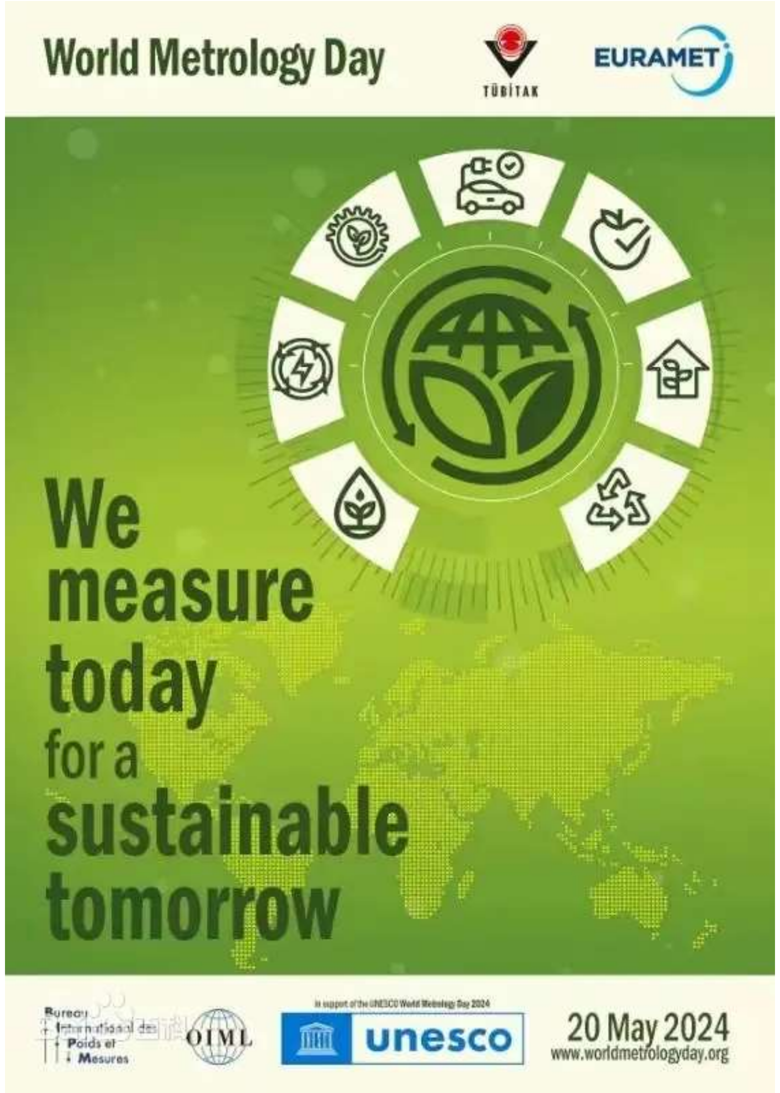
中国计量科学研究院
National Institute of Metrology,China

New Energy Vehicles and NIM’s Support to Its Development

National Institute of Metrology

May. 20, 2024



The theme for
World Metrology Day 2024
is sustainability.

1.1 Strategy

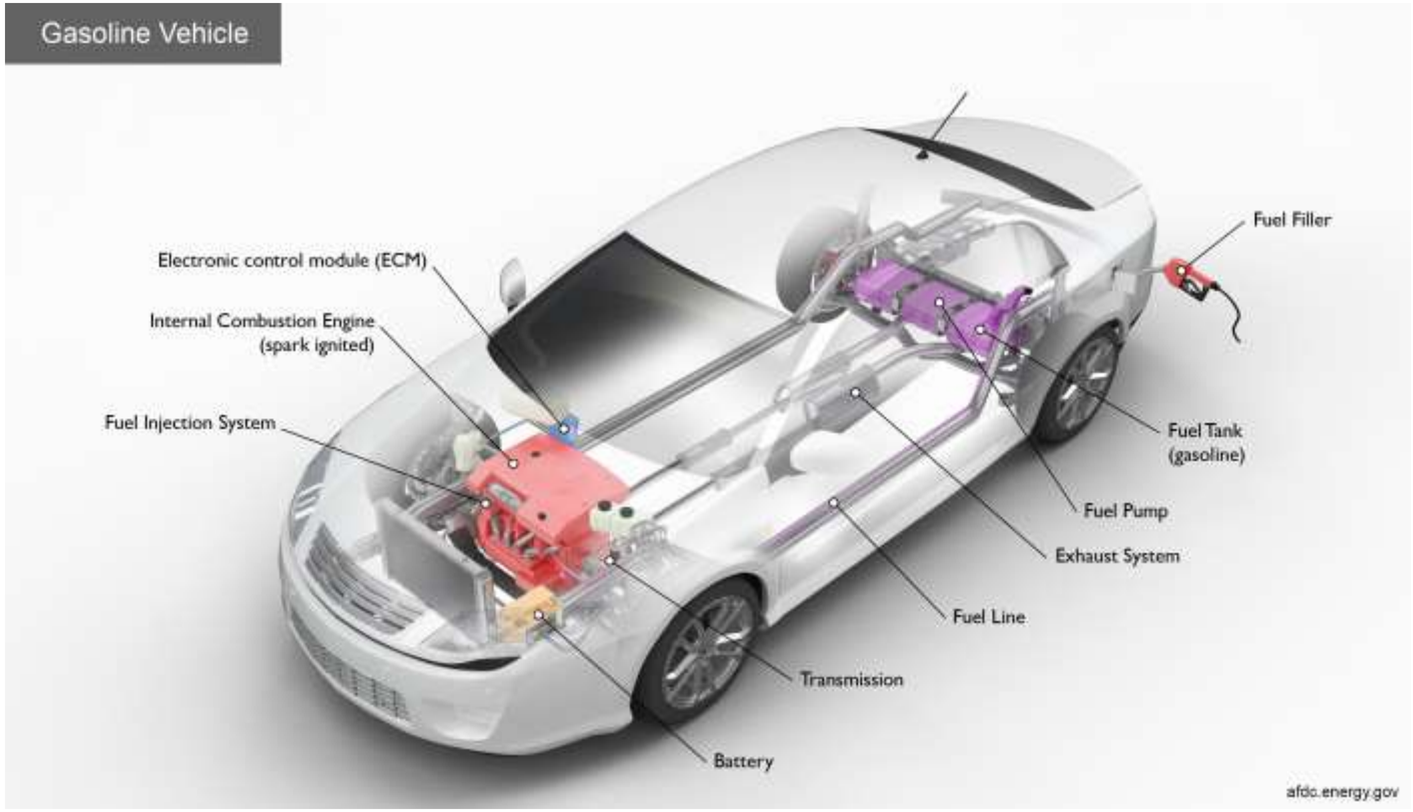
Lucid waters and lush mountains are invaluable assets.

China’s Carbon Peaking and Carbon Neutrality Goals

- On 22th September, 2020, Chinese government declared that it would peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060.

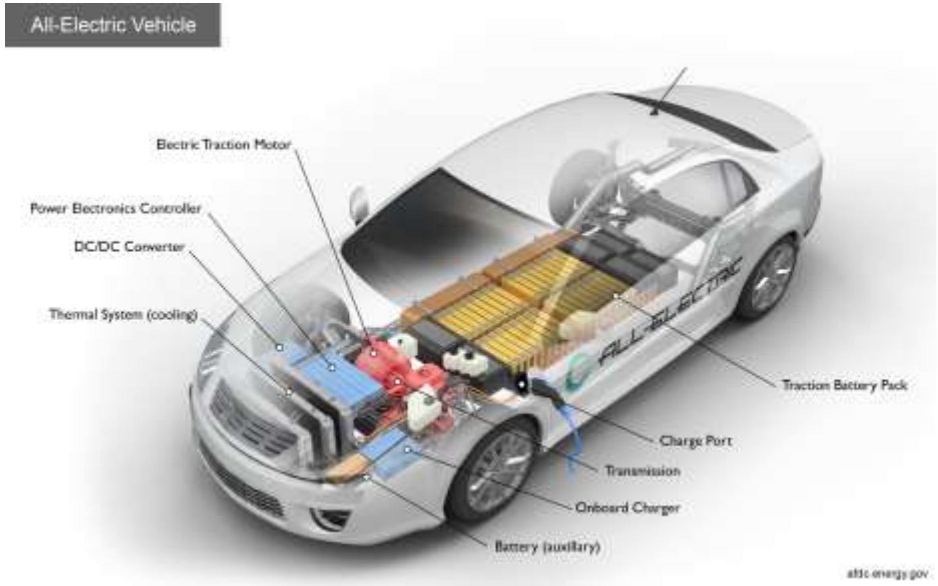
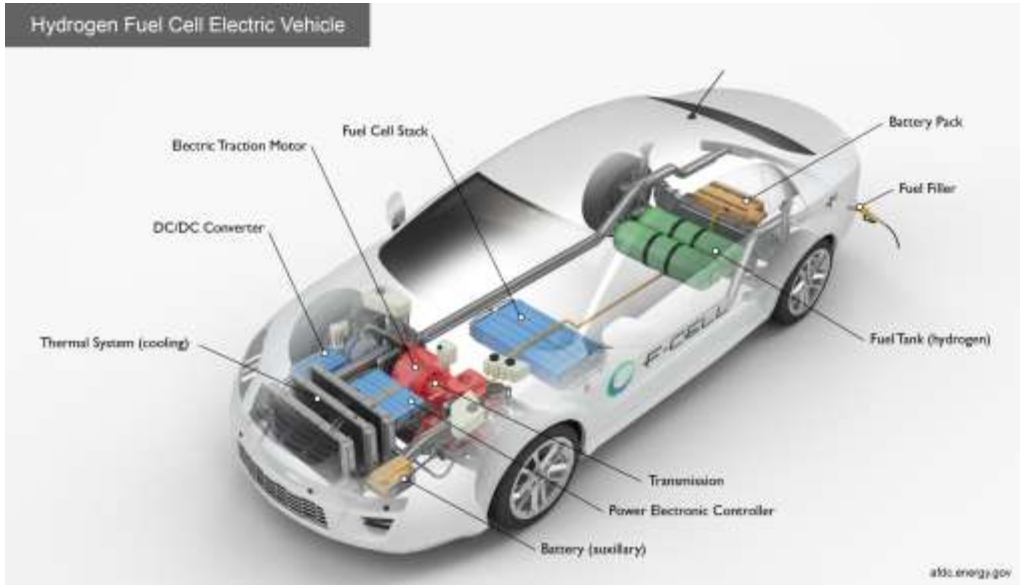
1.2 New Energy Vehicles

- Conventional fuel vehicles rely on internal combustion engines fueled by fossil fuels, leading to substantial greenhouse gas emissions that worsen climate change.



1.2 New Energy Vehicles

- Electric counterparts and Hydrogen fuel cell cars, pivotal elements in the new energy vehicle landscape, are steadily establishing a dominant presence in the future automotive industry, credited to their exceptional efficiency and environmental conscientiousness.

Electric Vehicle	Hydrogen Fuel Cell Vehicle
	

1.3 Trends in EV & FCEV

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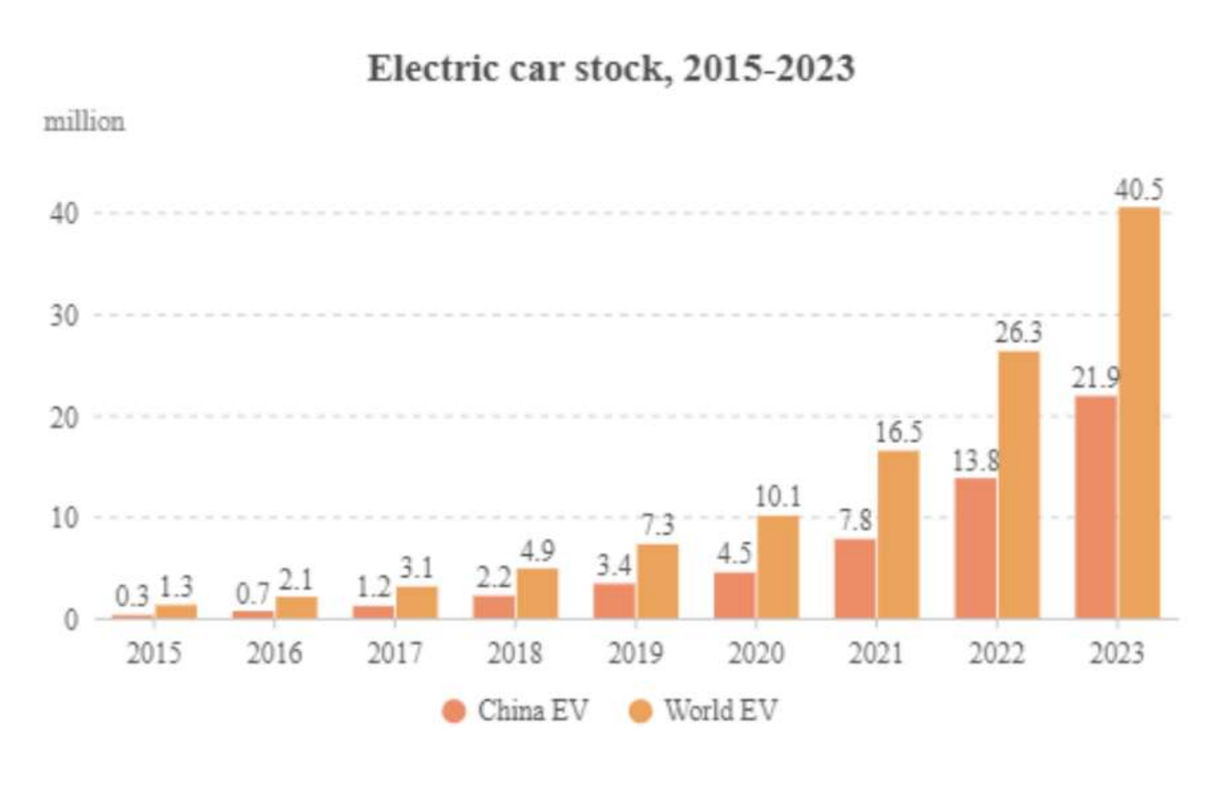
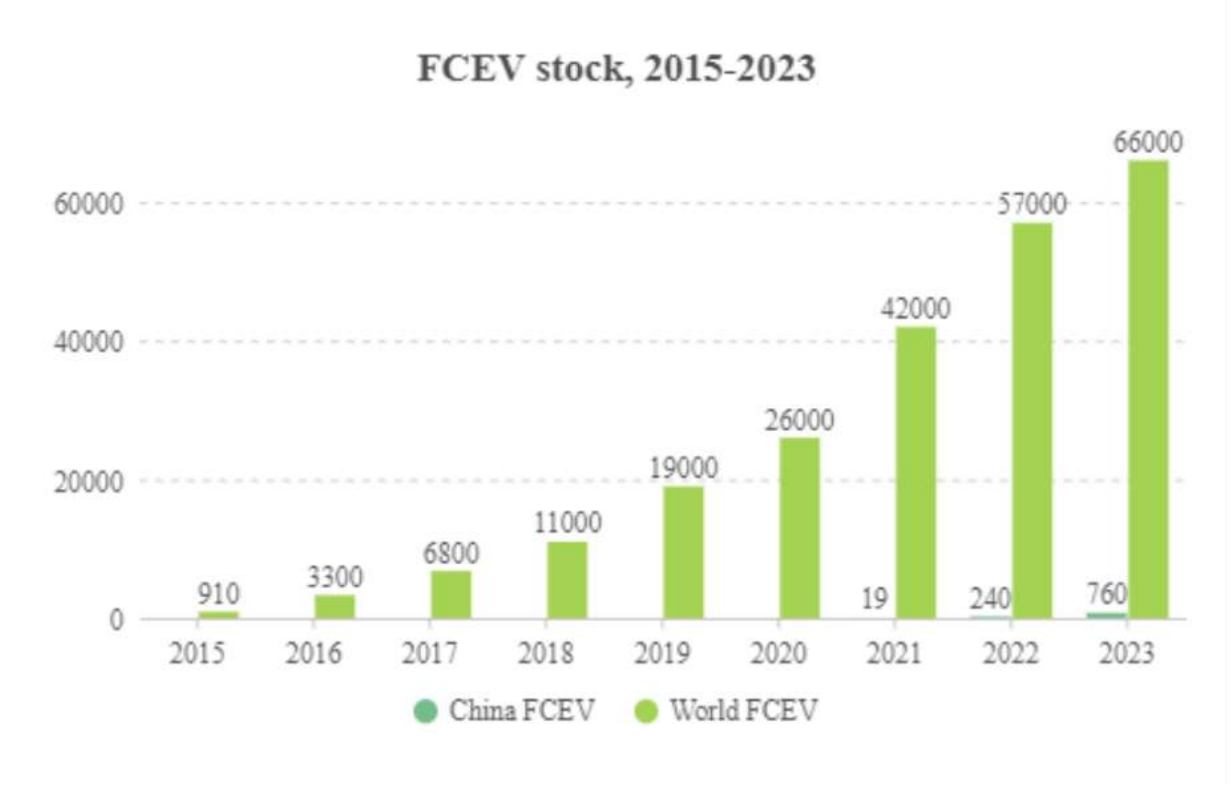
- Nearly one in five cars sold in 2023 was electric, with global sales reaching close to 14 million, 95% of which were concentrated in China, Europe, and the United States.

Electric Vehicle



Hydrogen Fuel Cell Vehicle



2.1 Measurement for HFCV

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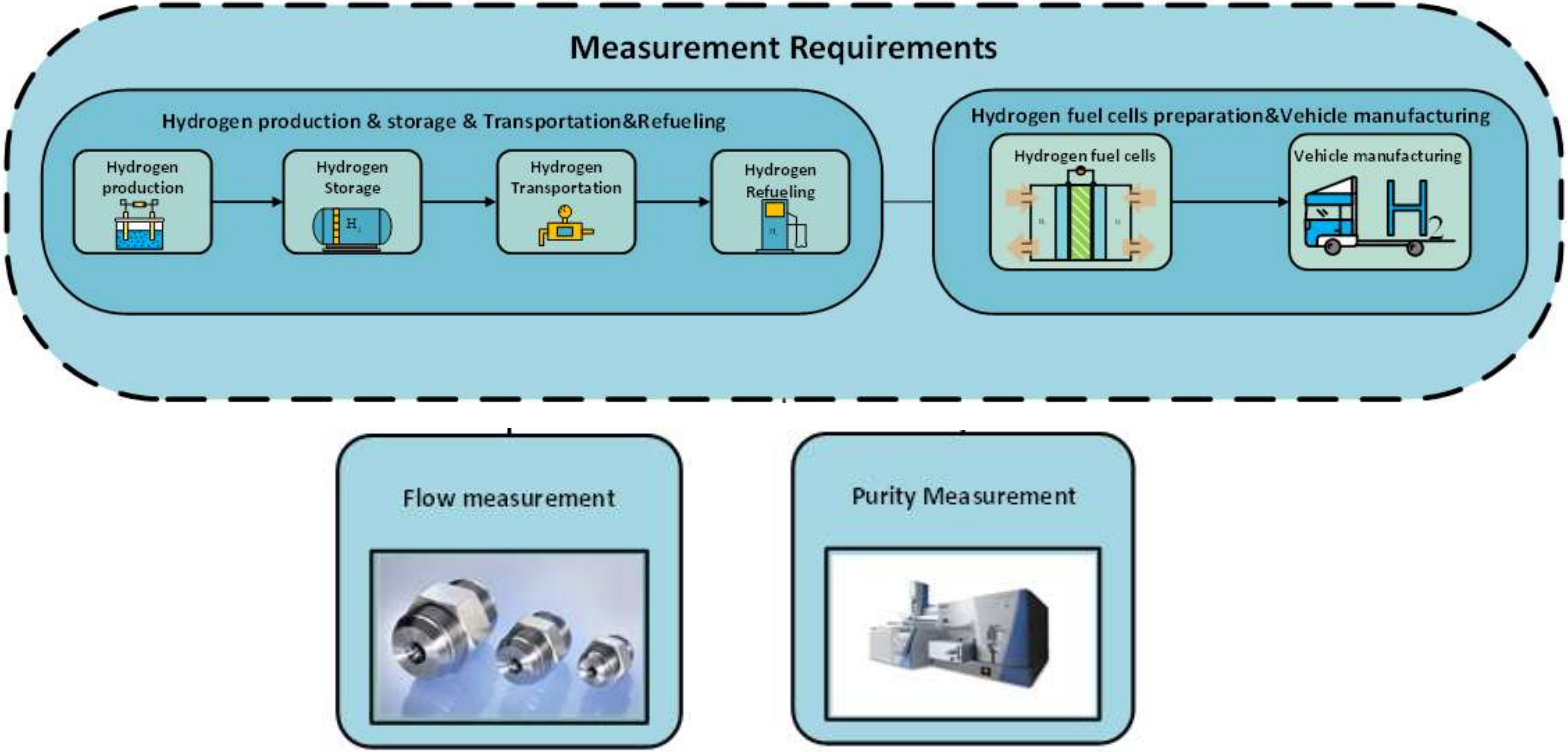


2.2 Gas Flow

pVTt facility
Nominal volume: 0.1/2 m^3
Pressure: (0.1~2.5) MPa
Temperature: (20±5) °C
Flowrate: (0.019~1367) kg/h
Uncertainty: 0.08% (*k*=2)

Primary standard

Sonic nozzle facility
Diameter: Dn50~Dn100
Pressure: (0.2~2.5) MPa
Temperature: (20±5) °C
Flowrate: (40~7200) Nm^3/h
Uncertainty: 0.15% (*k*=2)

Secondary standard

Close loop facility
Diameter: Dn50~Dn200
Pressure: (0.2~2.5) MPa
Temperature: (20±5) °C
Flowrate: (20~1400) m^3/h
Uncertainty: 0.20% (*k*=2)

Working standard

2.2 Gas Flow

pVTt facility

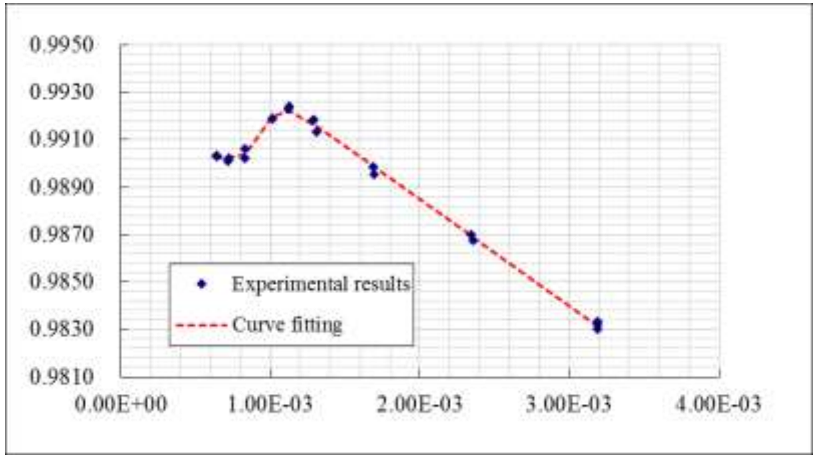
Nominal volume: 0.1/2 m^3

Pressure: (0.1~2.5) MPa

Temperature: (20±5) °C

Flowrate: (0.019~1367) kg/h

Uncertainty: 0.08% (*k*=2)



pVTt gas flow facility, air

Sonic nozzle, air
Pressure: (0.1~2.5) MPa
Flowrate: (1.14×10^{-3}~2.88) kg/min
Uncertainty: (0.08%~0.20%) (*k*=2)

1st stage

Sonic nozzle, hydrogen
Pressure: (0.18~4.6) MPa
Flowrate: (5.50×10^{-4}~1.37) kg/min
Uncertainty: ≤ 0.35% (*k*=2)

2nd stage

Sonic nozzle bench, hydrogen
Pressure: 9/18/36/70 MPa
Flowrate: (1.65×10^{-3}~10.41) kg/min
Uncertainty: ≤0.50%(*k*=2)

3rd stage

Coriolis flow meter, hydrogen
Pressure: (10~70) MPa
Flowrate: (0.1~7.2) kg/min
Accuracy grade: 1.5 grade

2.3 Hydrogen purity

GB/T 37244-2018（ISO 14687-2012）

项目名称	指标
氢气纯度(摩尔分数)	99.97%
非氢气体总量	300 μmol/mol
单类杂质的最大浓度	
水(H_2O)	5 μmol/mol
总烃(按甲烷计)[a]	2 μmol/mol
氧(O_2)	5 μmol/mol
氦(He)	300 μmol/mol
总氮(N_2)和氩(Ar)	100 μmol/mol
二氧化碳(CO_2)	2 μmol/mol
一氧化碳(CO)	0.2 μmol /mol
总硫(按 H_2S 计)	0.004 μmol/mol
甲醛(HCHO)	0.01 μmol/mol
甲酸(HCOOH)	0.2 μmol/mol
氨(NH_3)	0.1 μmol/mol
总卤化合物(按卤离子计)	0.05 μmol/mol
最大颗粒物浓度	1 mg/kg

[a] 当甲烷浓度超过 2 μmol/mol 时，甲烷、氮气和氩气的总浓度不准许超过 100 mol/mol。

Trace impurities in hydrogen affect hydrogen fuel cell performance and life

More than 11 national CRMs have been developed

Published number	Mole fraction（×10^{-6}）		Relative expand uncertainty
GBW06350	CO	0.200	8%
	CO_2	2.00	1%
	CH_4	2.00	
GBW06351	CO	0.200	8%
GBW06352	CO_2	2.00	1%
GBW06353	CH_4	2.00	1%
GBW06354	CO_2	2.00	1%
	CH_4	2.00	
GBW06355	He	300	1%
	Ar	100	
	N_2	100	
GBW06356	He	300	1%
GBW06357	Ar	100	1%
GBW06358	N_2	100	1%
GBW06359	Ar	100	1%
	N_2	100	
GBW(E)084014	O_2	5	9%
	N_2	100	1%

2.3 Hydrogen purity

CCQM-K164 Key Comparisons
Ar, N_2, He, CH_4, CO_2, C_2H_6, CO, DMS in hydrogen for fuel cell electric vehicle applications

Helium	300 μmol /mol
Argon	300 μmol/mol
Nitrogen	300 μmol/mol
Carbon dioxide	2 μmol/mol
Methane	100 μmol/mol
Ethane	1 μmol/mol
Carbon monoxide	0.2 μmol/mol
Dimethyl sulphide	0.005 μmol/mol
Hydrogen	

2.1 Participants

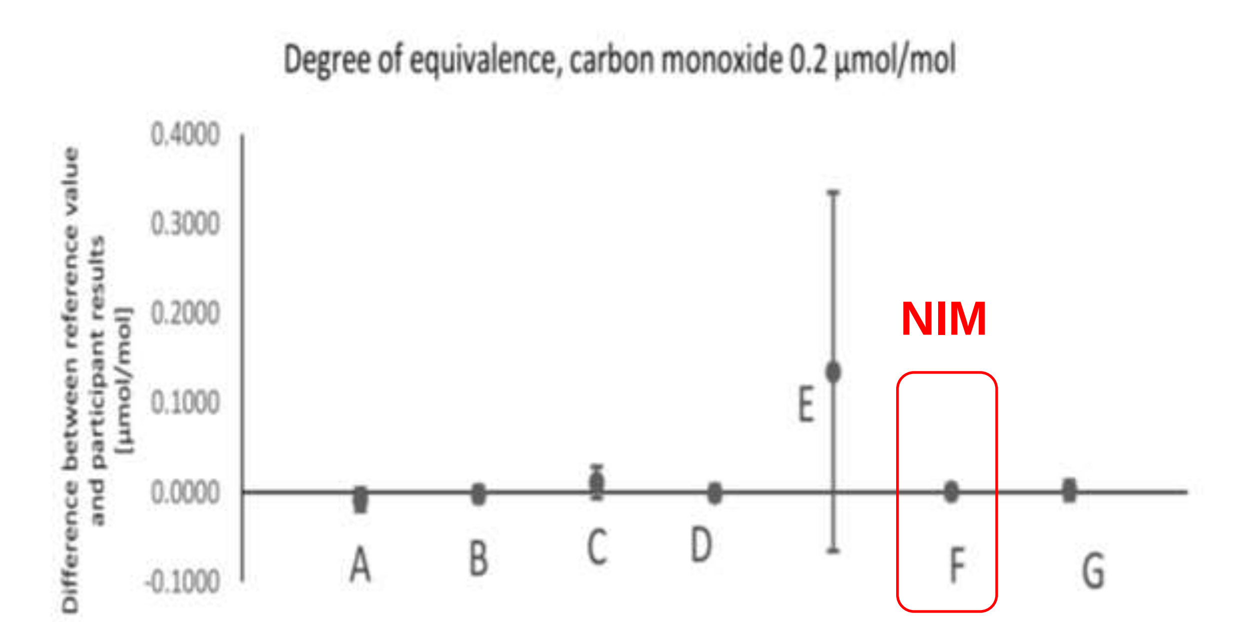
Table 2 lists the participants in this key comparison.

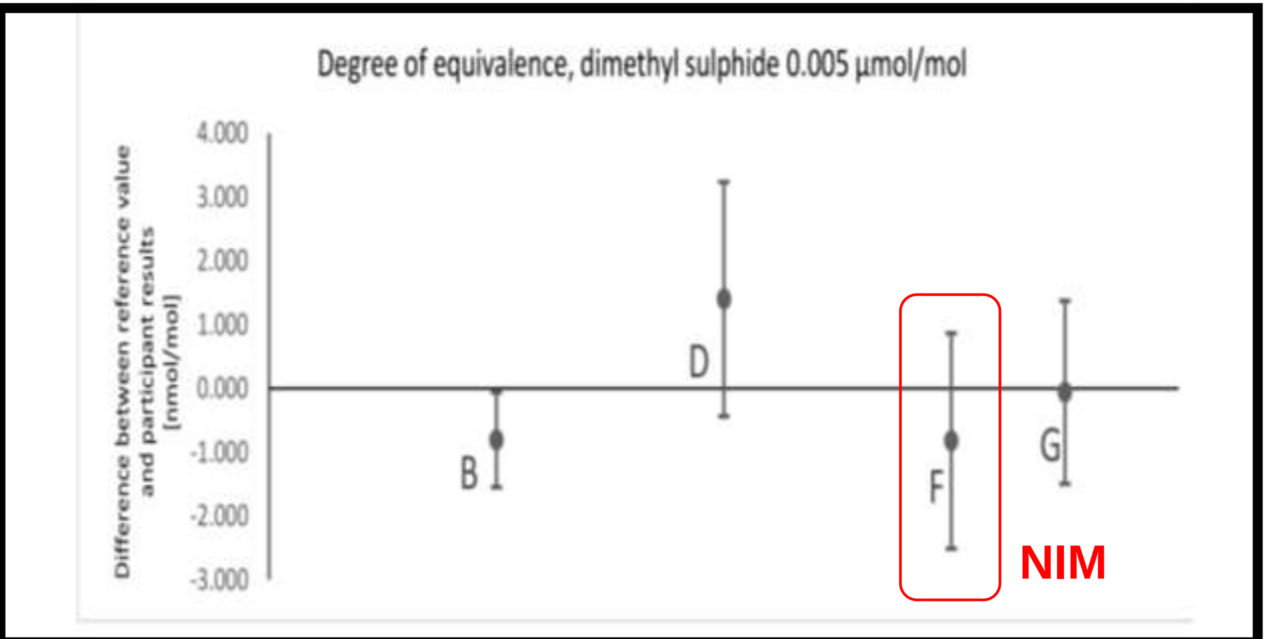
Table 2: List of participants

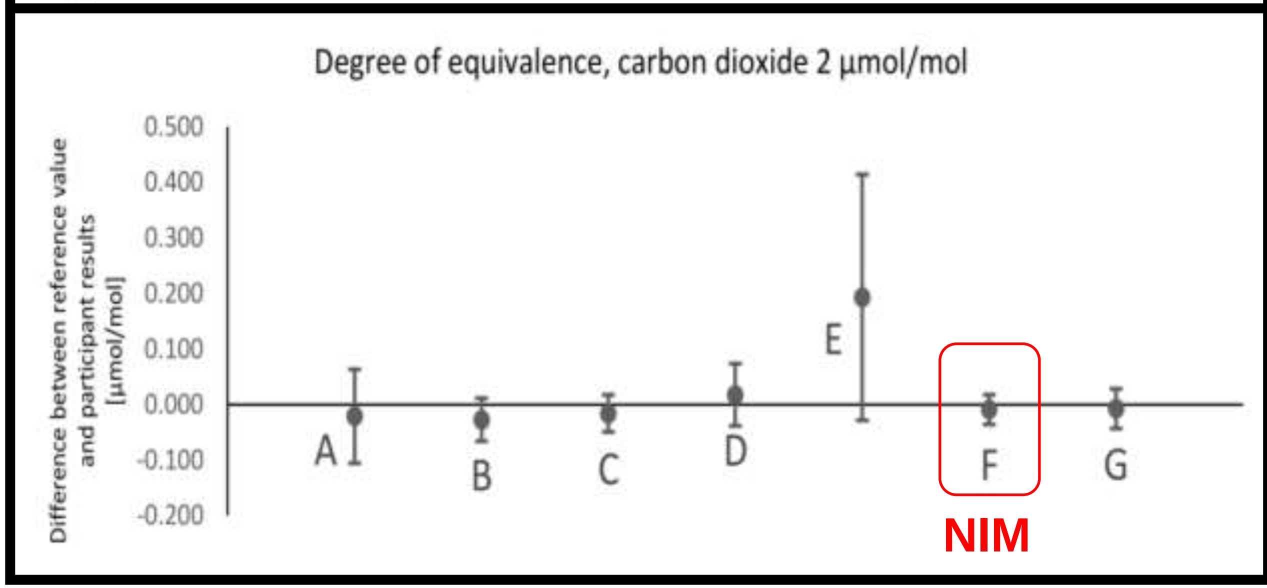
Acronym	Country	Institute
NPL	GB	National Physical Laboratory, Teddington, United Kingdom
BAM	DE	Bundesanstalt für Materialforschung und -prüfung, Berlin, Germany
KRISS	KR	Korea Research Institute of Standards and Science, Deajeon, Republic of Korea
NMIA	AUS	National Measurement Institute Australia, Lindfield, Australia
NMISA	ZA	National Metrology Institute of South Africa, Pretoria, South Africa
NIM	CN	National Institute of Metrology, Beijing, China
VSL	NL	Van Swinden Laboratorium, Delft, the Netherlands

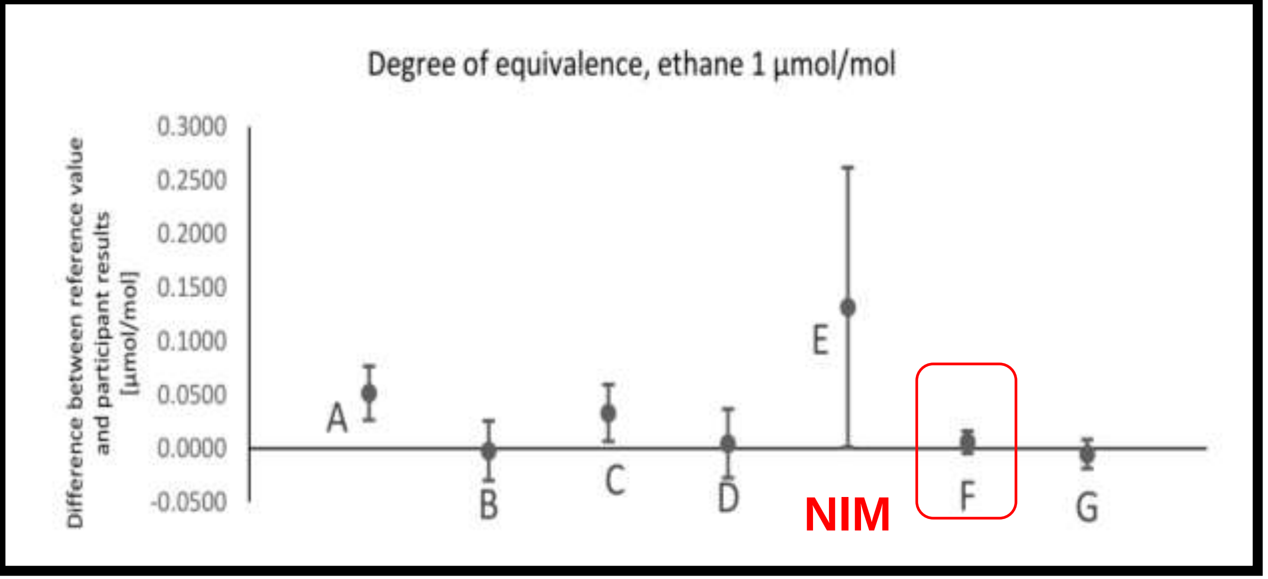
Draft A is discussing in CCQM meeting in Paris

2.3 Hydrogen purity

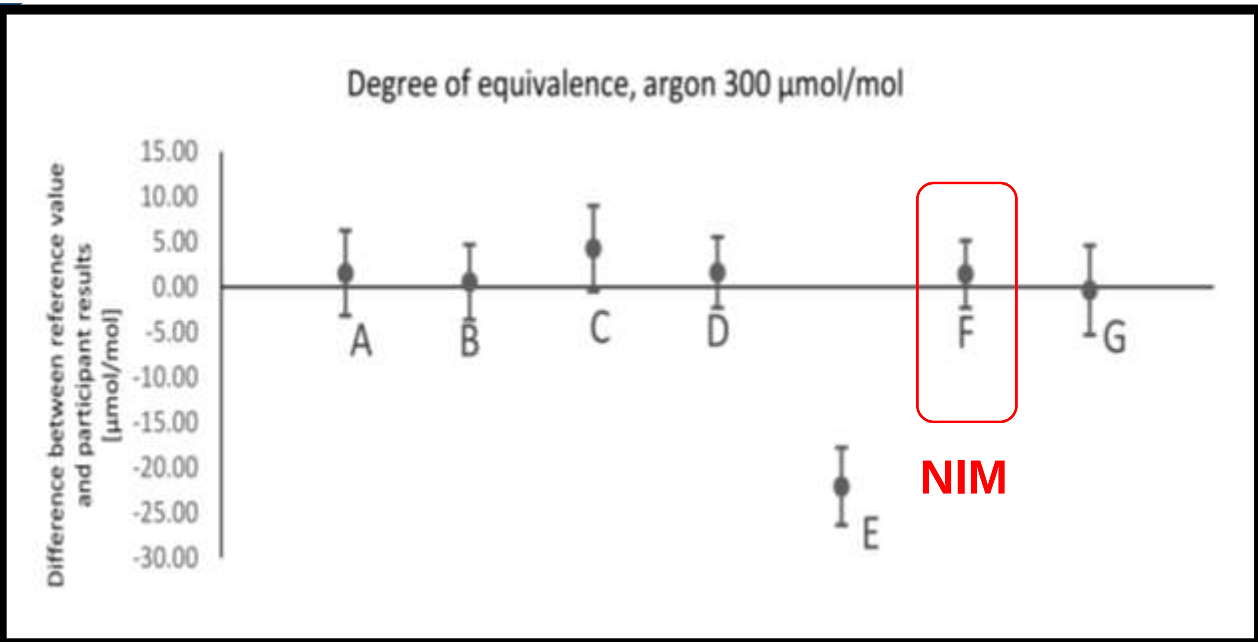


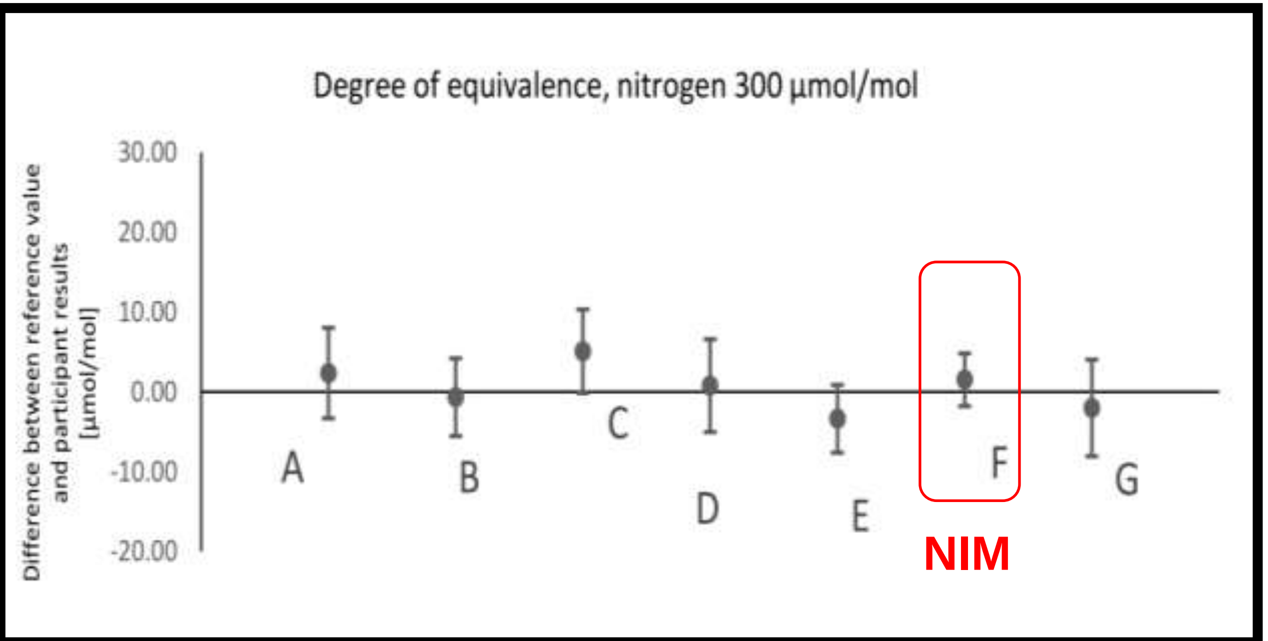


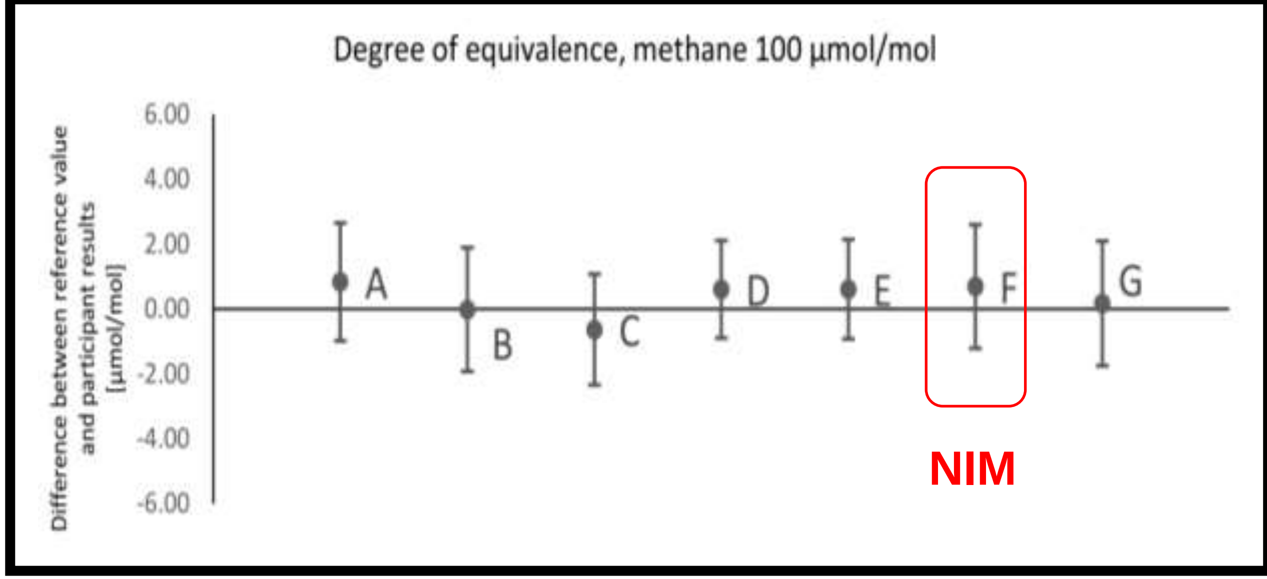


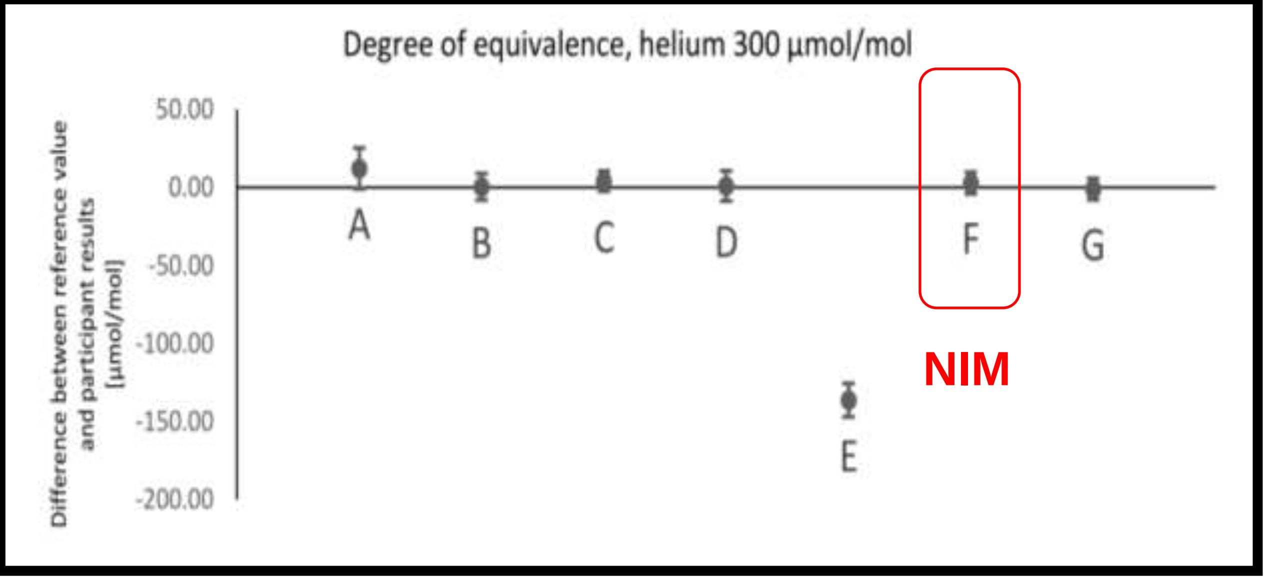


2.3 Hydrogen purity









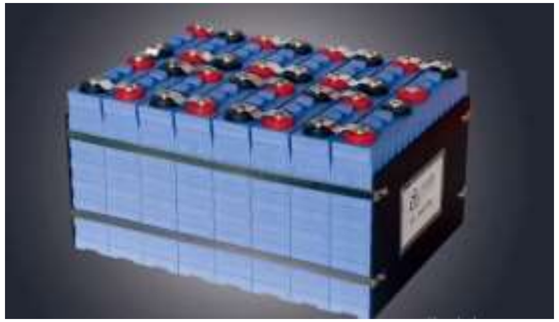
3.1 Measurement for EV

1

Upstream industry chain

Battery Charging Technology

1.Batteries preparation



2

Midstream industry chain

Electric vehicle manufacturing and distribution

1. Electric vehicle manufacturing

3

Downstream industry chain

Charging facility construction & vehicle maintenance

1.Charging infrastructure operation

2. Market services and maintenance

3.2 Charging Facilities

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- Up to the end of 2023, the public EVSE in China is growing to 2.73 M, including 1.2 M DC, and 1.5 M AC。
- Annual growth rate: 52%

- Up to the end of 2023, the public EVSE is growing to 3.90M, including 1.4 M DC, and 2.5 M AC。
- Annual growth rate: 44%

EV Charging Points, China, 2015-2023

EV Charging Points, World, 2015-2023

3.2 Charging Facilities

(1) Standards

GB/T 28569-2012	Electric Energy Metering for Electric Vehicle AC Charging Spot
GB/T 29318-2012	Electric Energy Metering for Electric Vehicle Off-board Charger

JJG 1148-2018	AC Charging Spot for Electric Vehicles
JJG 1149-2018	Off-board Charger for Electric Vehicles

JJG 1148-2022	AC Charging Spot for Electric Vehicles (for Trial Implementation)
JJG 1149-2022	Off-board Charger for Electric Vehicles (for Trial Implementation)

JJG 1192-2023	Calibrator of Off-board Chargers for Electric Vehicles
JJG 1193-2023	Calibrator of AC Charging Pile for Electric Vehicles

3.2 Charging Facilities

(2) Traceability

Traceability

National Primary Standard for AC Energy
$U=10\times10^{-6}$

JJG 1193-2023

AC Calibrator
Class 0.05

JJG 1148-2022

AC Charging Spots
Class 1 and Class 2

National Primary Standard for DC Energy
Class 0.01

JJG 1192-2023

DC Calibrator
Class 0.05

JJG 1149-2022

DC Charging Spots
Class 1 and Class 2

3.2 Charging Facilities

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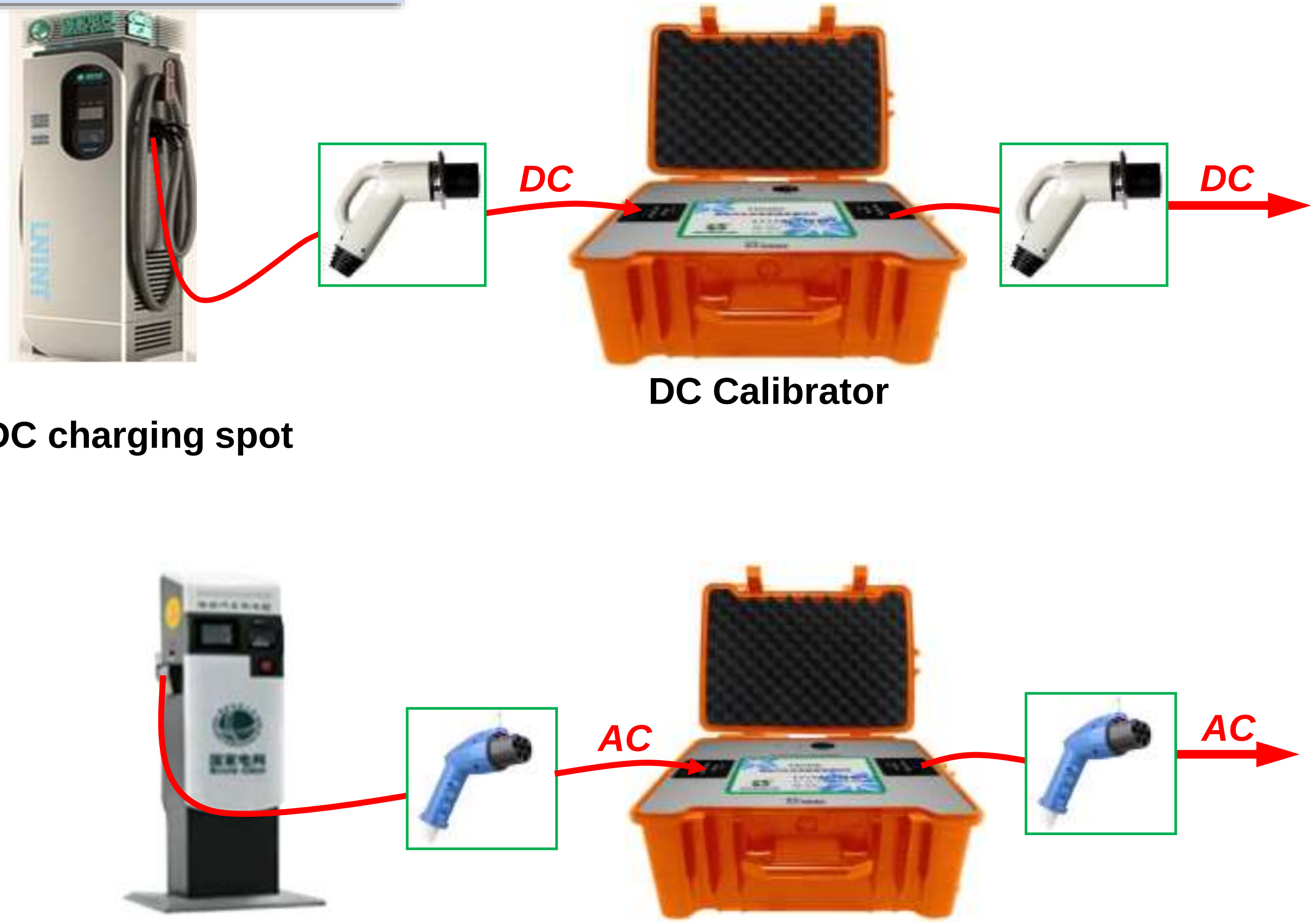
(3) Verification



DC Calibrator

DC charging spot

AC charging spot

AC Calibrator

Programmable electronic load suitable for type Approval

DC or AC Resistive Load suitable for onsite or lab verification

EV for onsite Verification

3.2 Charging Facilities

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(3) Verification

Load Testing Driver

- All in one car easy move
- Up to 180 kVA load
- Top or back heat radiation
- Interoperability, protocol consistency in site testing

(3) Verification

(1) Accuracy Class

Accuracy Class	
1	2
BMPE	
±1.0%	±2.0%

- For special ambient temperatures（-20℃ ≤ *T*<-10℃ or +40℃<*T*≤+50℃）considering the influence of ambient temperature changes, the BMPE is corrected by the value e.
- The ambient temperature should be measured outside the range of 0.5 m from the charging equipment.

Accuracy Class	
1	2
Average Temperature Coefficient (%/K)	
0.05	0.10

- e =C×|⊿T|

where,

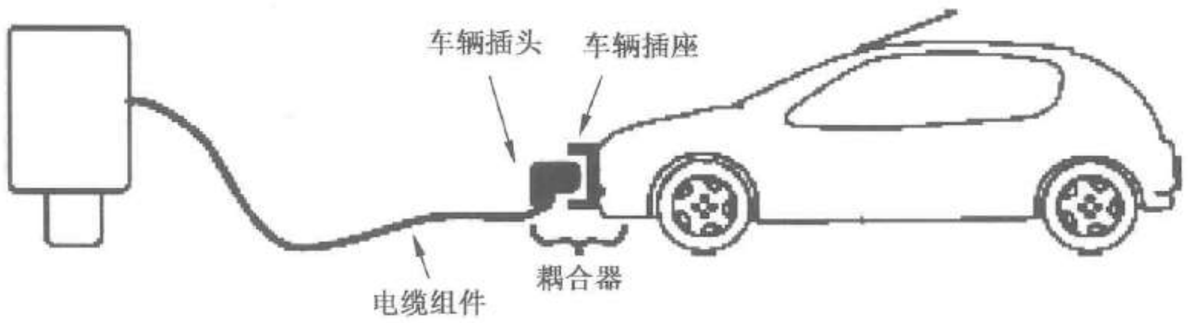
- C - average temperature coefficient, %/K;
- ⊿T -deviation value of ambient temperature, for high temperatures, it is the difference between the current ambient temperature and +40°C; for low temperatures, it is the difference between the current ambient temperature and -10°C.

(3) Verification

(2) Connection Point

The point where an electric vehicle is physically connected to a charging equipment.

Note: If the cable is a fixed part of the charging equipment, this point is defined as the connector at the cable's end. Otherwise, the connection point is defined as the point where the cable is inserted into the charging equipment.



注：电缆组件是充电设备的一部分。

图 3　连接方式 C

3.2 Charging Facilities

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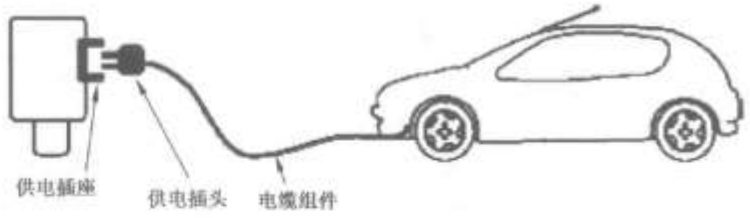
(3) Verification

(2) Connection Point

连接方式 A　case A connection

将电动汽车和交流电网连接时，使用和电动汽车永久连接在一起的充电电缆和供电插头，见图 1。

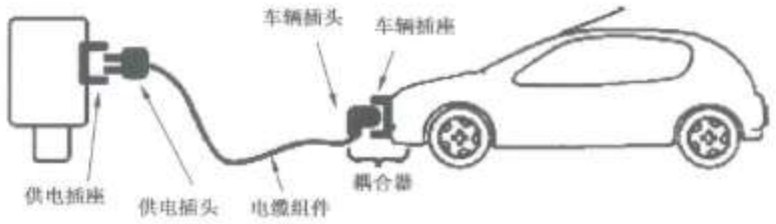


注：电缆组件是车辆的一部分。

图 1　连接方式 A

连接方式 B　case B connection

将电动汽车和交流电网连接时，使用带有车辆插头和供电插头的独立的活动电缆组件，见图 2。



注：可拆卸电缆组件不是车辆或者充电设备的一部分。

图 2　连接方式 B

(3) Verification

(3) Verification Items

Verification Items	Initial Verification	Subsequent Verification	In-Use Inspection
Visual Inspection	+	+	+
Operational Error	+	+	-
Time Error	+	+	-
Note: "+" indicates compulsory, and "-" indicates optional.			

(3) Verification

(4) Verification Period

- The verification period is generally not more than 3 years.
- The period of the charging equipment with online monitoring of metrological performance or anti-cheating features, the verification period can be appropriately extended.

3.2 Charging Facilities

(4) Novel Methods

Challenge

(1) Cost

Existing verification methods

High cost | **Low efficiency** | **Heavy Tasks**

One Metrological verification

Persons: **at least 2**

Electricity consumption: **3~5 kWh**

Time: **(20~40) min (depend on resolution)**

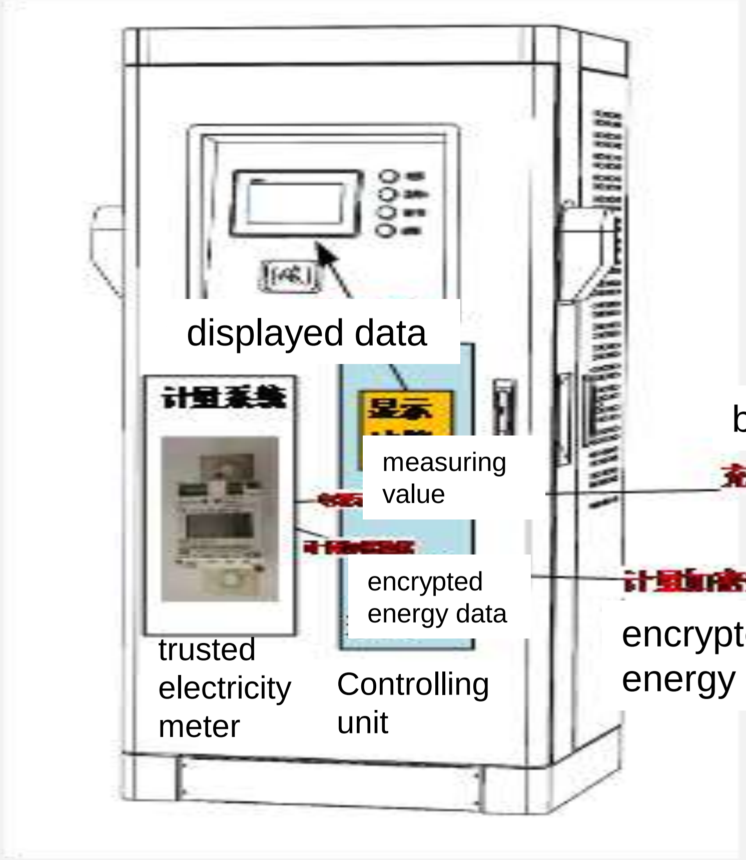
Money: **￥500-￥800**

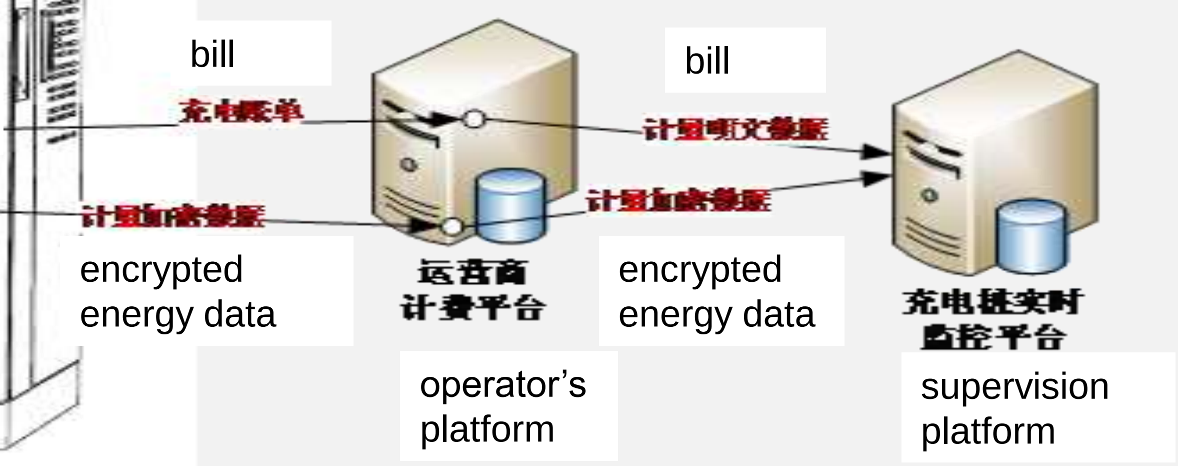
(2) Lack of durative supervision

3.2 Charging Facilities

Encrypted Energy Data Comparison

compare the energy value in a bill and the corresponding encrypted energy from the inner trusted electricity meter to prevent fraudulent conducts





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3.2 Charging Facilities

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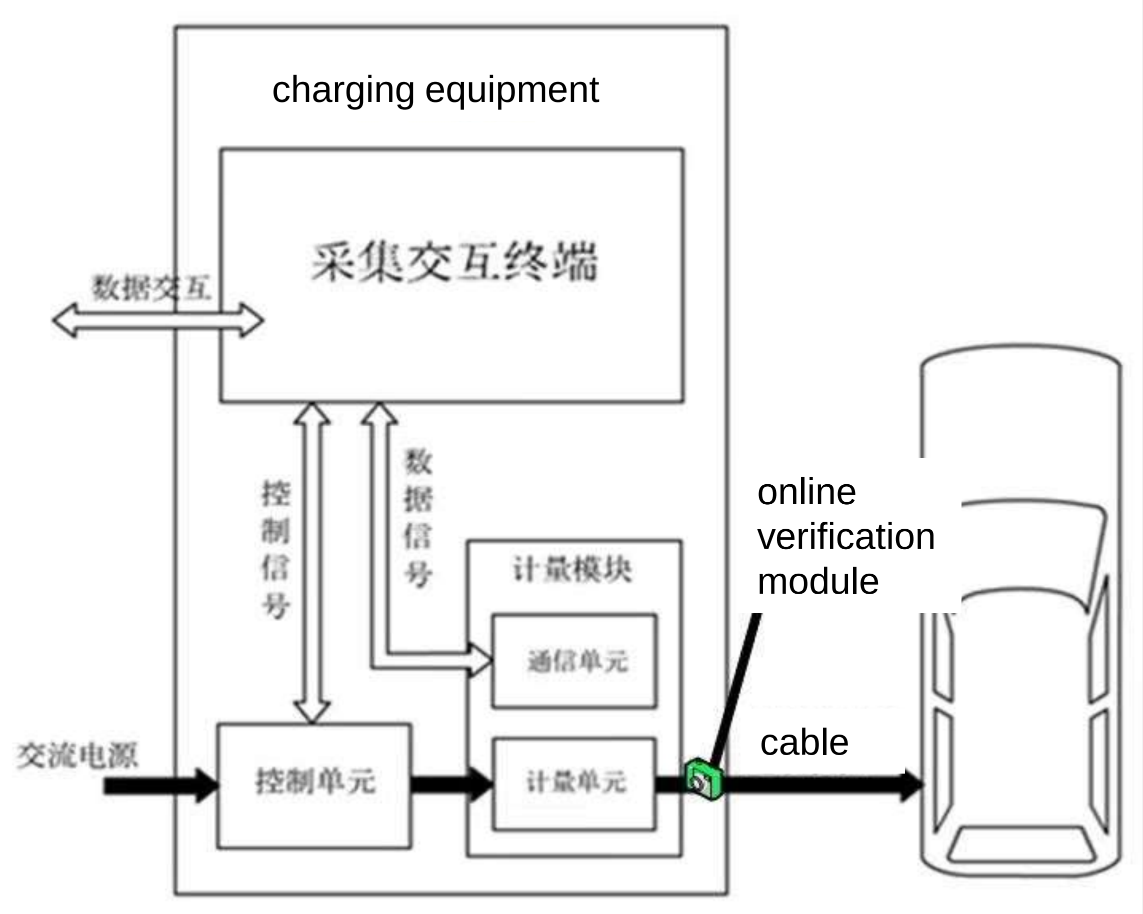
Online Verification Module



- An online verification module is installed inside. The module continuously measures voltage, current, power, energy. The values are transmitted wirelessly.
- Compare the values from the module and the charging equipment, we can obtain the error.

Anhui Institute of Metrology

3.2 Charging Facilities

Novel Calibrator

Virtual Load Calibrator

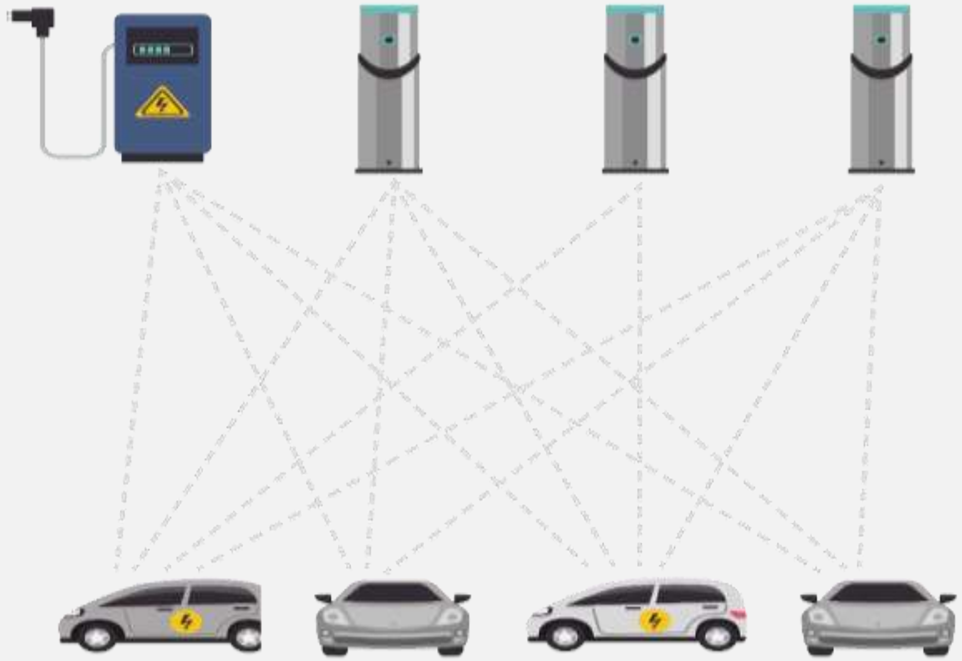
China's

Domestic

Manufacturers

3.2 Charging Facilities

EV-EVSE Interaction (Data-driven)



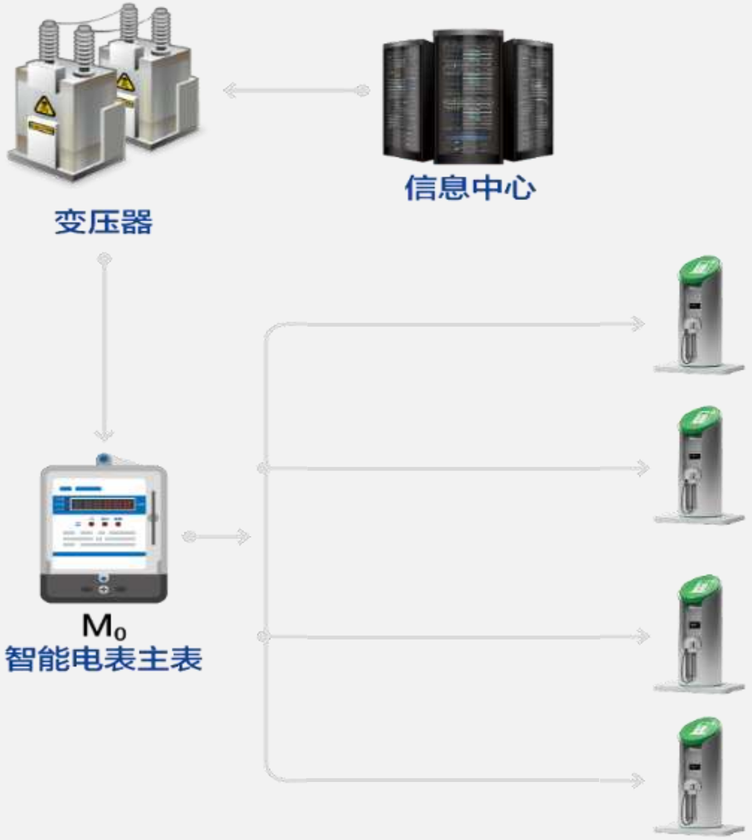
- Various EVs are charged in various charging equipment.
- EVs behave as transfer standards.
- The BMS in an EV's battery records voltage and current.
- By comparison of the charging results of one EV in two charging equipment, we indirectly compare the two equipment.

$$
\begin{bmatrix}
e_{v1}^{1} = U_{v1}^{1} - (U_{c1} + \Delta e_{c1}) \\
e_{v1}^{2} = U_{v1}^{2} - (U_{c2} + \Delta e_{c2}) \\
\cdots\cdots\cdots\cdots\cdots\cdots \\
e_{v1}^{n} = U_{v1}^{n} - (U_{cn} + \Delta e_{cn})
\end{bmatrix}
$$

Shenzhen Academy of Metrology & Quality Inspection

3.2 Charging Facilities

Energy Conservation Based Method (Data-driven)



Input Energy to a Charging Station

Output Energy from all EVSE
+
Loss

$$T(i)=\sum_{j=1}^{N}M_j(i)(1-\gamma_j)+L_0+L(i)$$

$$\begin{cases} M_1(1)(1-\gamma_1)+M_2(1)(1-\gamma_2)+...+M_n(1)(1-\gamma_n)+L_0+L(1)=T(1) \\ M_1(2)(1-\gamma_1)+M_2(2)(1-\gamma_2)+...+M_n(2)(1-\gamma_n)+L_0+L(2)=T(2) \\ M_1(3)(1-\gamma_1)+M_2(3)(1-\gamma_2)+...+M_n(3)(1-\gamma_n)+L_0+L(3)=T(3) \\ ... \\ M_1(m)(1-\gamma_1)+M_2(m)(1-\gamma_2)+...+M_n(m)(1-\gamma_n)+L_0+L(m)=T(m) \end{cases}$$

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3.2 Charging Facilities

Data-driven Remote Error Evaluation

- Energy Conservation Based Method
- EV-EVSE Interaction

+

Verification

- Statistical Verification
- Online Verification Module
- On-site Automatic Verification

- The data-driven method is the key part, while verification is the supplemental to it.
- Integrating the data-driven method, statistical verification and other verification method, it is expected that cost of supervising public charging equipment becomes 40% to 50% of the cost of traditional verification.

3.2 Charging Facilities

(5) Future Work

(1) OIML G22 Type Evaluation

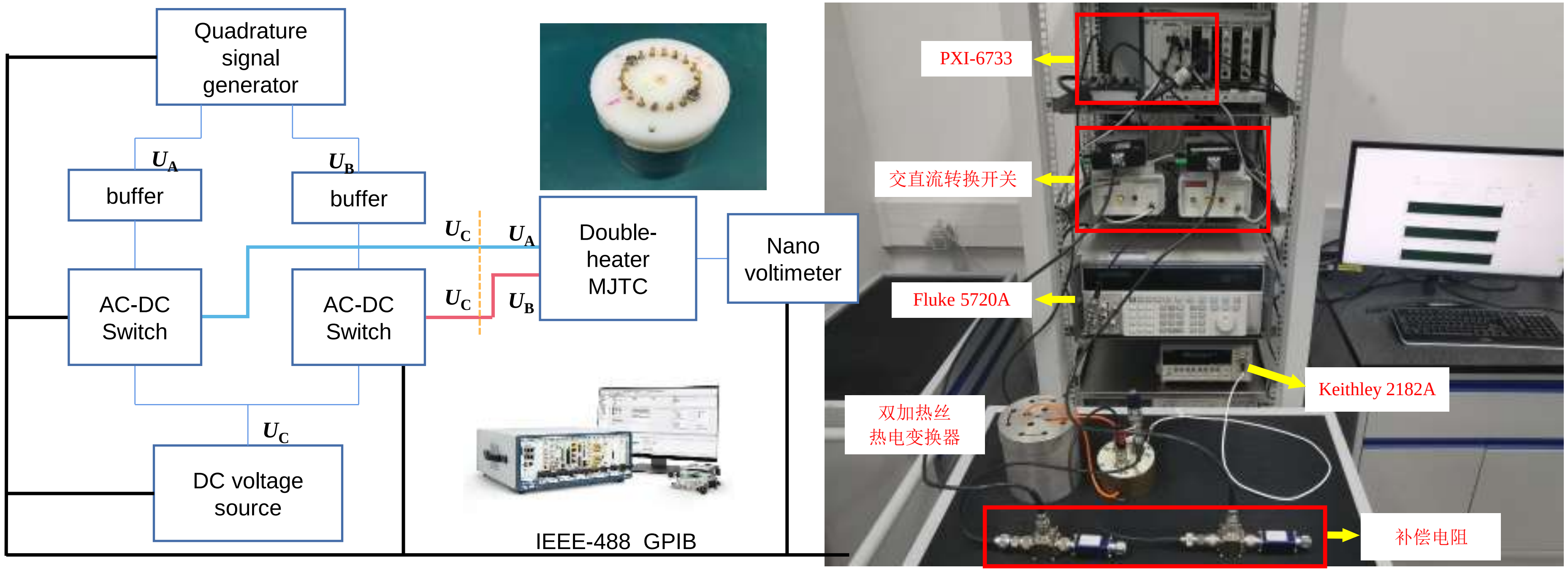
- More tests on safety, reliability, communication, software, etc.

(2) Super Charger – MW charging

- Now the maximum value of DC charging power has arrived 600 kW in China. In future, there will be DC charging equipment with more power.
- It is necessary that we use the phantom load method to do verification.
- Therefore, the manufacturers are needed to give phantom load interfaces.

(1) Electrical Characteristics of Batteries

a) Electrochemical Impedance Spectroscopy (EIS)



Battery EIS analyer calibration at ulta-low frequencies

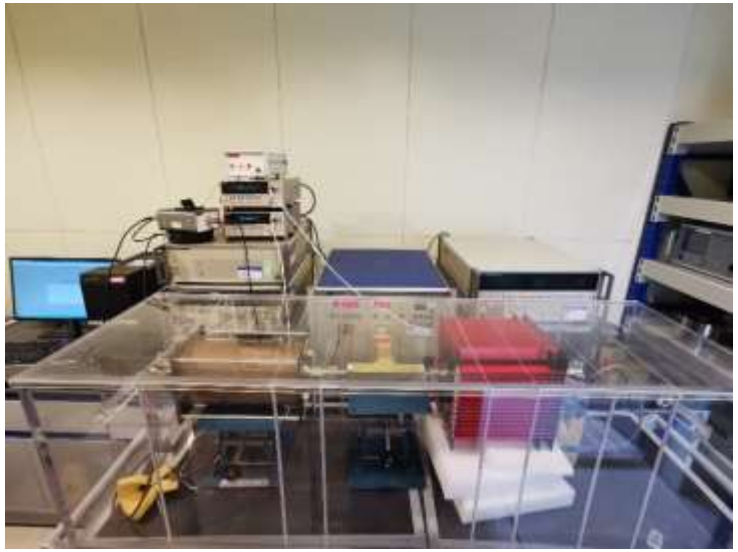
AC-DC voltage transfer system based on double-heater Multijuction Thermal Converter

Standard uncertain for ac voltage of 1 V at 100 mHz is 20 μV/V

3.3 Battery

(1) Electrical Characteristics of Batteries

b) Battery internal resistance traceability

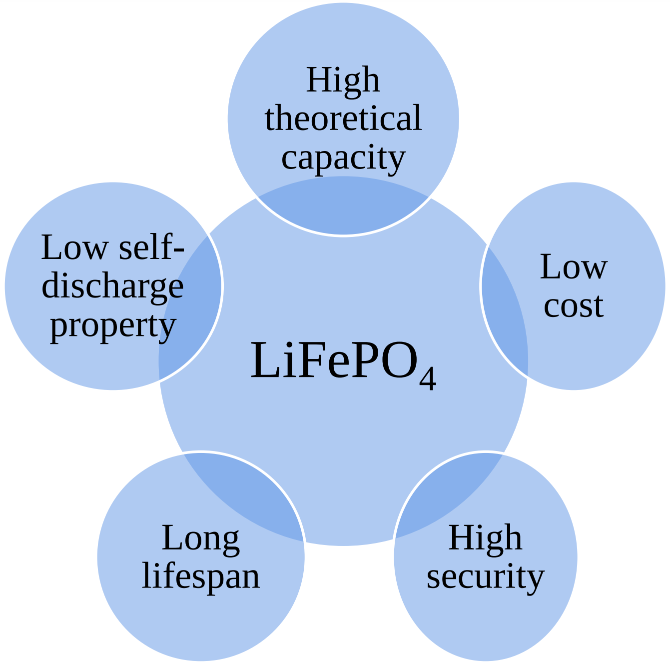


Cage-like ac shunts were developed for the impedance traceability of battery internal resistance at frequency up to 100 kHz

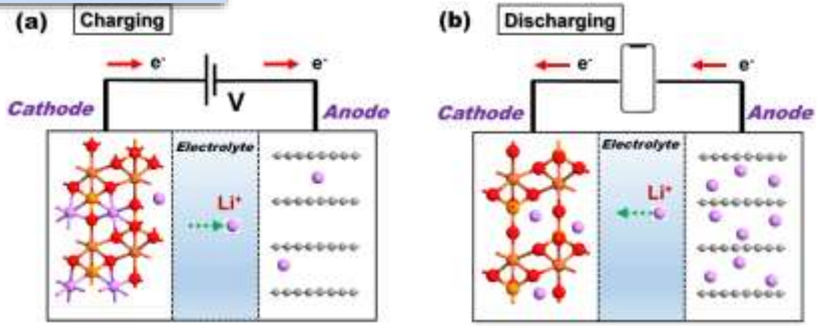
Analysis of SoC and SoH based on the precision measurement of frequency response of battery internal resistance

3.3 Battery

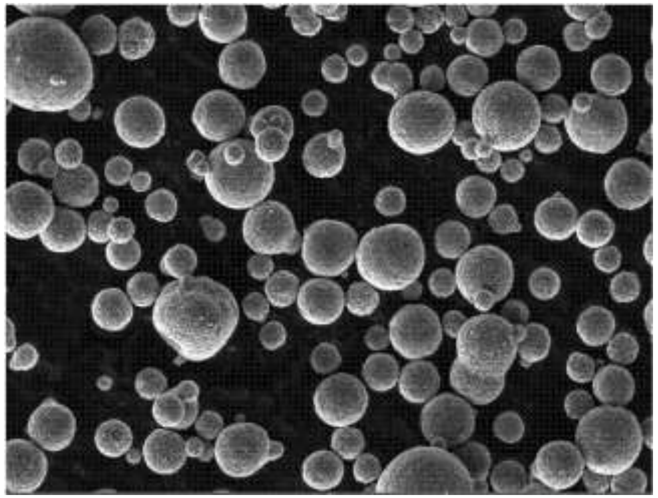
(2) LiFePO4 measurement



Advantages of $LiFePO_4$ as a new energy material

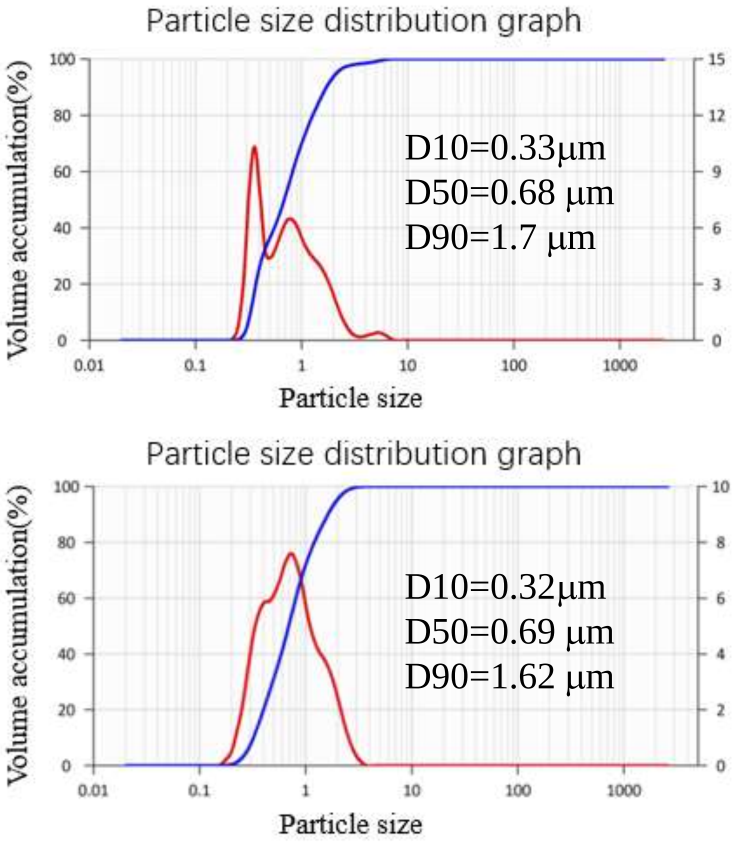


Schematic of the charging and discharging mechanism of a lithium-ion battery[1]



SEM image of $LiFePO_4$

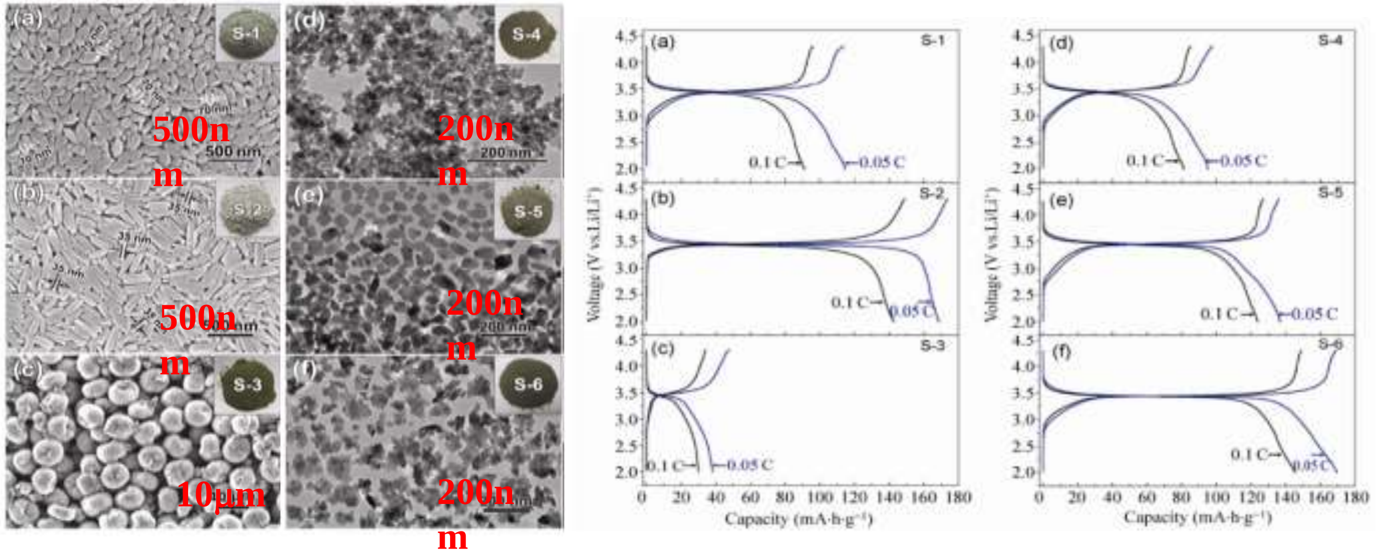
Particle size characterization of two types of $LiFePO_4$ powder materials produced by different manufacturers



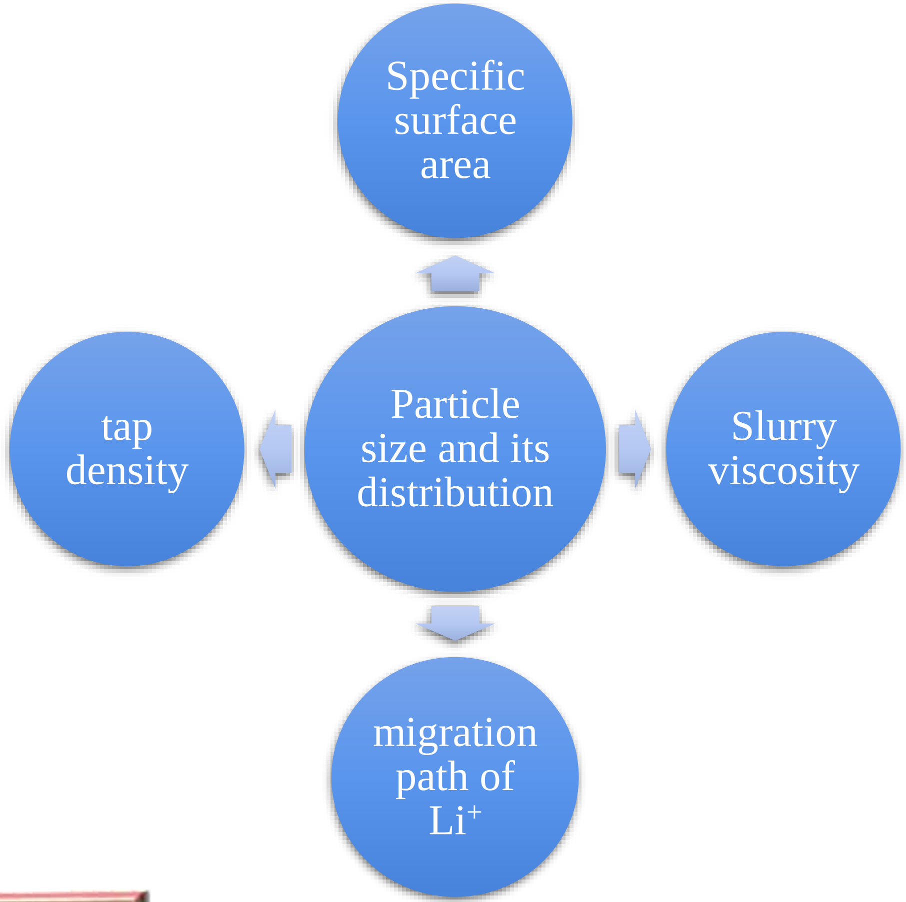
[1] Kanungo S, et al. Nanomaterials, 2022, 12(19): 3266.

3.3 Battery

(2) LiFePO4 measurement



indicating that particle size and shape have a significant impact on the electrochemical performance of $LiFePO_4$.



Problems

Low material energy density

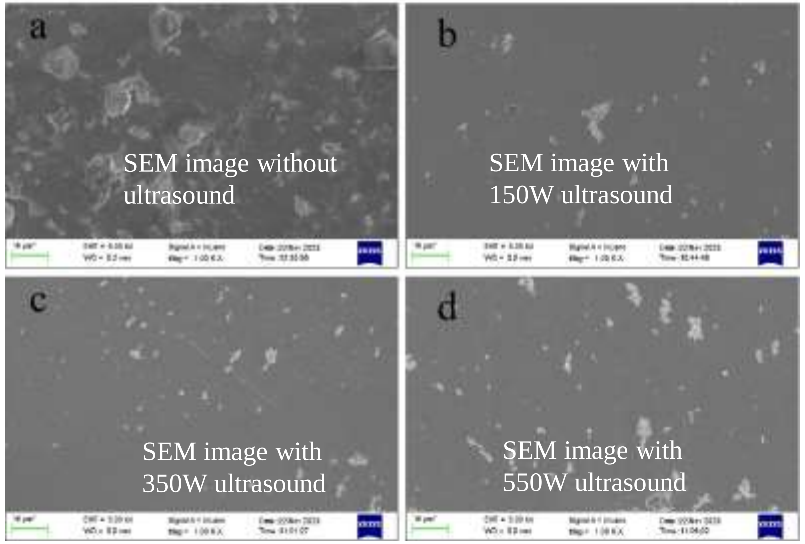
Slow charging speed

Nan C,et al. Nano Research, 2013, 6: 469-477.

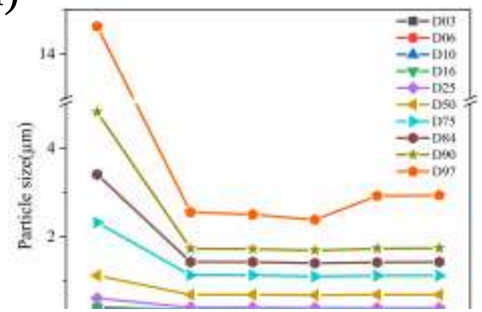
3.3 Battery

中国计量科学研究院
National Institute of Metrology,China

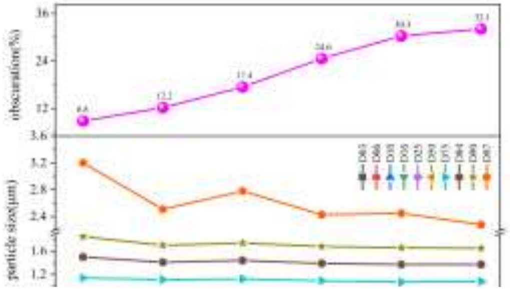
(2) LiFePO4 measurement



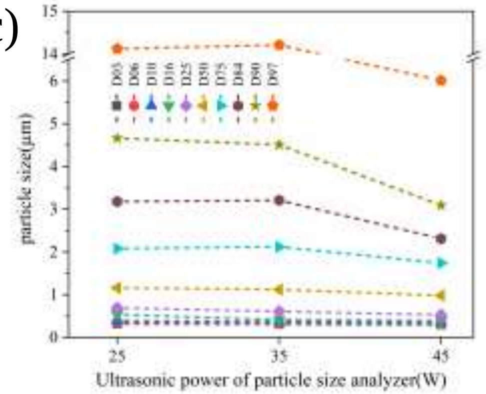
(a)



(b)

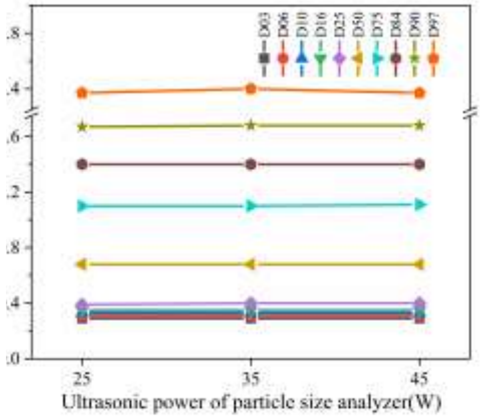


(c)



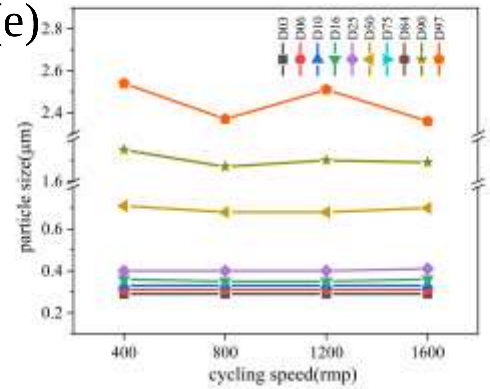
without high-power ultrasound by ultrasonic processor

(d)



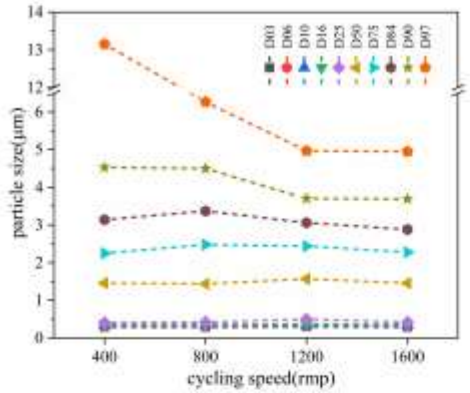
with high-power ultrasound by ultrasonic processor

(e)



without high-power ultrasound by ultrasonic processor

(f)



with high-power ultrasound by ultrasonic processor

The test factors of laser particle size analyzer were investigated as shown in the figure above.

3.3 Battery

National Institute of Metrology,China

(2) LiFePO4 measurement

Next step plan

(1) certified reference materials


TECHNICAL SPECIFICATION

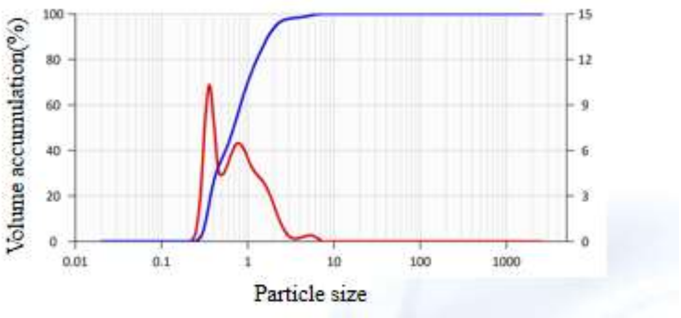
ISO/TS 14411-1

Preparation of particulate reference materials —

Part 1:

Polydisperse material based on picket fence of monodisperse spherical particles

Particle size distribution graph of dynanonic $LiFePO_4$



We are Planning to prepare a polydisperse certified reference materials based on the particle size distribution diagram of dynanonic $LiFePO_4$.

(2) Establishing the National Standards:

Nanotechnology - Measurement of polydisperse particle size and distribution of lithium iron phosphate micro-nano particles- Laser diffraction methods

(3) Carrying out metrological comparison cooperation

Number	Organization Name	Appointment position	Secretariat	secretary /assistant
1	APMP/TCMM	chairman	Ren Lingling	Pu Cheng
2	VAMAS/TWA41	co-chairman	Ren Lingling	Pu Cheng
3	CCQM/SAWG	representative	Yao Yaxuan	
4	VAMAS	commissioner	Ren Lingling	
5	China Standard Materials Committee	commissioner	Ren Lingling	
6	CSTM/FC00	secretary general	Ren Lingling	LiShuo
7	Chinese New Materials and Nanometric Technology committee	secretary general	Ren Lingling	JingSenling
8	SAC/TC279	commissioner	Ren Lingling	
9	SAC/TC279/sc1	commissioner	Ren Lingling	
10	CSTM/FC00	commissioner	LiShuo	
11	CSTM/FC56	commissioner	LiShuo	

4 Summary

- China's Carbon Peaking and Carbon Neutrality Goals
- Transportation is one of the most concerned area.
- NIM focuses on measurement for new energy vehicles, including standard and regulations, traceability, calibrators, novel techniques.
- The amount of new energy vehicles has a rapid growing trend. We need to prepare for it as soon as possible.

Happy World Metrology Day