Solving the V2G End-End Interoperability Challenge

A QualityLogic Webinar
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Smart Energy Leadership

Steve Kang, GM, Smart Energy, QualityLogic

- Steve is a leading technical expert on IEEE 2030.5, SunSpec Modbus, IEEE 1547, and other smart energy protocols and grid codes. He has contributed to development of industry standards for testing smart energy protocols and grid codes. He teaches QualityLogic's IEEE 2030.5 CSIP, CSIP AUS and IEEE 1547/EN 50549 workshops to engineering teams around the globe. He is the General Manager of QualityLogic's smart energy division and is responsible for delivering leading testing products and services for the Smart Energy industry.

James Mater, Director of Strategy, Smart Energy QualityLogic

- James is one of the industry-leading experts on smart grid standards, interoperability, and the maturity of eco-systems of products based on these standards. James has given dozens of presentations and authored multiple papers on interoperability in the smart grid. He is a member of UL 1741 SC, SunSpec J3072 Profile and Task53 WGs and more. He co-founded and co-chairs the V2G Forum and Chairs the End-End Demo Work Group. His current focus has been on V2G standards, V2G implementation testing and ISO 15118 interoperability.

Agenda

- **QualityLogic's Role**
- **The Big Picture for V2G**
- **Challenges to Achieving Interoperable V2G**
- **Achieving end-end interoperability**
  - Task53 5-3-3
  - V2G Forum End-End Demonstration
- **Summary**

QualityLogic's Role

Driving Smart Energy Interoperability

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Contributing to International Standards and Alliances

- IEEE 2030.5, CSIP and Related Standards
- IEEE 1547 and UL 1741 STP Working Groups
- Founding member of V2G Forum – Industry Group Harmonizing V2G
- Chair V2G Forum End-End Demonstration Work Group
- Member of IEA Task53 Initiative – International Bidirectional Charging
- SunSpec Specifications and Work Groups
- OpenADR Alliance
- CharIN Member

Customers include leading:

- EV OEMs
- EVSE OEMs
- Utilities
- Solar and Storage Inverter OEMs
- Aggregators/CPO/CNOs
- Certification Labs
- Research Labs

QualityLogic Product Portfolio

Protocol Tests

- IEEE 2030.5/CSIP Test
- OpenADR 2.0 Test
- SunSpec Modbus Conformance Test
- IEEE 2030.5 Protocol Stack
- IEEE 1815.2 (DNP3)

Grid Code Tests

- IEEE 1547/UL 1741 SB Grid Codes
  - Interoperability Testing with all 3 protocols
  - Lab Equipment Control
  - Auto Data Analysis
  - Anti-Islanding (2H26)
- EN 50549 Grid Codes

EV and V2G Tests

- CCS Analyzer (ISO 15118-2, -20, MCS, DIN 70121)
- UL 1741 SC
- SAE J3072 IEEE 2030.5 (2H26)
- SAE J3072 ISO 15118-20 Amend 1 (2H26)
- OCPP 2.1 1547 Tests (2H26)
- J3072 EV and UL 1741 SC Emulators (2H26)

Training

- IEEE 2030.5 Workshop
- IEEE 1547 Workshop
- OpenADR 2 & 3 Workshop
- V2G Workshop
- Utility Consulting
- Leadership in 2030.5, UL 1741 SC, SunSpec CSIP Test WG, V2G Forum, IEA Task 53

Tackling V2G-AC

- **Actively working on missing components with partners**
  - UL 1741 SC Test Software
  - J3072 Test Software
  - J3072 EV Simulator
  - UL 1741 SC EVSE Simulator
- **Working with early adopters of the standards**

V2G-AC EVSE Tools

UL 1741 SC Protocol Test Harness for Comms and Type Tests

J3072 EV Simulator

V2G-AC EV Tools

J3072 Protocol Test Harness for Interop and Type Tests

UL 1741 SC EVSE Simulator

V2G: The Big Picture

Global Progress Towards V2G

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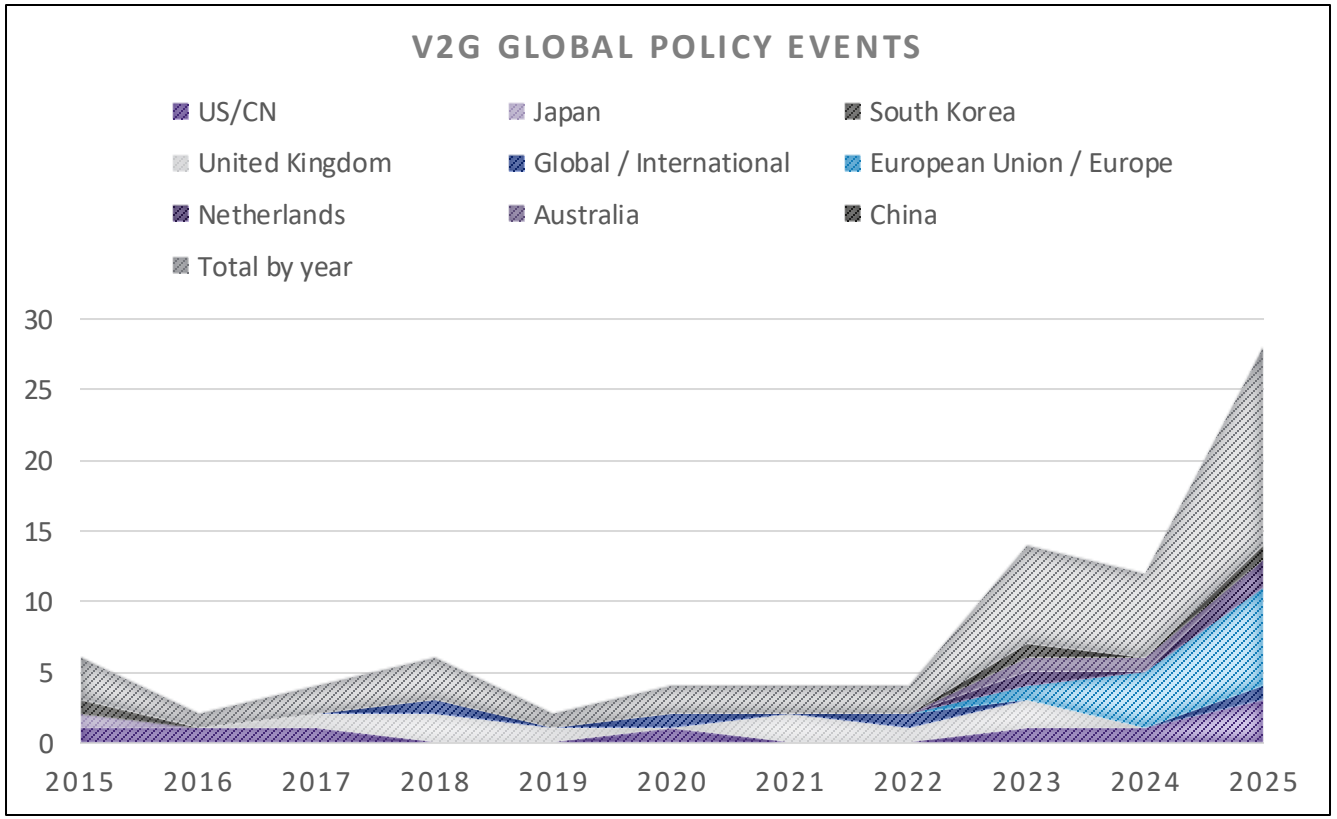
V2G Policy is Trending Up

- **Census of notable V2G / V2X policy-facing reports, white papers, national position papers, roadmaps, and legislation from 2015 through 2025.**
  - Academic papers excluded unless they are clearly policy-facing or fill a country/year gap
- **The terminology shifts over time.**
  - From 2015–2019, documents usually say V2G.
  - From 2021 onward, governments increasingly use V2X or VGI, because policy needs to cover V2H, V2B, V2L, smart charging, and direct grid export.
- **UK, California, Germany, the Netherlands, AU, and the EU are the clearest policy leaders**
- **Legislation is still relatively sparse.**
  - Most countries have reports, pilots, roadmaps, and position papers rather than binding V2G mandates.
  - Strongest legislative examples are UK smart-charge-point regulation, EU AFIR and delegated standards, California SB 59, and Germany's 2025 tax/energy-law amendments.



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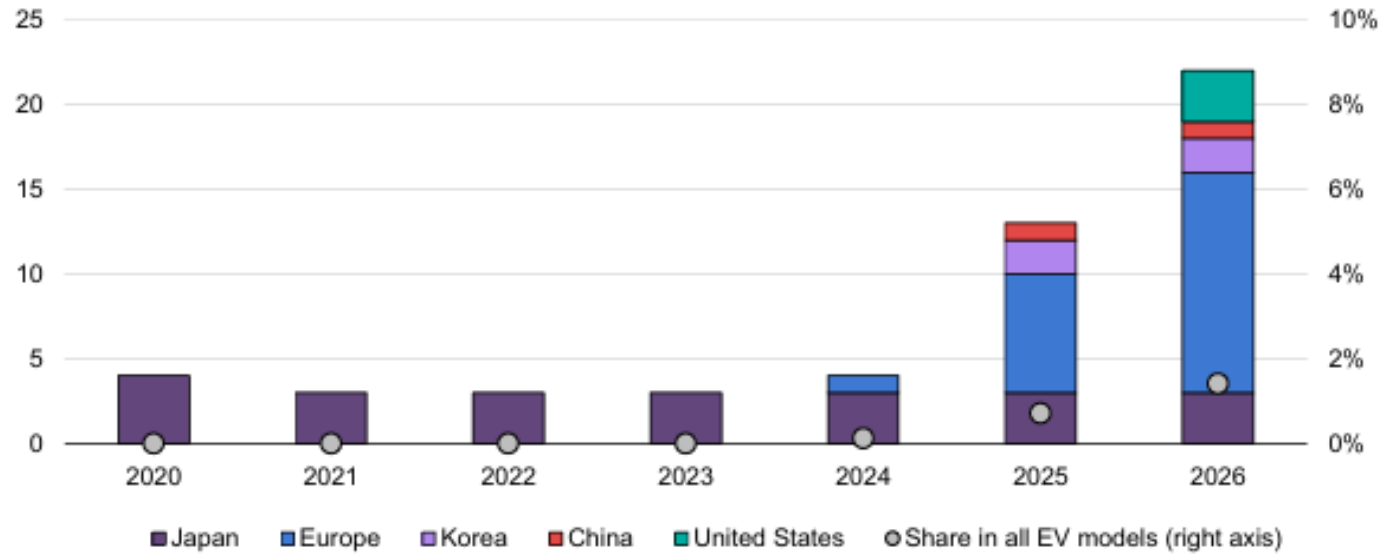
V2G Capable EVs Coming to Market

- **EV models with V2G charging capabilities have seen rapid growth over the last 2 years**
  - But remain scarce and mostly not capable of multiparty interoperability.
  - 22 models have V2G capabilities today, accounting for less than 1.5% of all EV models.
  - Including V2H and V2L-capable models, the # of models is at least three times higher.
  - Chinese OEMs only account for one of the models, but it is used in one of the first V2G offers available to private EV owners worldwide, in the United Kingdom.

Figure 8.14 Number of electric vehicle models in production with vehicle-to-grid charging capability, 2020-2026



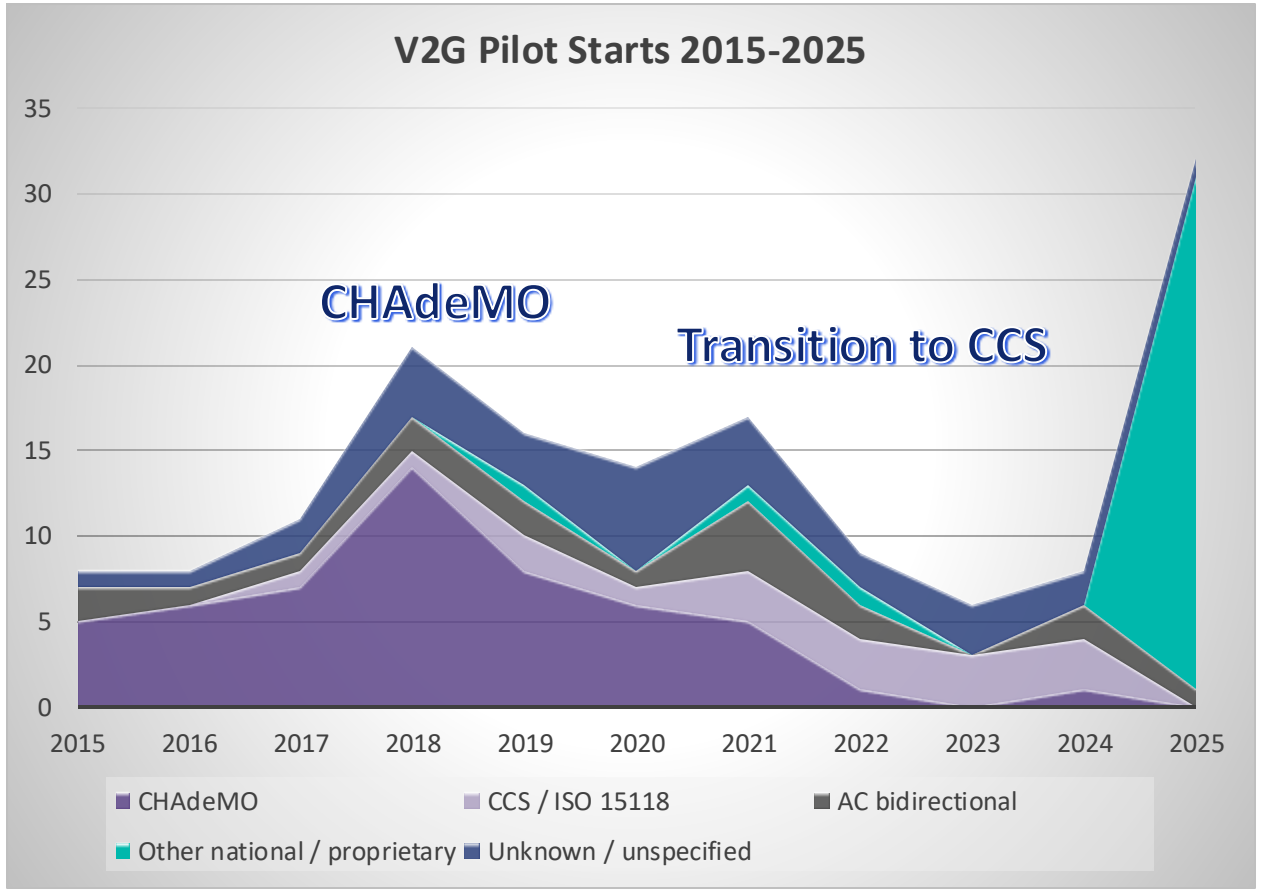
IEA. CC BY 4.0.

Note: Models included only if capability stated by manufacturer during years of production.
Sources: IEA analysis based on ev-database.org and OEM webpages.

** Source: IEA Global EV Outlook 2026. Global EV Outlook 2026: Growing sales amid an energy crisis, Pages 176-79*

V2G Pilots Not End-End and Reflect Transition from CHAdeMO to CCS

- **None of the 152 pilots to date are end-end interoperable**
- **2015–2020 pilot base was heavily CHAdeMO, while 2021 onward shifts toward CCS / ISO 15118, AC bidirectional, and China national-standard projects**.
  - 2025 jump is mostly China's announced first batch of 30 large-scale V2G interaction pilots across nine cities
- **2021–2024 was the transition period.**
  - CCS became the dominant EV fast-charging interface in Europe and North America, Pilots transitioned from CHAdeMO to CCS.
  - V2G value demonstrated in pilots but serious bottlenecks prevent scaling: standards and policy.
  - Shift to managed charging and V2H focus as more practical but steppingstones to V2G.



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Challenges in Getting to Interoperable V2G

Complexity, Lack of Conformance Certification, and More

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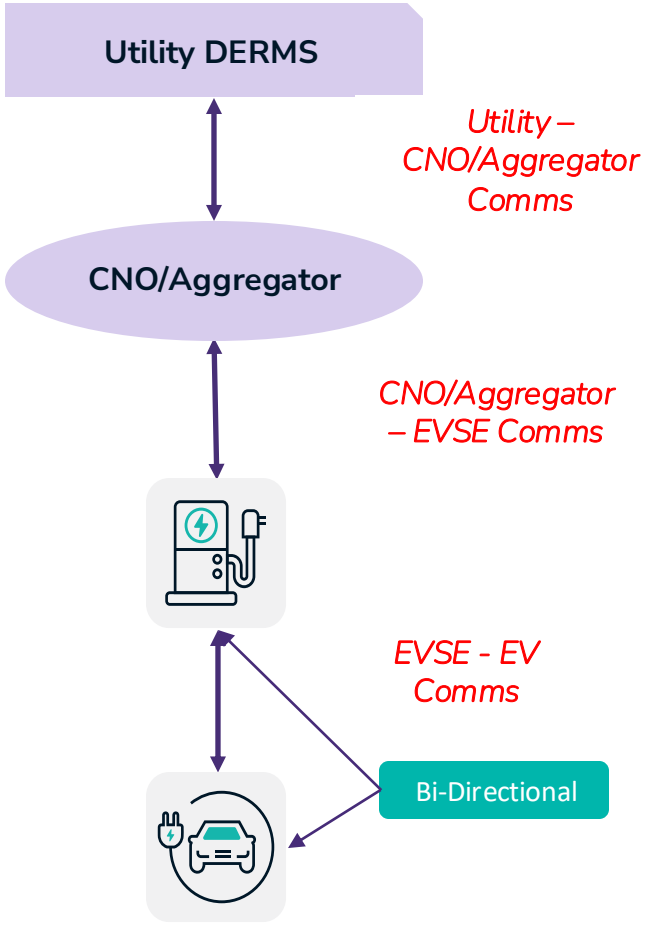
V2G Interoperability Challenges

1. ***V2G end-end interoperability testing* includes the utility, CNO DERMS/CMS systems, EVSE and EV OEMs.**
    1. Just starting to be addressed by the Task53 Initiative and the V2G Forum.
2. ***Multiple standards organizations, standards* and regional differences in standards**
    1. Largely structural – unlikely to achieve total international harmonization but coalescence on key standards.
    2. Standards are split among independent SDOs – IEEE, SAE, OCA, IEC, ISO, SunSpec, UL each develop relevant standard(s)
3. ***Charging technologies need to work seamlessly for V2G to succeed*.**
    1. This prerequisite of V2G is based on an immature standard (ISO 15118-20) that needs to mature to support interoperable V2G.
4. ***Missing or differing standards and certifications.***
    1. Missing profiles and test specifications, especially for V2G-AC.
    2. Need to accelerate efficient certifications to V2G standards.
5. ***There are no commercial test tools available YET* to conduct development and certification testing based on the new V2G-AC standards.**
    1. Some components such as Grid and EV/EVSE Simulators are available commercially, but key protocol and functional tests are missing.
    2. Early adopters are developing their own: expensive and creates interoperability challenges.

#1 End-End Interoperability Testing

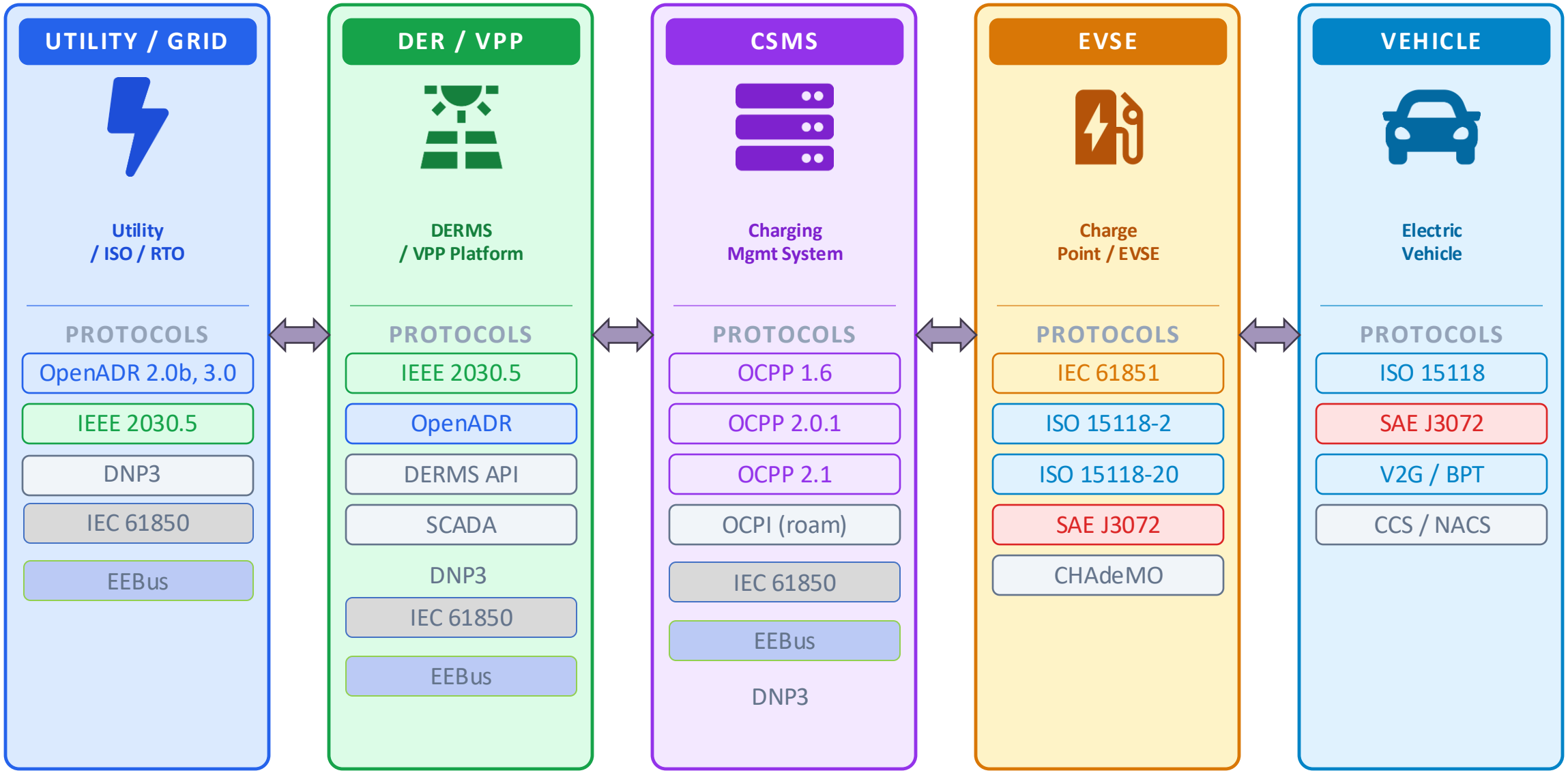
- **No formal specification or certification for V2G end-end interoperability currently exists.**
- **Solutions offered today: closed systems with a combination of standard and proprietary interfaces.**
- **Current V2G End-End Testbed projects addressing the issue**:
  - Task53
  - V2G Forum End-End Demonstration Project



#2 Multiple SDOs and Standards

- **Most countries have their own grid code**
  - Similarities but different parameters
  - Different regulations and certifications
  - Not designed with V2G in scope
- **Technical standards developed by different and competing SDOs**.
  - Vary by country and jurisdictions
  - Immature V2G standards
- **Test specifications, test tools, and certification processes complex**
  - "Homologation" new systems concept for V2G complexity
  - Widely differing approaches

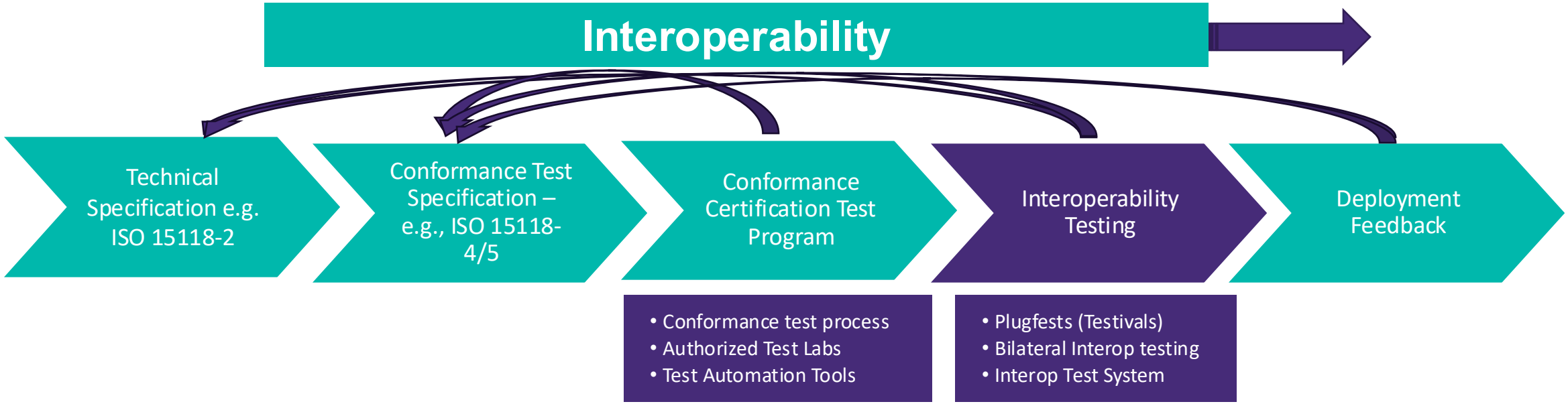
EV Standards Stack



Coordinating Standards

- **Increasing ad hoc collaboration**
  - CharIN-Task53
  - SAE and ISO
  - V2G Forum and CharIN
- **More collaboration needed beyond ad hoc**

#3 Achieving Charging Interoperability



V2G Book-ended by Two Major but Different Industries

- **Two historically independent industries with different business drivers, cultures and interoperability perspectives**
- **Most market power concentrated between these two: aggregators/CNO/CPO and EVSE OEMs caught in the middle**

Electric Utilities

Independent Conformance Certification → No Interoperability Testing And Few Interop Requirements → Expecting Interoperability

Vehicles

Conformance Self-Certification → No Certification Program Focus on Interoperability Testing → Expecting Interoperability

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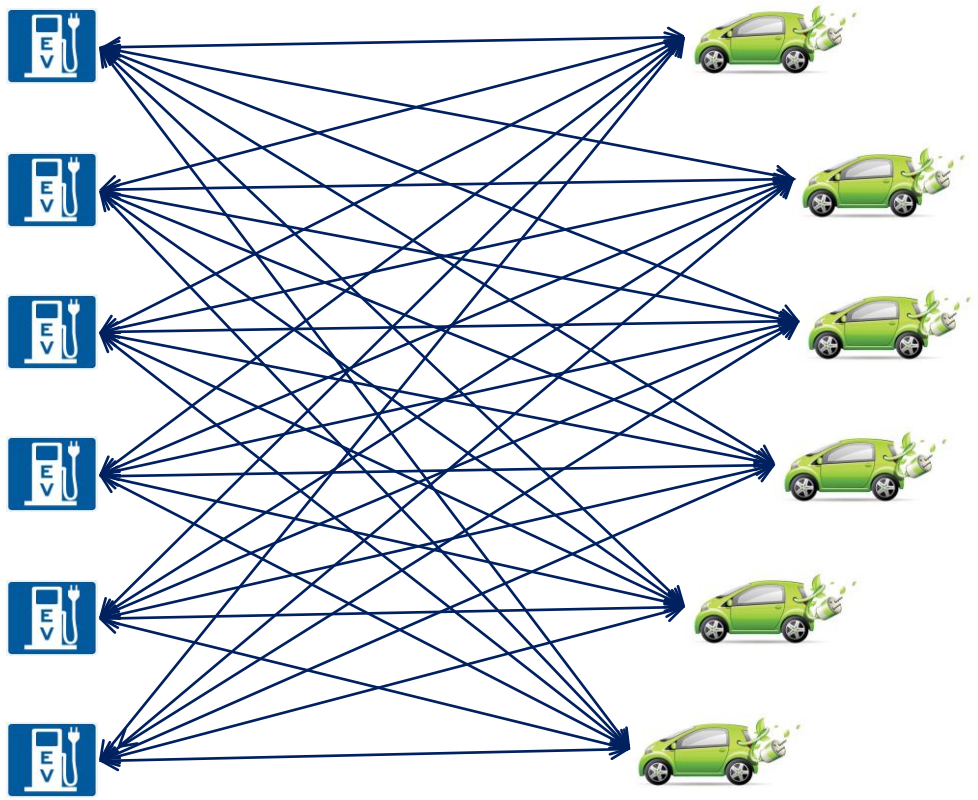
CCS Interoperability Challenge: Bi-Lateral Interop

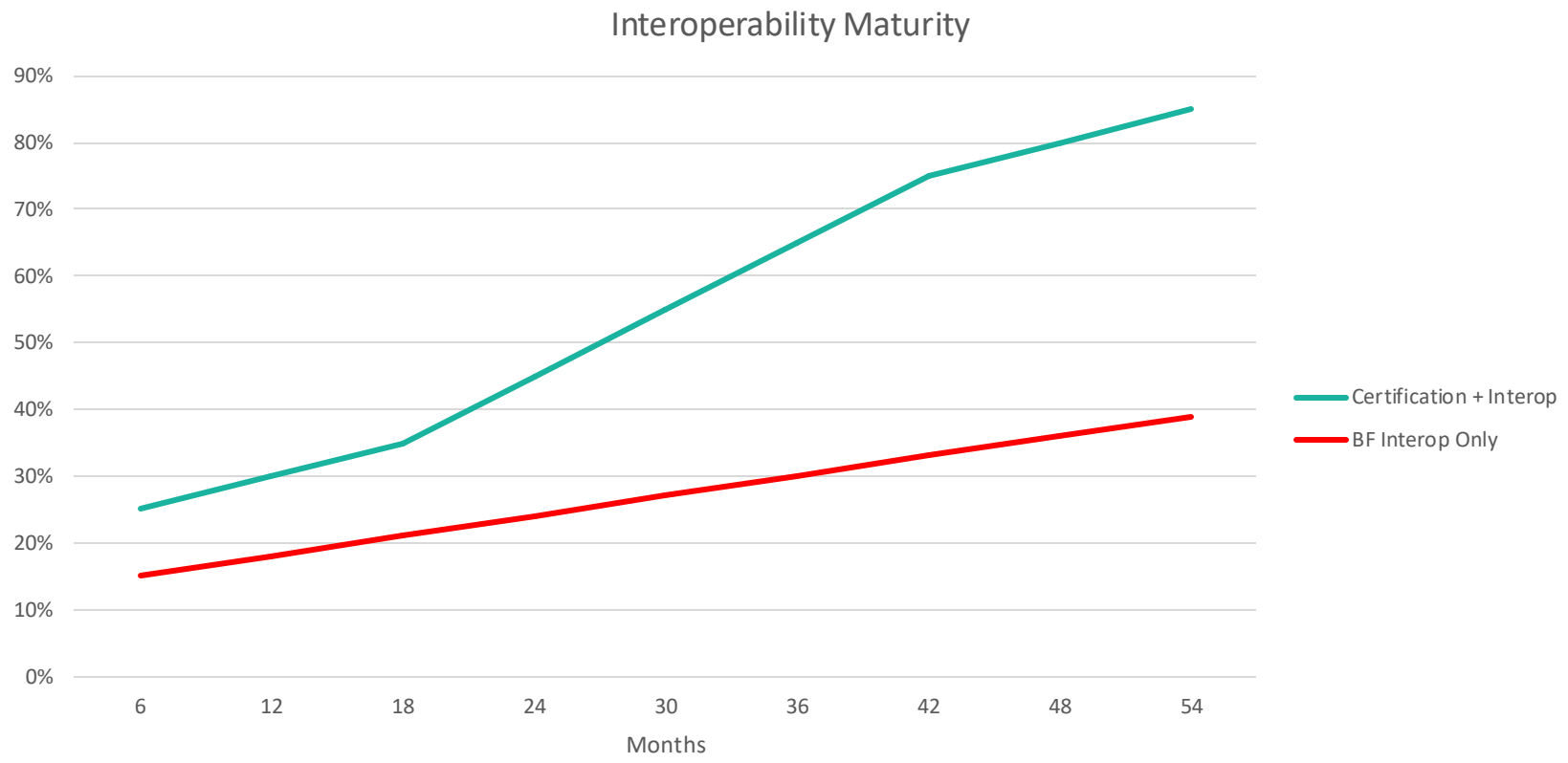
Bilateral Interoperability (every OEM responsible for interop with all EVs or EVSEs)

- **Charge or conform to the standard**
- **Non-conformant solutions**
- **Expensive process**
- **Difficult to scale**

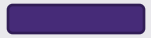
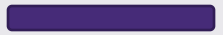
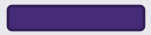
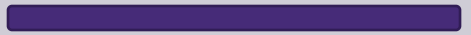


The Impact of Certification on Interoperability Maturity

- Conformance certification creates a baseline for all players and speeds maturity. Interoperability testing ensures interoperability maturity.
- Interoperability testing only is much slower to achieve maturity



EV Comms Certification Programs and Maturity

Standard	Certification Program(s)	Owner	ATLs	Certified Products	Interop Maturity
OpenADR	OpenADR 2.0a/b	OpenADR Alliance	10	>200	
IEEE 1815 (DNP3)	DNP3	DNP3 Users Group	1	11	
IEEE 2030.5	CSIP	SunSpec Alliance	11	66	
ISO 15118	ISO 15118-4/5	CharIN	2	1	
OCPP	OCPP 1.6	OCA	6	200	
CHAdeMO	CHAdeMO	CHAdeMO	7	>400	
SunSpec Modbus	SunSpec Modbus	SunSpec Alliance	11	69	
IEEE 1547.1	UL 1741 SB	OSHA	11	>100	
802.11	Wifi Certified	Wifi Alliance	12	~70,000	

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Solving the Charging Interop Challenge

- **Industry improving –2 interop but –20 next challenge**
- **Pressure industry to use CharIN certification program**

#4 V2G Standardization and Certification Gaps

- **Lack of CCS Certifications**
  - CharIN program exists but is not being used yet
- **Grid Codes and Interoperability**
  - Lack of EU communications specification in grid codes. Included in IEEE 1547 and AS/NZS 4777. Can't be interoperable without standardized communications.
  - Weak interop testing in IEEE 1547.1-2020 and UL 1741 SB.
- **Lack of V2G Conformance Testing and Certification**
  - Technical specifications – e.g., UL 1741 SC, J3072 Test Spec, ISO 15118-2X Test Spec, IEC 61851-1 ED 4 and ISO 5474-2 Ed 2
  - Test tools and test bed limited availability
  - Certification programs not yet in place: coming soon for UL 1741 SC
- **EVSE/EV Roles in V2G-AC**
  - Lack of international agreement on roles of EVSE vs EV – e.g., UL 1741 SC vs IEC 61851-1 ED 4
- **No End-End Interoperability Testing Process**
  - Task53 working to develop an end-end V2G Interop test process
  - V2G Forum Demonstration Project

NLR US V2G-AC Gaps and Scope

- **Scope**
  - Develop Conformance test procedures and test tools for UL 1741 SC and J3072
  - Set up test site and demo tools with OEMs
  - *Does not address end-end interoperability*
- **Gaps**
- **UL 1741SC will fill the standard gaps for *enabling* grid interconnection of V2G-AC.**
  - Incorporation of UL 1741 SC into Rule 21 will be discussed during the current Rule 21 revision process.
- **Ensuring communication protocol translation: OCPP2.1 to AMD1, IEEE 2030.5 to AMD1, OCPP2.1 to IEEE 2030.5, etc.**
  - As a small but significant example: sign conventions are different
- **Authorized EV list and deny list development (and communication protocol)**
- **V2H … transition from/to other V2X modes and voltage quality**

Key V2G-AC Standards	Published	Draft	Unwritten
UL 1741 SC	Q2 26	✓	
UL 1741 SC Test Spec			✓
SAE J3072	✓		
SAE J3072 Test Spec			✓(2027/8)
J3072 IEEE 2030.5 Profile	Q2	✓	
J3072 IEEE 2030.5 Profile Test Spec			✓
J3072/J3068 SunSpec Modbus Profile			✓
J3072/J3068 SunSpec Modbus Profile Test Spec			✓
ISO 15118-20 Am 1 SAE	Q2 26	✓	
ISO 15118-20 AM 1 SAE Profile			✓
-20 Am 1 SAE Test Spec			✓

#5 Lack of Commercial Test Tools for V2G-AC Testing

- **EV and EVSE Simulators include grid code simulation capabilities.**
- **The Grid Codes must be communicated from the DSO to the EV through a CMS and/or EVSE.**
- **No EU standard exists yet for the DSO messaging.**
- **The EV and EVSE must be conformant to ISO 15118-20 Am 1 EU and needs tools to ensure conformance.**
- **They must also be able to charge using -2 and DIN protocols. Conformance testing with the same EV or EVSE Simulator.**
- **The CMS and EVSE need to communicate using OCPP 2.1 and need conformance test tools that include grid code message validation.**
- **Payment, roaming and other backend systems out of scope.**

V2G-AC Tools/Requirements	EV -20 Am 1 Charging/Bidi Conformance	EVSE -20 Am 1 Charging/Bidi Conformance	EV Grid Code Compliance	EVSE/CMS Comms	DSO/CMS Comms ??
EV -20 Am 1 Simulator		✓			
EVSE -20 Am 1 Simulator	✓			✓	
-20 Am 1 Conformance Tester	✓	✓			
Grid Simulator			✓		
Power Analyzer			✓		
Grid Code AC Test System			✓		
Sniffer or MITM System	✓	✓	✓		
Session Analyzer	✓	✓	✓		
OCPP 2.1 Conformance Tester		✓		✓	

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Task 53 End-End V2G Interoperability Demonstration Project

A voluntary project to design, assemble and demonstrate end-end interop

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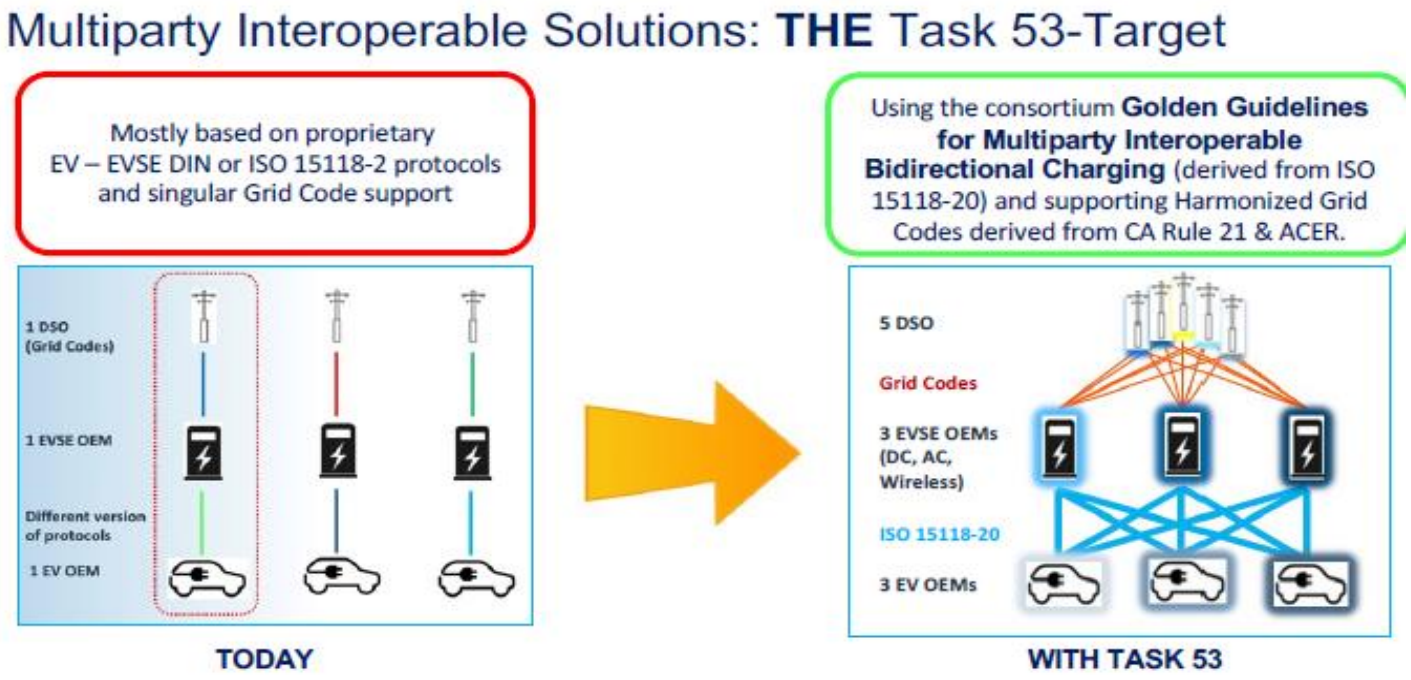
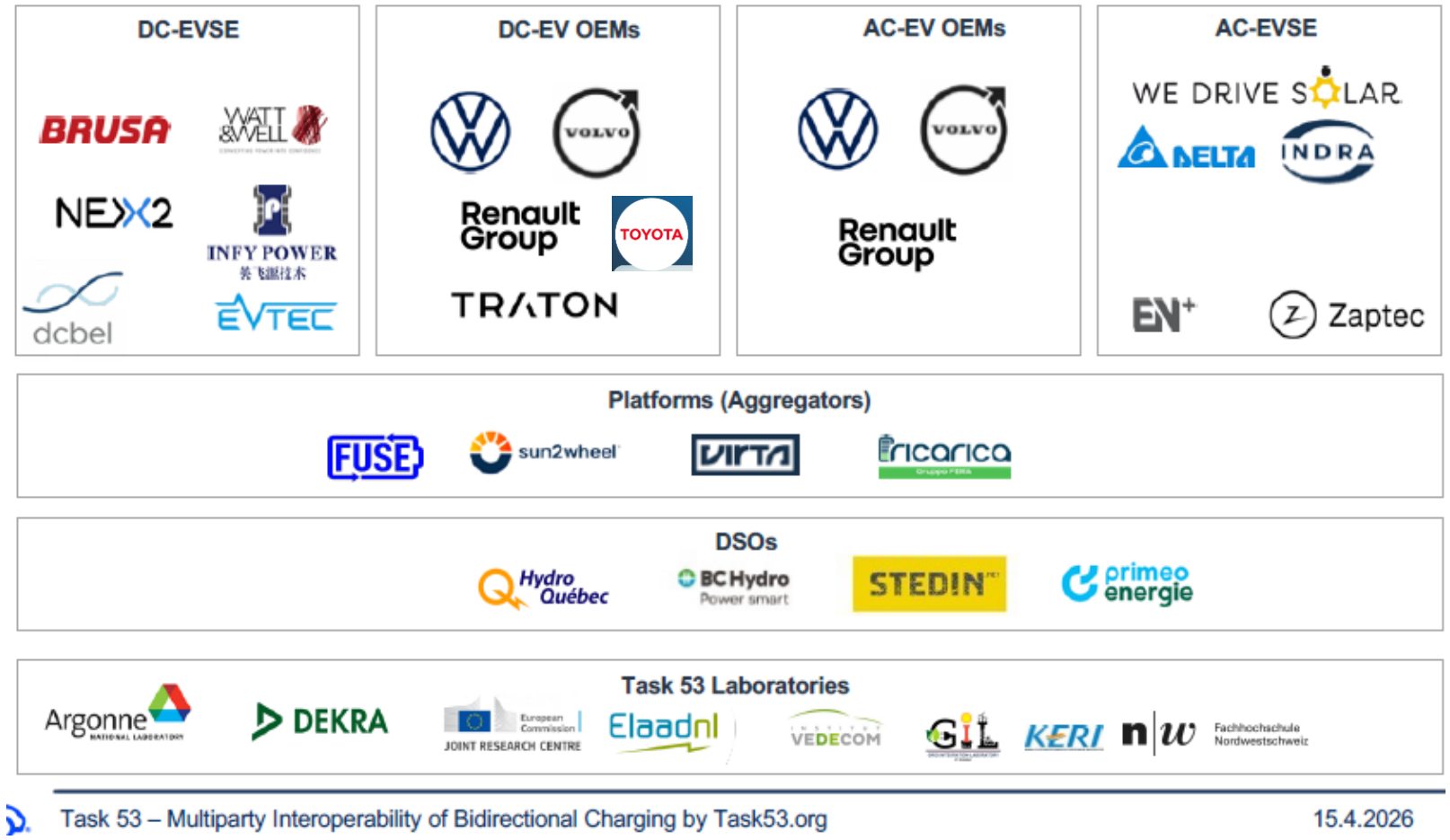
End Goal of Task 53

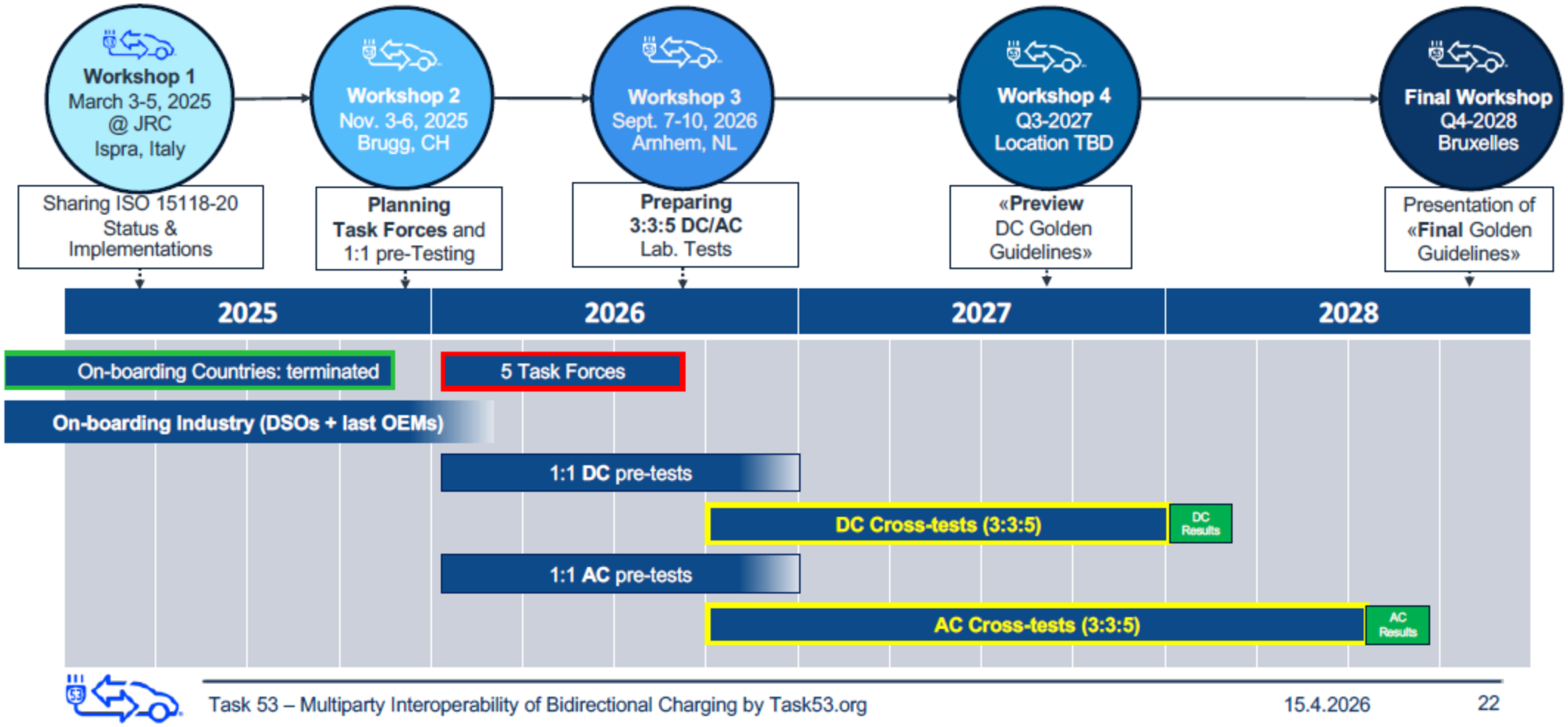
- **Objective: To ensure interoperability (aiming at a consortia-agreement) between bidirectional charging between vehicles (EV), charging stations (EVSE) and distribution grids (DSO).**
- **Deliverables: Successful interoperable V2G-operations with at least 3 different EV-OEMs, at least 3 different bidirectional-EVSEs and 5 different DSOs**



Task53 Participants to Date



Task53 Timeline



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Task53 Observations and Challenges

- **EU Centric**
  - Focus on ISO 15118–20 and OCPP 2.1 beneficial globally
  - Defining the end-end interoperability process is globally valuable
  - Rest of standards EU centric
- **Small number of utilities and OEMs**
  - Speculation is that V2G is not priority for many utilities and OEMs: of interest but assumed to be longer-term; higher priorities
  - Difficult to achieve 5-3-3 Interoperability testing
- **Interoperability Challenge: Participants are using a variety of test tools/systems for V2G (for ISO 15118-20)**
  - Commercial tools from KeySight, Comemso, Vector, Trialog, ChargeByte, real EVs or EVSEs
  - Increases the probability of inconsistent implementations in lab testing
  - Still debating pre-testing against bi-lateral vs "golden reference implementations"

V2G Forum V2G End-End Demonstration Project

A voluntary project to design, assemble and demonstrate

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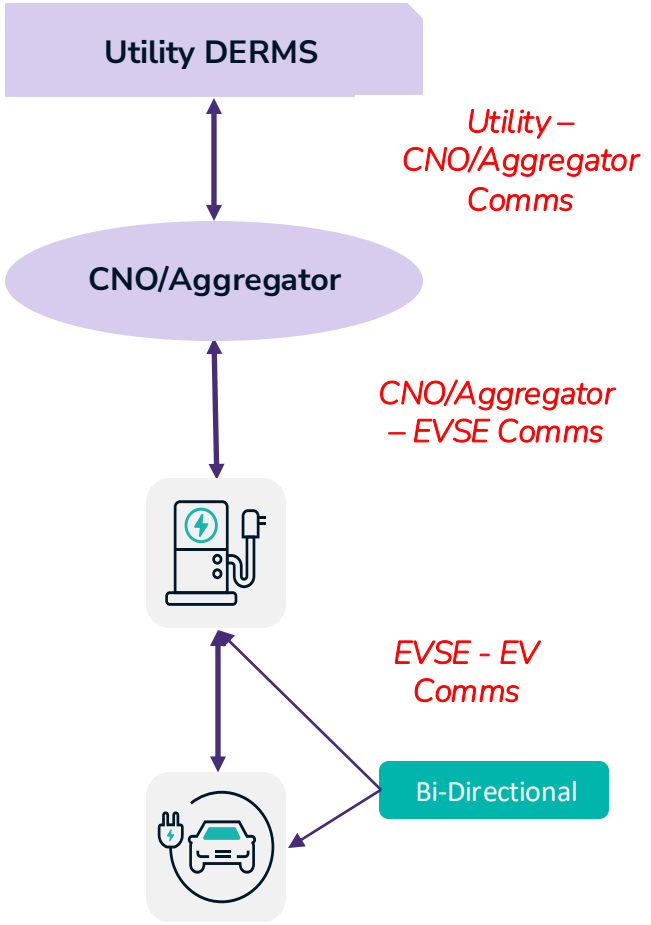
DRAFT Goals for End-End Testbed

- **Goals:**
  - Develop a *V2G End-End Test System Specification* describing scope, assumptions, components, interface and functional standards for V2G.
  - Identify *minimum recommended V2G use cases and test cases* to support interoperability, conformance, and certification activities based on emerging US V2G standards.
  - Specify *required system components*, including physical devices, simulators, emulators, and software platforms.
  - Define *component-level requirements and interfaces* aligned with relevant standards.
  - Identify potential *V2G Testbed component vendors* and invite them to participate with systems that meet the V2G Testbed requirements.
- **Deliverables: Interoperable V2G end-end operations with at least one high-priority use case.**
  - Demonstration components could be real/prototype products and/or simulated components
- **We can define success as 1) demonstration of successful end-end use case implementation using standard communications or 2) documenting the major gaps and hurdles to achieving such a goal, including recommendations for addressing them.**



End-End Work Group and Specification

- **Initial (rough) draft available to work group members**
- **All are welcome to join – just ask Dan Coran to add you dcoran@smartgridobserver.com**

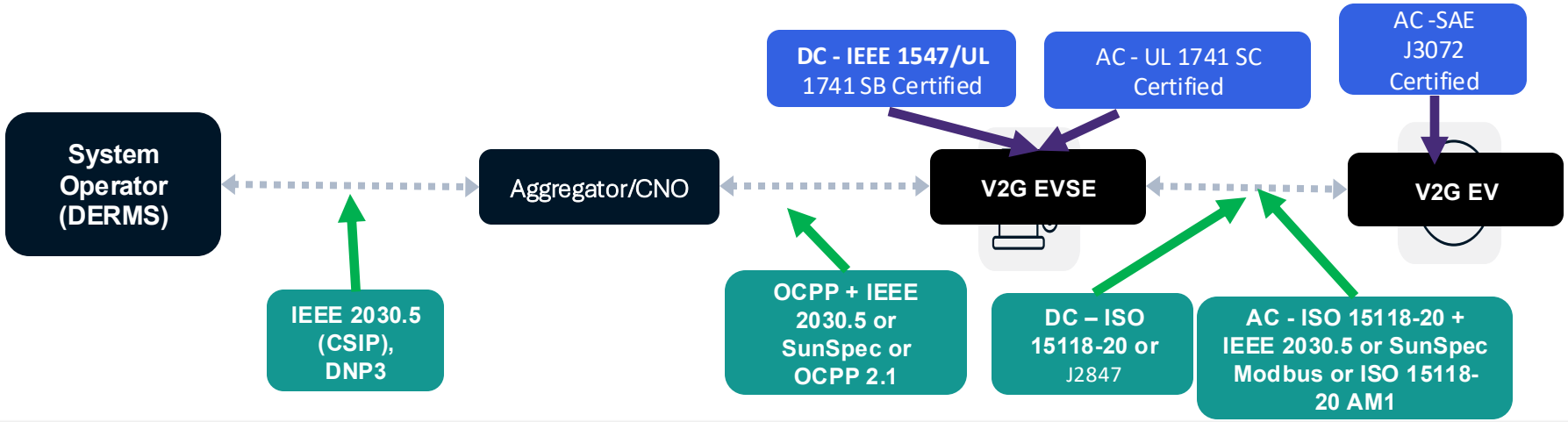
End-End Interoperability Principals and Standards

No industry standard for end-end interoperability certification

- It would be useful to have some form of V2G End-End test bed and certification program to insure complete V2G system interoperability and performance.

End-End Interoperability testing principles (proposed and under discussion).

- Each V2G system (EV, EVSE, CMS, DNO) should be independently tested and should be able to pass any available certifications for protocols and safety standards.
- EVSE and EV simulators should simulate compliant protocol, grid code and electrical behaviors and should also be able to act as a test system..
- Testing should be automated as much as possible to reduce time, costs and improve interoperability.
- Translation points or gateways which must translate between protocols should be validated for correct translations.



End-End Testbed Emerging Challenges

- **Multiple standards paths – mismatch of conformant equipment**
  - An EVSE conformant to OCPP 1.6 + IEEE 2030.5 can't interoperate with CMS that doesn't support IEEE 2030.5.
  - A J3072 EV using SunSpec Modbus over J3068 won't interoperate with a UL 1741 SC EVSE supporting J3072 IEEE 2030.5 unless it can translate between them (but no standard translation so…).
  - *Mitigation: specify a specific standards combination*.
- **Even if products certified, still likely to be some interop issues**.
  - For most V2G standards, certifications are not yet available.
  - *Mitigation 1: Create an end-end test system to "certify" conformance to the testbed specification(s).*
  - *Mitigation 2: Conduct bi-lateral and multi-lateral interops of systems using the priority use cases for the testbed.*
- **Test tools themselves not standardized or qualified**.
  - Different OEMs may use different test tools which yield slightly different results.
  - *Mitigation: qualify one or more test tools (conformance, interop, grid code, simulators, etc) and require pre-test success with them.*

Institutional Challenges to End-End V2G

- **Competing interests**
  - Focus on demonstrating interoperability from a utility perspective
  - Focus on creating a certification testbed for V2G
  - Focus on showing a successful, standards-based V2G end-end system
  - Vendor focus on testing and showing their specific products
  - Competing standards ecosystems – IEEE 2030.5 vs ISO 15118 and OCPP
- **Competing interests means**
  - Debates over goals, methods, standards, test scenarios, etc.
- **Funding (or lack thereof)**
  - Working with a volunteer community
- **Mitigation of institutional challenges?**
  - Working on this issue

Summary

- **End-End V2G standardization and interoperability is recognized as a critical challenge**
- **At least 5 major challenges to achieving V2G end-end Interoperability**
  - Task53 and V2G Forum attempting to address end-end, standardized V2G interoperability
- **Testing and certification are here for V2G-DC, but just starting for V2G-AC**
- **Extremely complex challenge**
  - Most likely: sub-eco-systems standardized around specific standards chain
  - EU, US, Chinese, other V2G versions
  - ISO 15118-20 and OCPP looks like primary V2G standards globally
- **Efforts underway to address end-end interoperability**
  - Task53 5:3:3 and V2G Forum End-End Demonstration
  - QualityLogic is pleased to be part of these of both of these efforts

Want to Learn More?

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QualityLogic V2G-Related Products & Services

Smart energy training courses for IEEE 2030.5, IEEE 1547.1, and OpenADR 2 give your team:

- Provides your team with practical and technical understanding of these important standards
- Taught by experts who helped create these standards
- ***Full V2G Technical Workshop coming soon***

Testing Products and Consulting

- Verify grid support functions that are central to V2G technology IEEE 1547.1 and EN 50549
- Verify DER protocol implementations for conformance and interoperability IEEE 2030.5/CSIP, SunSpec Modbus and ISO 15118/CCS
- Leverage our standards and testing expertise through consulting

QualityLogic Executive Workshops

Executive Workshops

- Introduction to Communications Standards for Vehicle-to-Grid Integration
- Introduction to IEEE 2030.5 for DER and EV Integration
- Introduction to IEEE 1547-2018 Interoperability
- Introduction to OpenADR for Demand Management

Final Remarks

- **Video Recording, Presentation and Questions/Answers will be shared with all those registered after today**
- **Thank you for attending today's V2G Webinar**
- **Please email smartenergynews@qualitylogic.com to contact the QualityLogic Team**