NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Hybrid Power Plants Challenges and Opportunities

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August 24-26, 2020

Topical Expert Meeting # 101

Why Hybrid Power Plants

- Enhance flexibility of renewable generation
- Provide reliability for the grid of the future

Challenge: Highly complex systems that must be customized to a given application

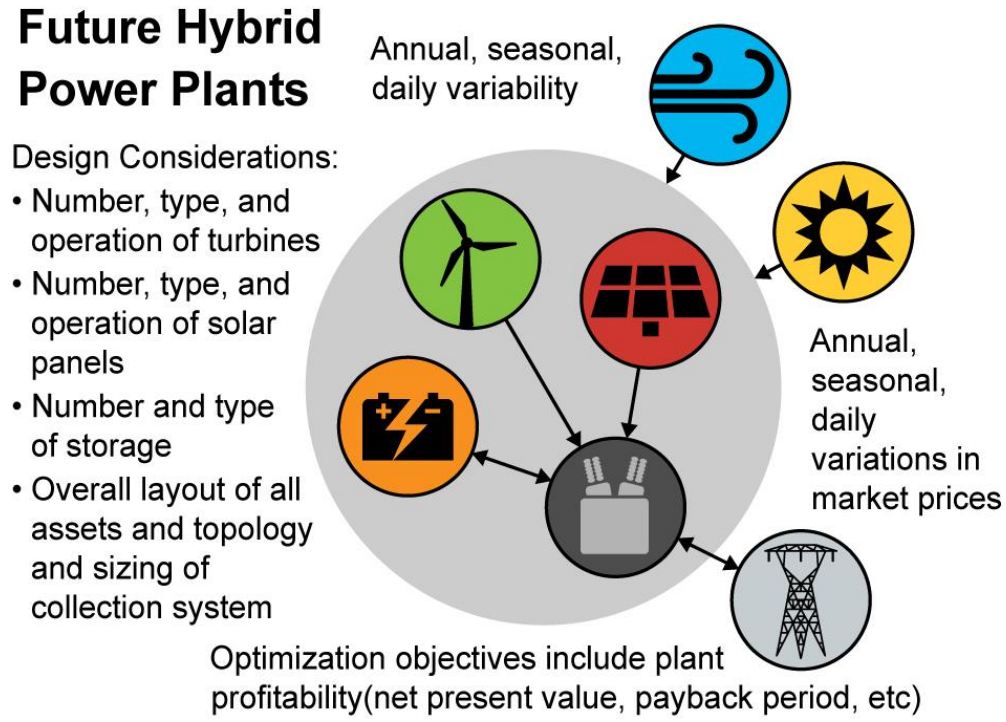
Goal of this Meeting

Overall: Accelerate the development and deployment of hybrid power plants

- What are our biggest roadblocks?

- **Topical Experts Meeting (TEM):** If this were to become an IEA Task
  - Determine areas of international collaboration
  - Determine the role of this task

- **Critical Areas:**
  - Benefits of hybrid power plants
  - Microgrids and control
  - Sizing/Optimization and Storage solutions

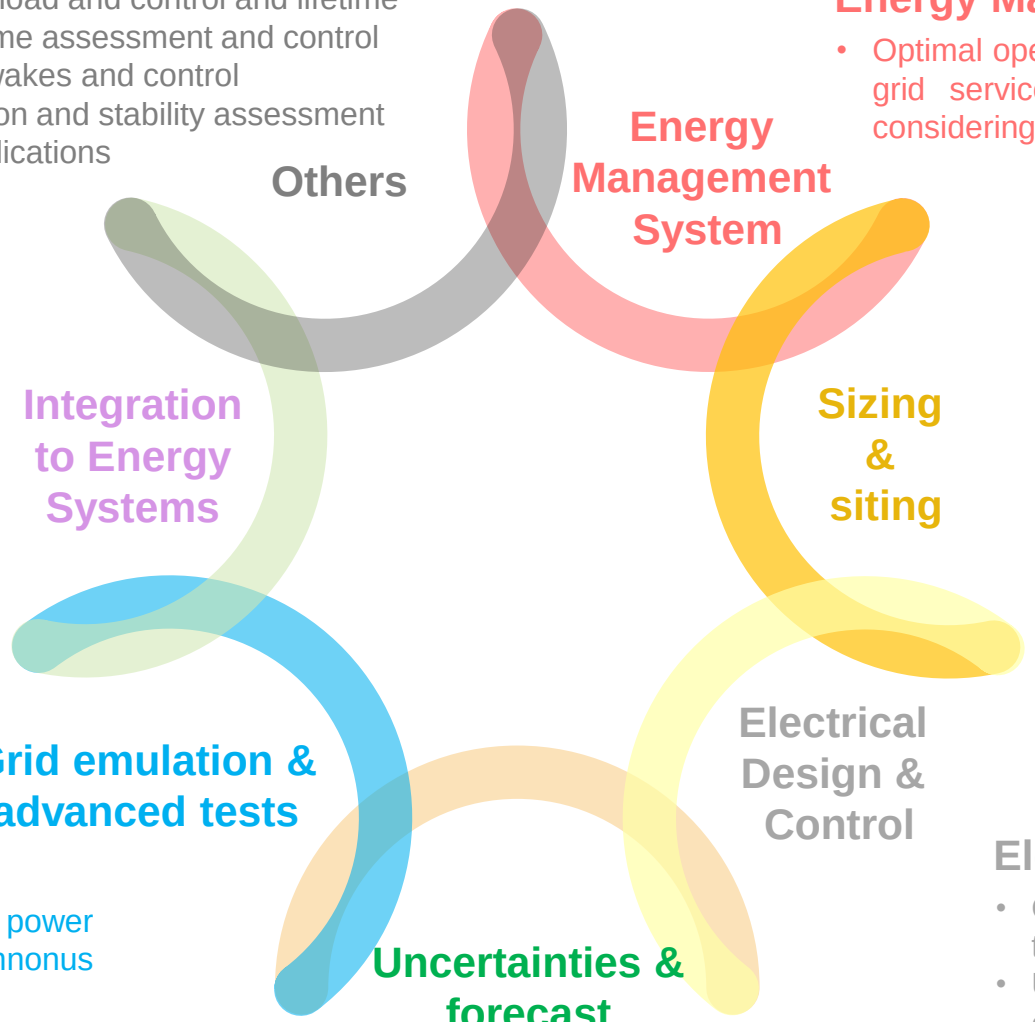


Others

- Wind turbine load and control and lifetime
- Storage lifetime assessment and control
- Wind farms wakes and control
- Grid interaction and stability assessment
- Offshore applications

Energy Management System

- Optimal operation on markets: energy markets, grid service markets and capacity markets considering uncertainties, component lifetime



Integration to Energy Systems

- Co-operation with other energy sectors
- Power2X
- Co-ordinated Control
- Load Balancing

Sizing and siting

- Resource assessment
- Physical Design Optimization
- Selection / hybridization of storage technologies
- Optimal sizing of wind-solar-storage
- Hybridization of existing wind or solar plants

Grid emulation & advanced tests

- Emulation of future converter dominated power systems using CGI and / or synchnonus condenser to emulate grid
- Development of new test methods / grid codes
- Validation of models

Uncertainties & forecast

- Variability for combined wind-solar-storage
- Market forecasts
- Hybrid power forecast
- Real time power simulation
- Assessment of flexibility & grid services

Electrical Design and Control

- Optimal electrical design – utilization of wind turbine DC links and inverter
- Use of electrical auxiliaries (supercapacitor, chopper, FACTS)
- Hierarchical control / Distributed control
- Grid services
- Blackstart capability

Introduction – Organizing Committee

Jennifer King – Senior Engineer
National Renewable Energy Laboratory
Control/Optimization in Hybrid Systems

Katherine Dykes – Head of Section
Technical University of Denmark

Kaushik Das – Researcher
Technical University of Denmark
Sizing, operation and control of Hybrid Power Plants

Nicolas El Hayek –
Project manager RE
IEA Wind Task 11
Planair SA

Eric Lantz – Group Manager of Systems Engineering
National Renewable Energy Laboratory
Techno-economic analysis

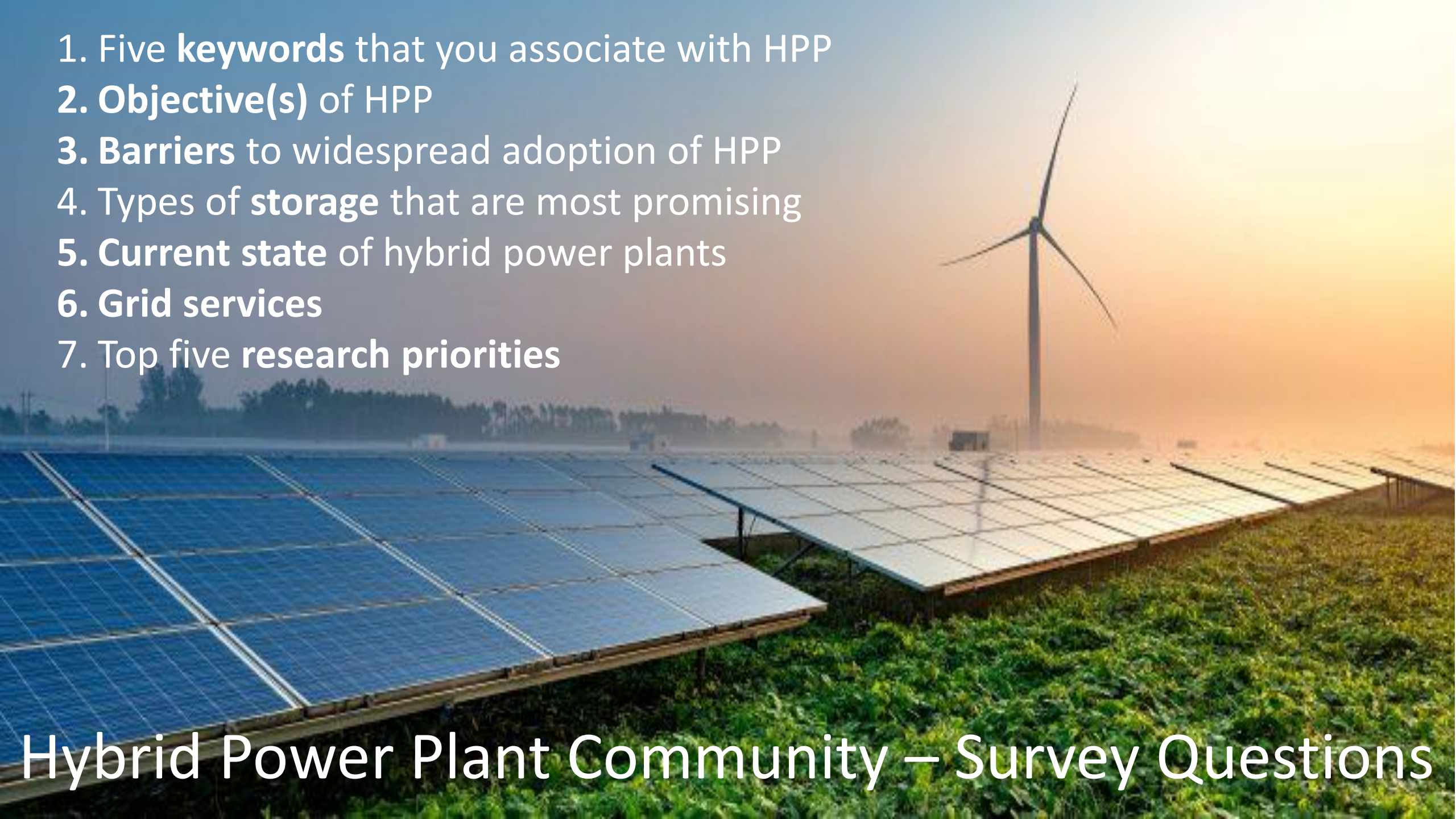
Vahan Gevorgian – Chief Engineer
National Renewable Energy Laboratory
Control/HIL of Hybrid Systems

Dave Corbus – Program Manager
National Renewable Energy Laboratory
Wind-Grid Integration

Lucas Mosca – Project manager microgrids
IEA Wind Task 11
Planair SA

Brian Smith – Wind Lab Program Manager
National Renewable Energy Laboratory

Survey Results

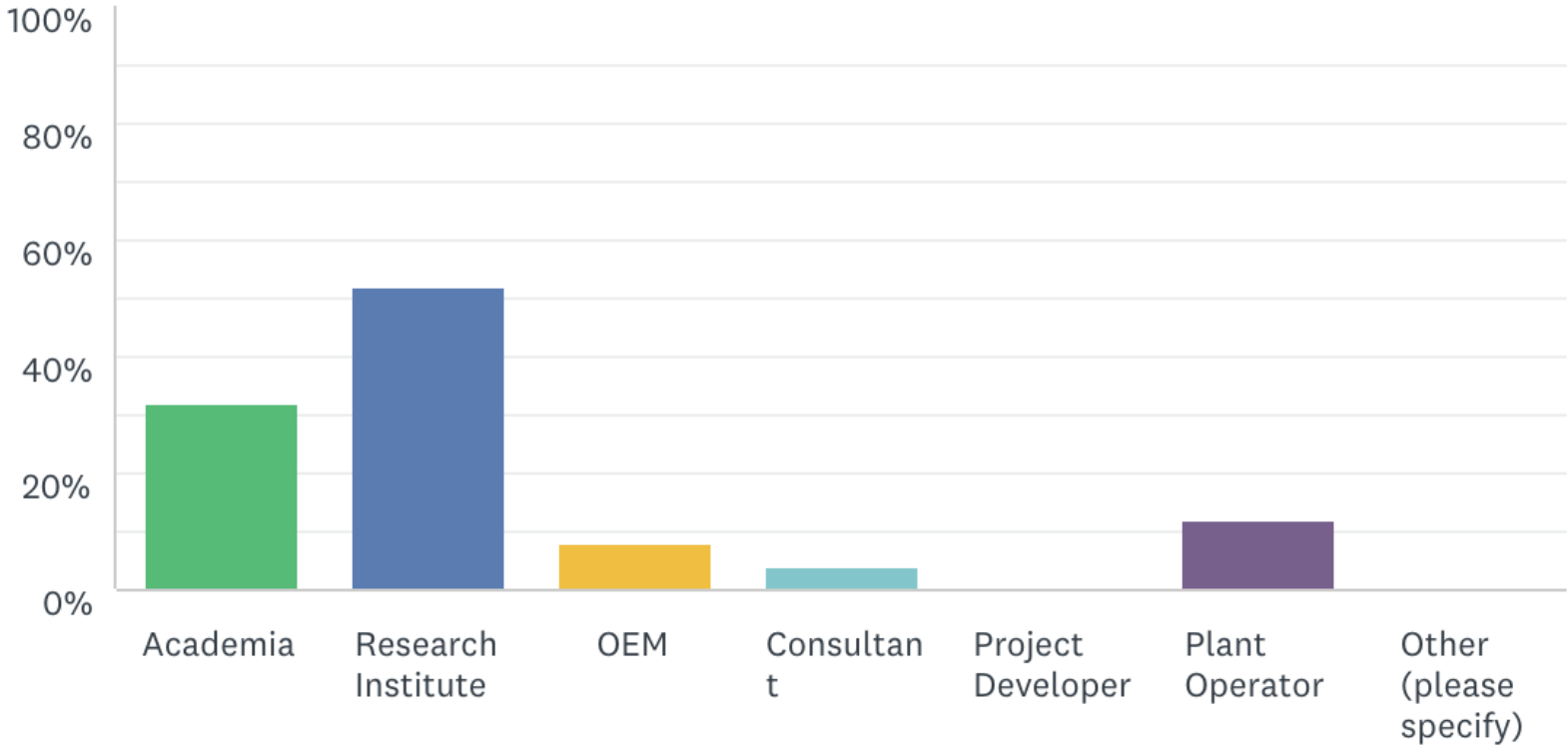


1. Five **keywords** that you associate with HPP
2. **Objective(s)** of HPP
3. **Barriers** to widespread adoption of HPP
4. Types of **storage** that are most promising
5. **Current state** of hybrid power plants
6. **Grid services**
7. Top five **research priorities**

Hybrid Power Plant Community – Survey Questions

Where is Everyone From?

- Belgium
- Canada
- Switzerland
- Germany
- Denmark
- Spain
- Finland
- France
- Ireland
- Japan
- Netherlands
- Norway
- Sweden
- United Kingdom
- United States

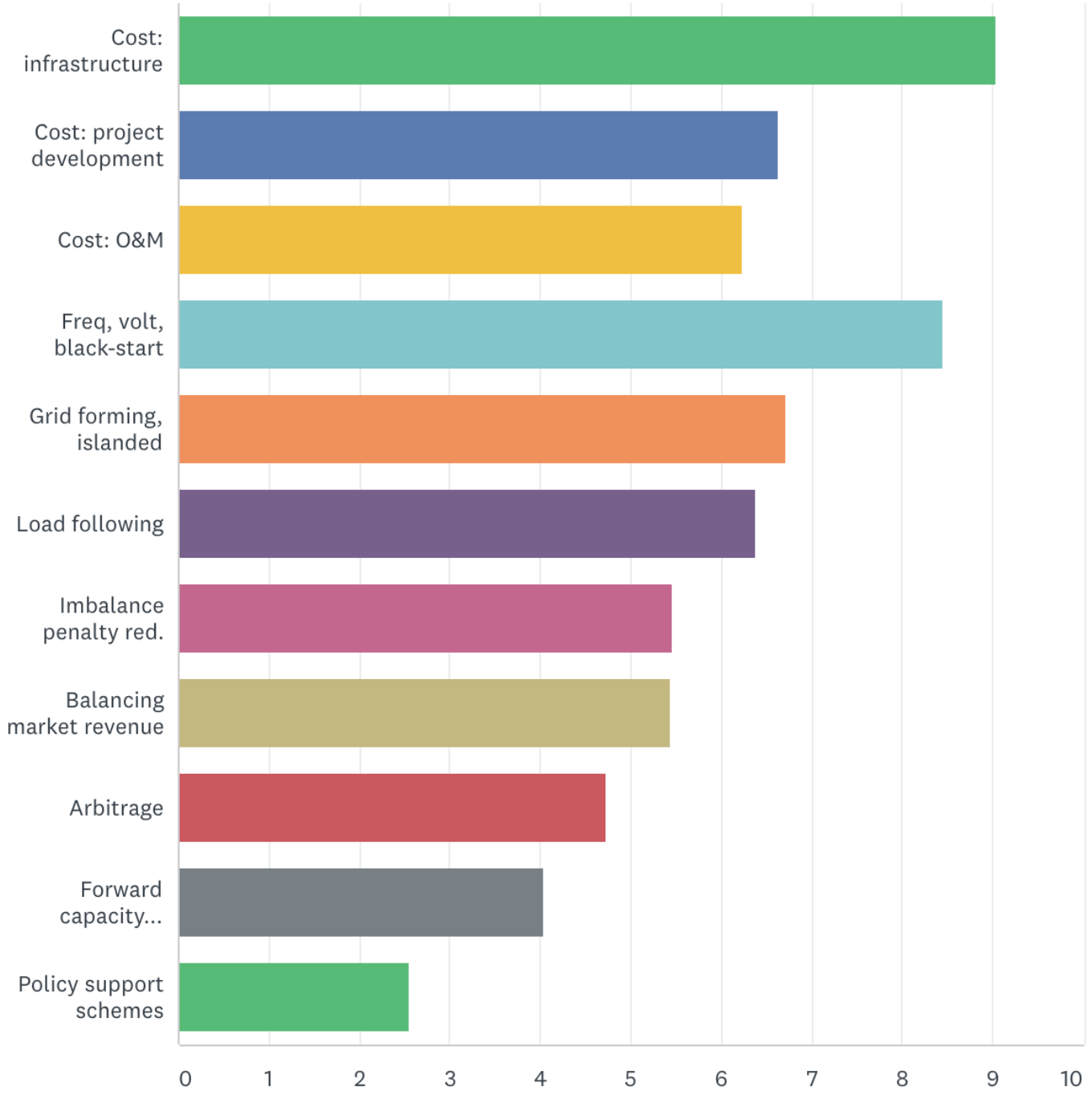



Forecasting
Realtime
reduction
Technology
Optimization
Increase
Grid
Colocation
Power
Hybrid
Storage
System
Energy
Cost
Solar
Services
Plant
sizing
Increased
modeling
Wind
Ancillary
control
Dispatchability
Complementary
Renewable
Arbitrage
Simulation
stability
systems
Battery
Complementarity
demandproduction
Reliability
resources
microgrids
Compliance
capacity
Intelligent
Variability
compared
cocontrol
Offgrid
ORE
Fossilfree
ramp
analysis
Risk
Policy
floating
demonstration
Interconnection
electronics
cut
rates
predictions
Stochastic
plants
sources
Diesel
Island
LCOE
Microgrid
generation
development
Pumped
Reduced
Aggregation
Operational
costs
Integration
Creating
Efficiency
intermittence
markets
Fly
Survey
standards
utilization
frameworks
flexibility
Onshore
Complexity
Colocated
Customizable
Operation
Manageability
Futuristic
Coordination
hardwareintheloop
Scheduling
Shared
results
Optimal
Firm
Challenges
Virtual
testing

Objectives of HPP

- Rank based on importance of HPP being able to achieve the following

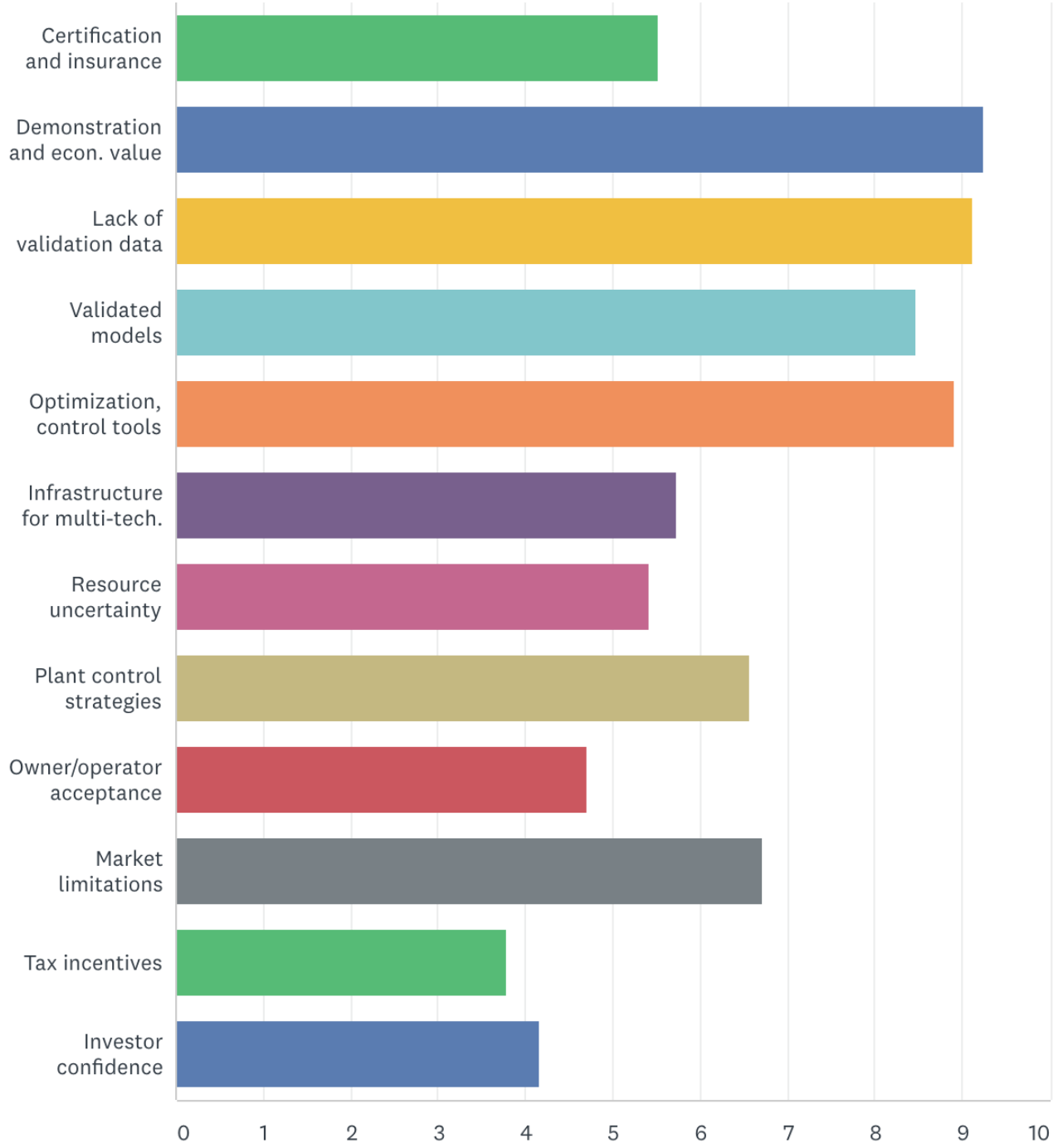
- Top responses:
  - Cost reduction: infrastructure
  - Grid services (freq support)



Main Barriers for HPP

- Rank 1 through 10
- Weighted average

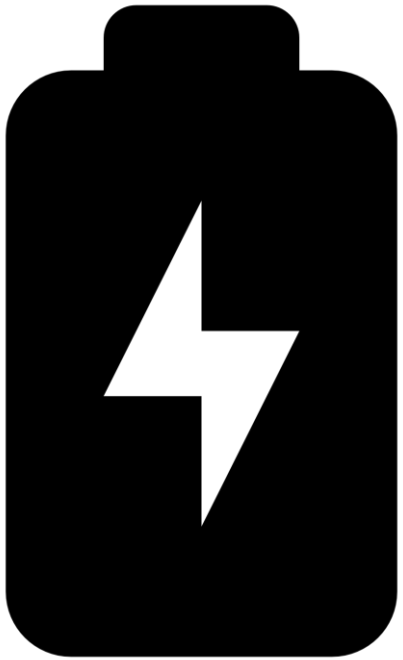
- Top responses:
  - Demonstration of economic value
  - Lack of validation/verification data
  - Optimization and control tools



	1	2	3	4	5	6	7	8	9	10
Imbalance penalty red.	0.00% 0	8.33% 2	4.17% 1	4.17% 1	4.17% 1	8.33% 2	41.67% 10	20.83% 5	4.17% 1	4.17% 1
Balancing market revenue	0.00% 0	4.00% 1	12.00% 3	16.00% 4	8.00% 2	0.00% 0	4.00% 1	28.00% 7	24.00% 6	4.00% 1
Forward capacity markets	0.00% 0	0.00% 0	4.00% 1	4.00% 1	12.00% 3	12.00% 3	8.00% 2	12.00% 3	0.00% 0	44.00% 11
Cost: project development	4.17% 1	12.50% 3	12.50% 3	8.33% 2	12.50% 3	16.67% 4	0.00% 0	25.00% 6	8.33% 2	0.00% 0
Grid forming, islanded	4.00% 1	16.00% 4	12.00% 3	4.00% 1	12.00% 3	32.00% 8	4.00% 1	0.00% 0	4.00% 1	8.00% 2
Arbitrage	4.00% 1	12.00% 3	0.00% 0	0.00% 0	8.00% 2	8.00% 2	16.00% 4	4.00% 1	28.00% 7	4.00% 1
Policy support schemes	4.00% 1	4.00% 1	0.00% 0	4.00% 1	4.00% 1	0.00% 0	4.00% 1	0.00% 0	4.00% 1	4.00% 1
Cost: O&M	8.00% 2	4.00% 1	16.00% 4	8.00% 2	12.00% 3	12.00% 3	8.00% 2	8.00% 2	12.00% 3	12.00% 3
Load following	8.33% 2	8.33% 2	16.67% 4	8.33% 2	12.50% 3	8.33% 2	8.33% 2	0.00% 0	8.33% 2	20.83% 5
Freq, volt, black-start	29.17% 7	16.67% 4	12.50% 3	12.50% 3	16.67% 4	0.00% 0	0.00% 0	0.00% 0	8.33% 2	0.00% 0
Cost: infrastructure	37.50% 9	12.50% 3	8.33% 2	29.17% 7	0.00% 0	0.00% 0	8.33% 2	4.17% 1	0.00% 0	0.00% 0

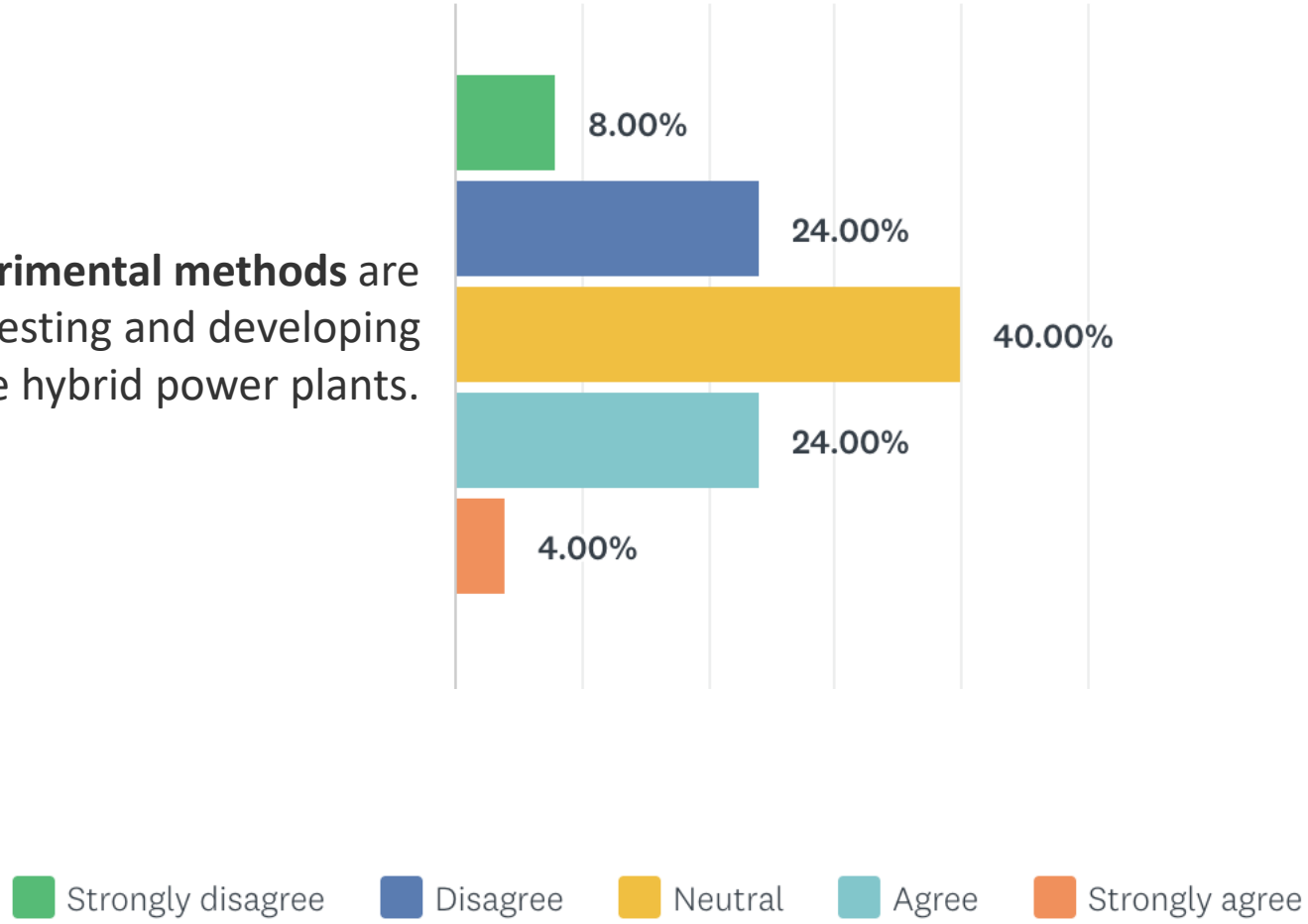
Most Promising Storage Technologies

- Lithium-ion
- Lead acid
- Flow battery
- Site-dependent
- Hydrogen
- Green Methane
- Fly-wheel
- CAES
- Redox flow
- Fuel cell
- Super capacitors
- Compressed air
- Heat storage
- Carnot batteries
- Pumped hydro storage
- Ultracapacitors



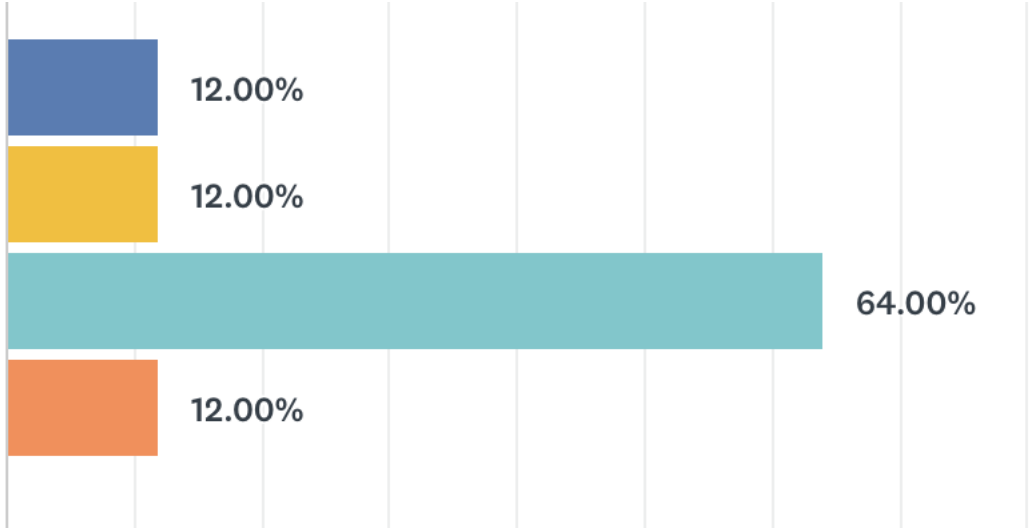
Current State of Hybrid Power Plants

Existing **experimental methods** are sufficient for testing and developing viable hybrid power plants.



Experiments and Validation

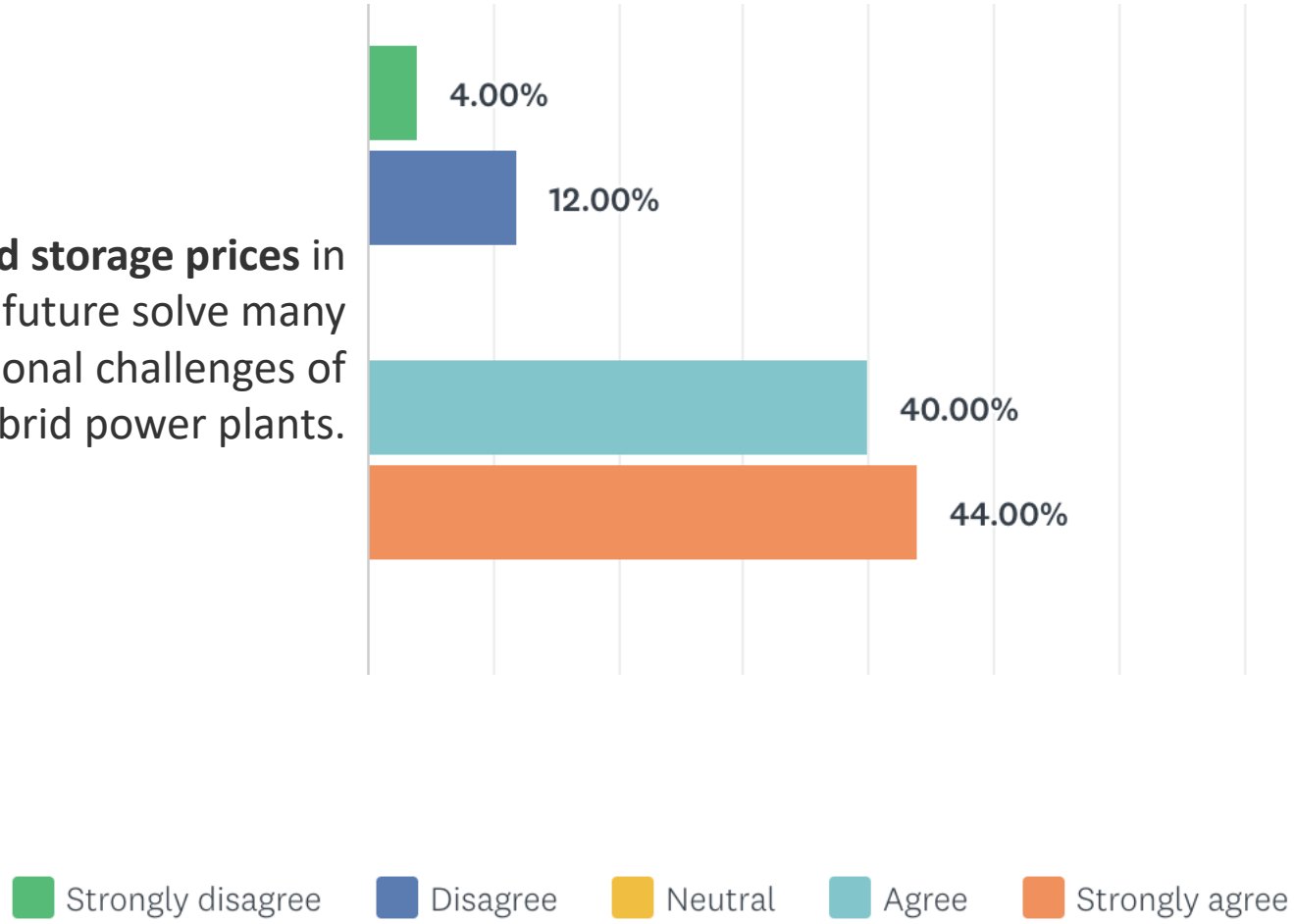
We should prioritize collecting **experimental validation data** over other research priorities



Strongly disagree | Disagree | Neutral | Agree | Strongly agree

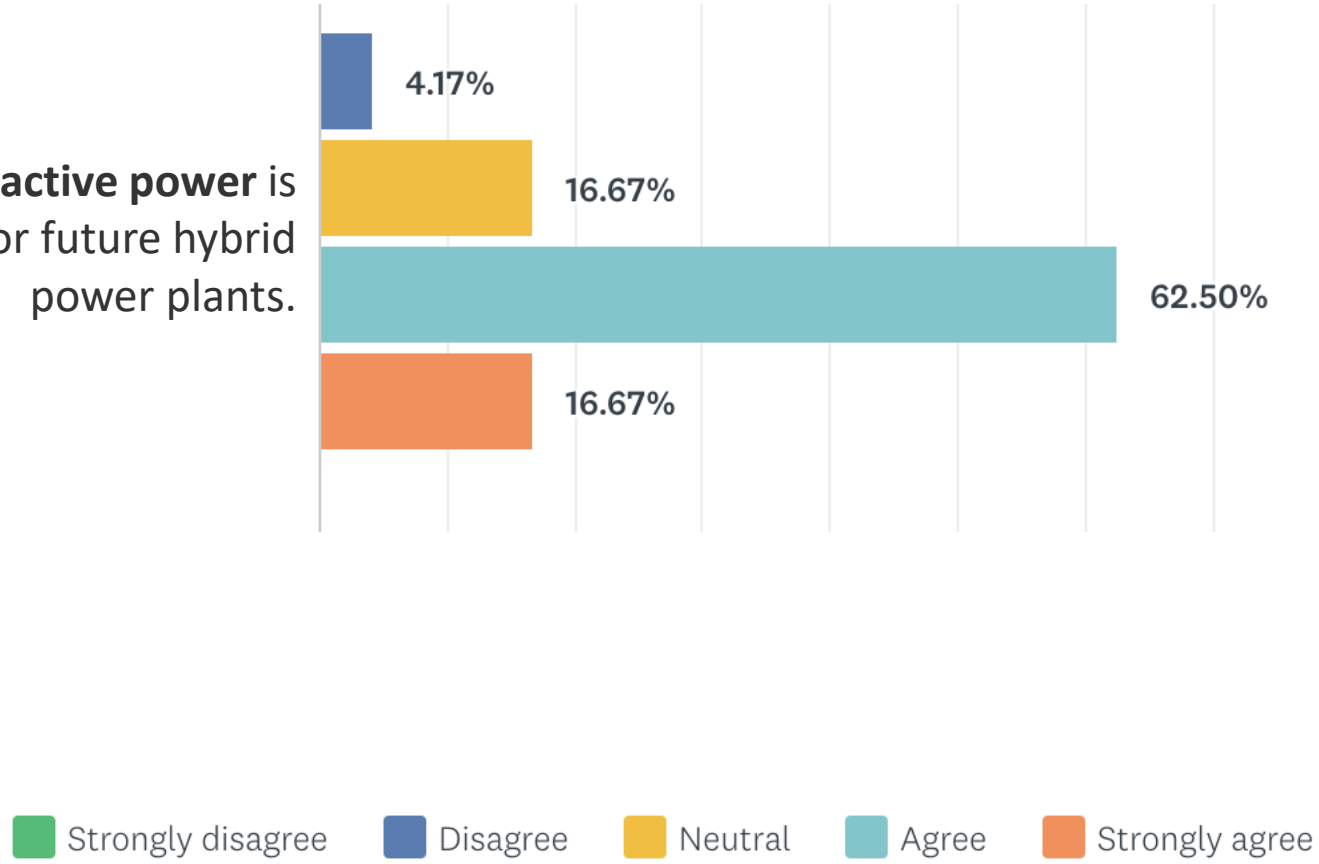
Storage

Reduced storage prices in the future solve many operational challenges of hybrid power plants.



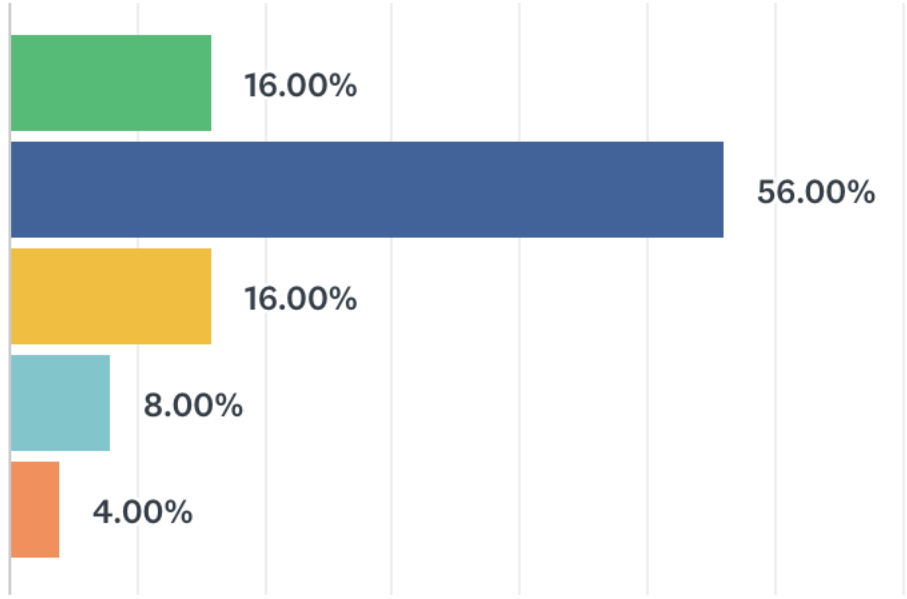
Reactive Power

Providing **reactive power** is essential for future hybrid power plants.



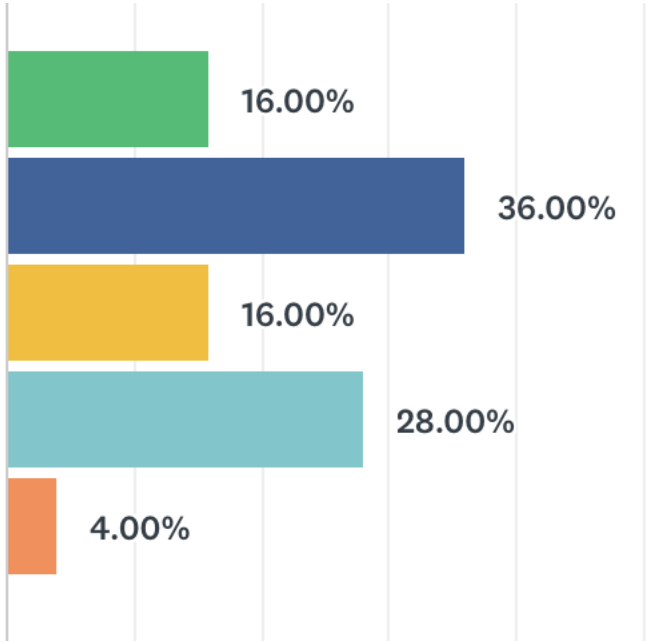
Market Design

Today's markets are sufficient for hybrid power plant bidding.



Hybrid versus Single Technology Plants

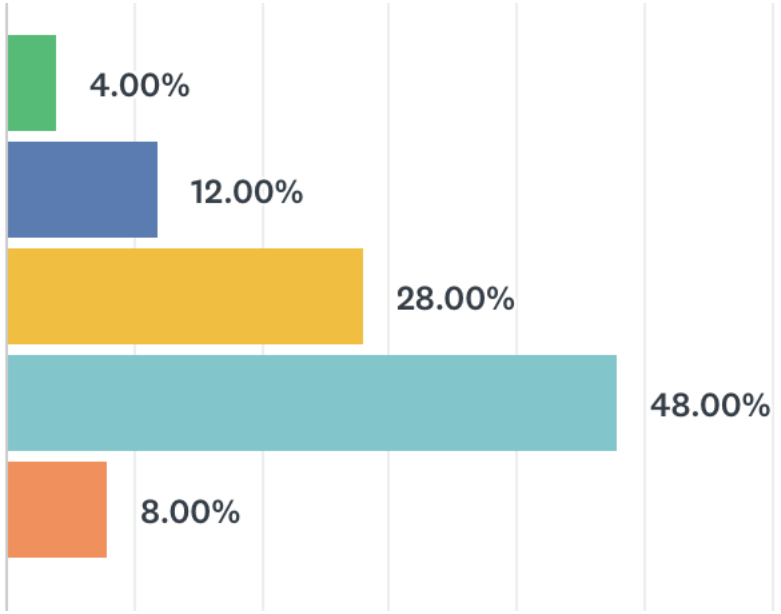
Only hybrid power plants should be developed in the future.



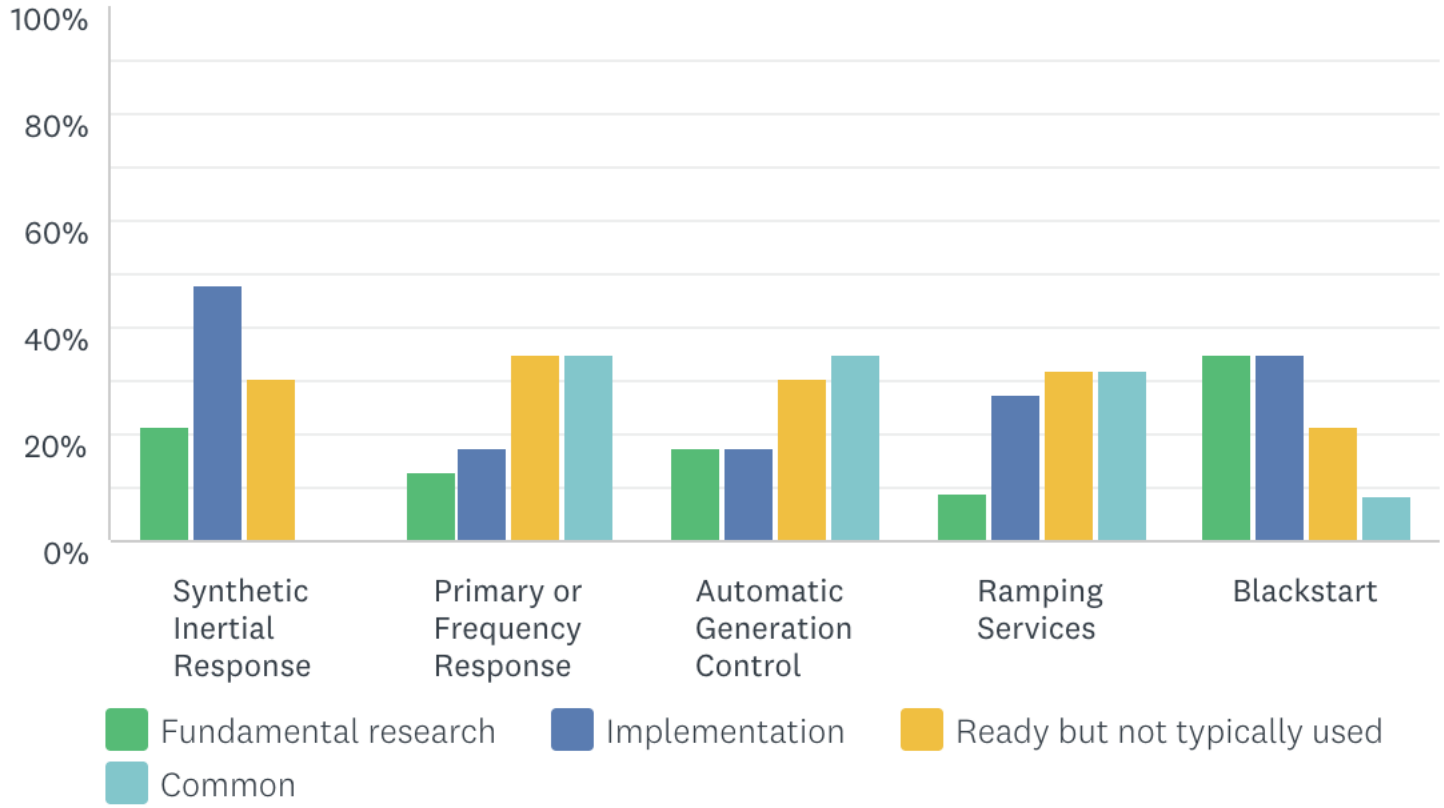
Strongly disagree | Disagree | Neutral | Agree | Strongly agree

Ancillary Services

Hybrid power plants are **primarily** good for grid services.



Grid Services



Research Priorities – Drive Breakout Session

Day 1: Breakout Topics – Benefits of HPP

- Shared infrastructure for co-located plants
- Co-located vs. Virtual power plants
- Field demonstrations/validation of hybrid plants
- Resource assessment/importance of complementarity
- Markets/policy changes needed to accommodate HPP
- Metrics to assess HPP (LCOE, curtailment, etc.)
- Modeling needs (e.g. timescales)

Research Priorities – Drive Breakout Session

Day 2: Microgrids and Control

- Grid services to consider by HPP
- Behind-the-meter vs. front-of-the-meter hybrids
- Hybrids as a price maker
- Forecasting
- Dispatchability of HPP
- Grid reliability/stability
- Control needs (e.g. timescales, coordinated control across technologies)

Research Priorities – Drive Breakout Session

Day 3: Sizing/optimization and Storage

- Storage solutions to consider for HPP
- Combined storage solutions
- Most important design considerations in HPP (DC vs. AC coupling/inverters/etc.)
- Other value streams beyond electricity
- Reference hybrid plants (how to address high degree of customizability)
- How to design for operation (minimize size of storage)
- Optimization needs (derivative free, gradient-based, how to handle scale of problem)

Agenda

Day 1: Benefits of HPP (Kaushik Das, Technical University of Denmark and Eric Lantz, NREL)
Introductions
5:00 – 5:15 am – Task 11 Intro: Nicolas El Hayek – IEA Wind Task 11, Planair SA
5:15 – 5:30 am – Intro to TEM and relevant survey results (Katherine Dykes, Technical University of Denmark & Jennifer King, NREL)

Technology Snapshots
5:30 – 6:40 am – Technology talks from experts on the benefits of hybrid power plants (10 min each)

- Mark Ahlstrom – NextEra Analytics
- Hannele Holttinen – IEA Wind Task 25, Recognis
- Charlie Smith – Energy Systems Integration Group
- Kaushik Das – Technical University of Denmark
- Thomas Ebel – South Denmark University
- Daniel Dixon/Ellen Phelan – EirGrid

6:40 – 7:20 am – Break

7:20 – 8:00 am – Technology talks from experts on benefits of hybrid power plants (10 min each)

- Aaron Barker – National Renewable Energy Laboratory
- Mohammad Amin – NTNU
- Andrew Mills – Lawrence Berkeley National Laboratory

Breakout
8:00 – 9:00 am – Breakout and reported results (Breakout chairs and notetakers)