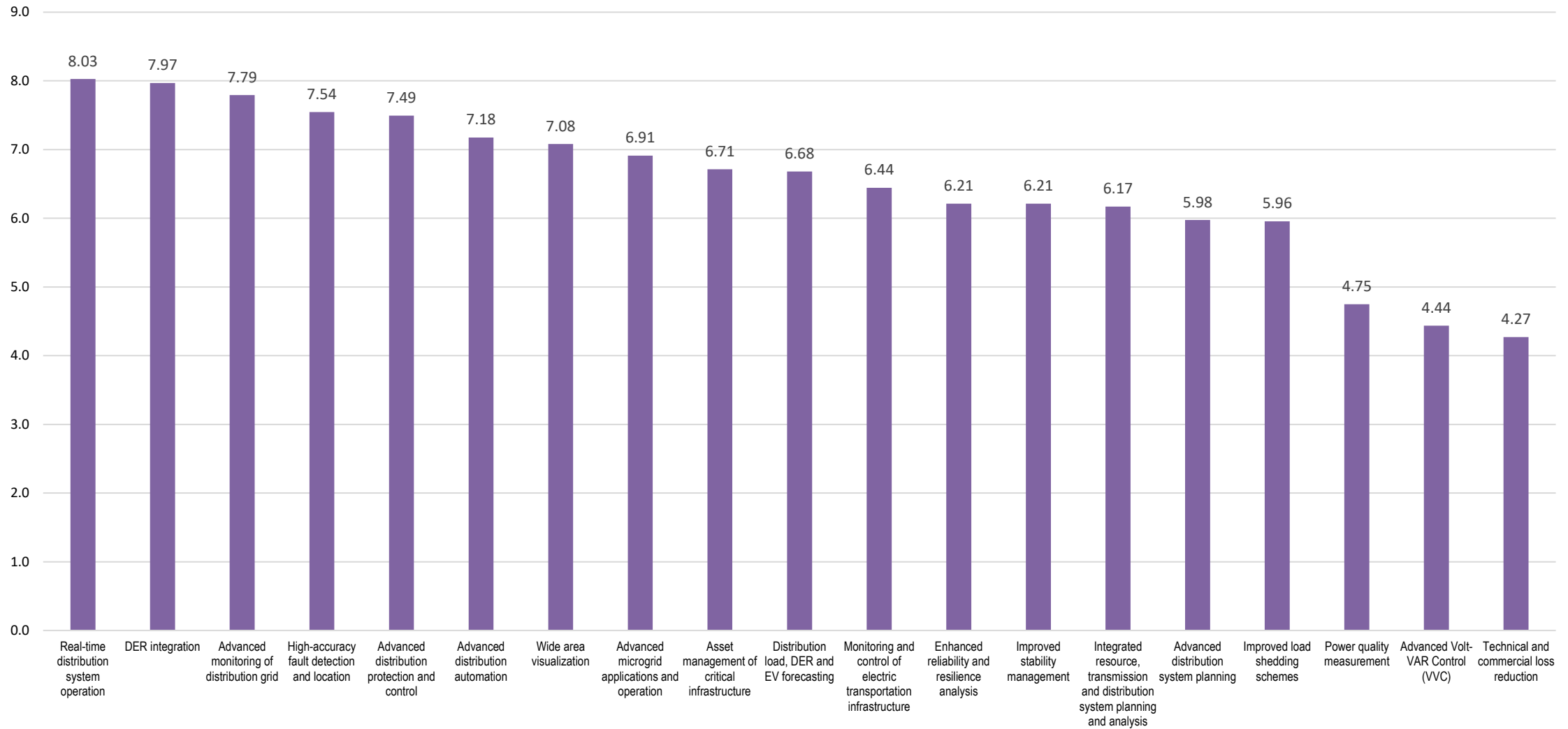
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Preliminary Prioritization Results

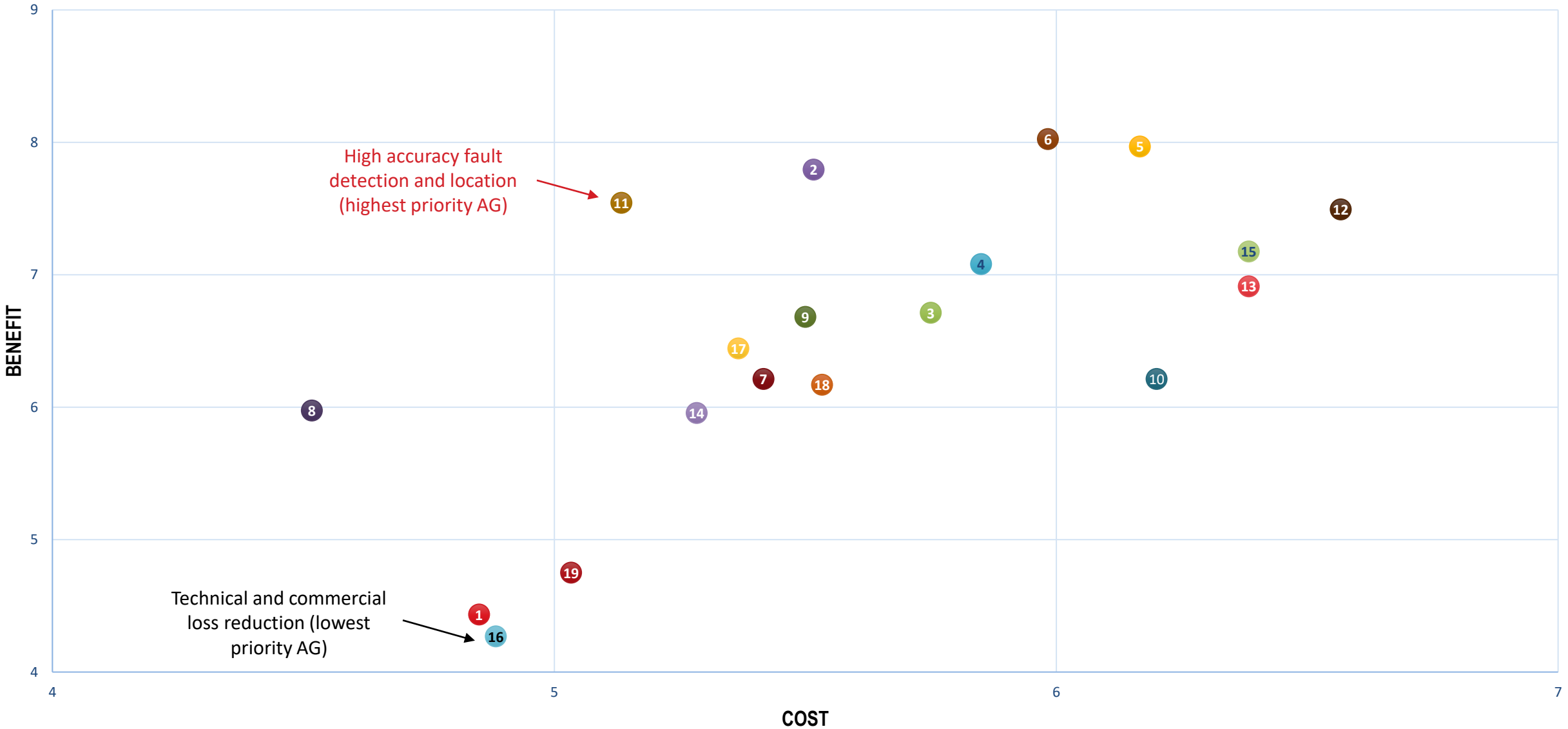
Prioritization results were used along with potential interdependencies among AGs to develop a proposed timeframe for implementation and overall roadmap

| APPLICATION NUMBER | APPLICATION DESCRIPTION | BENEFIT-COST RATIO | BENEFIT-COST RATIO NUMERICAL | PRIORITY NUMBER |
|--------------------|---|--------------------|------------------------------|-----------------|
| A11 | High-accuracy fault detection and location | | 1.47 | 1 |
| A2 | Advanced monitoring of distribution grid | | 1.41 | 2 |
| A6 | Real-time distribution system operation | | 1.34 | 3 |
| A8 | Advanced distribution system planning | | 1.32 | 4 |
| A5 | DER integration | | 1.29 | 5 |
| A9 | Distribution load, DER and EV forecasting | | 1.21 | 6 |
| A4 | Wide area visualization | | 1.21 | 7 |
| A17 | Monitoring and control of electric transportation infrastructure | | 1.20 | 8 |
| A3 | Asset management of critical infrastructure | | 1.17 | 9 |
| A7 | Enhanced reliability and resilience analysis | | 1.15 | 10 |
| A12 | Advanced distribution protection and control | | 1.14 | 11 |
| A14 | Improved load shedding schemes | | 1.13 | 12 |
| A15 | Advanced distribution automation | | 1.12 | 13 |
| A18 | Integrated resource, transmission and distribution system planning and analysis | | 1.11 | 14 |
| A13 | Advanced microgrid applications and operation | | 1.08 | 15 |
| A10 | Improved stability management | | 1.00 | 16 |
| A19 | Power quality measurement | | 0.94 | 17 |
| A1 | Advanced Volt-VAR Control (VC) | | 0.91 | 18 |
| A16 | Technical and commercial loss reduction | | 0.87 | 19 |

Prioritization Results – Application Benefit



Prioritization Results – Application Benefit-Cost Ratio



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Application Requirements

| Proposed Group Number | Application Group | Minimum Availability % | Maximum Latency (ms) | Minimum Report Rate (Hz) |
|-----------------------|---|------------------------|----------------------|--------------------------|
| AG1 | AVVC | 80 | 2000 | 1 |
| AG2 | Advanced monitoring of distribution grid | 95 | 1000 | 30 |
| AG3 | Asset management of critical infrastructure | 80 | 5000 | 1 |
| AG4 | Wide area monitoring and visualization | 95 | 1000 | 30 |
| AG5 | DER integration | 80 | 2000 | 1 |
| AG6 | Real-time distribution system operation | 95 | 2000 | 1 |
| AG7 | Enhanced reliability and resilience analysis | 80 | 5000 | 1 |
| AG8 | Advanced distribution system planning | 95 | 5000 | 30 |
| AG9 | Distribution load, DER, and EV forecasting | 80 | 5000 | 1 |
| AG10 | Improved stability management | 99 | 500 | 30 |
| AG11 | High-accuracy fault detection and location | 99.9 | 300 | 30 |
| AG12 | Advanced distribution protection and control | 99.9 | 150 | 30 |
| AG13 | Advanced microgrid applications and operation | 99 | 500 | 30 |
| AG14 | Improved load shedding schemes | 80 | 5000 | 1 |
| AG15 | Advanced distribution automation | 99 | 300 | 30 |
| AG16 | Technical and commercial loss reduction | 70 | 5000 | 1 |
| AG17 | Monitoring and control of electric transportation infrastructure | 80 | 5000 | 1 |
| AG18 | Integrated resource, transmission and distribution system planning and analysis | 80 | 5000 | 1 |
| AG19 | PQ assessment and analysis | 99.9 | 5000 | 120 |