

Public chargers for electric vehicles

April 23, 2010

TEPCO

How to resolve trade-off problem of battery cost and driving range

Lessons and learns from EV in 1990's



Cost \$100,000

Price \$ 50,000

Driving Range 100~120km

Weight 1,550kg

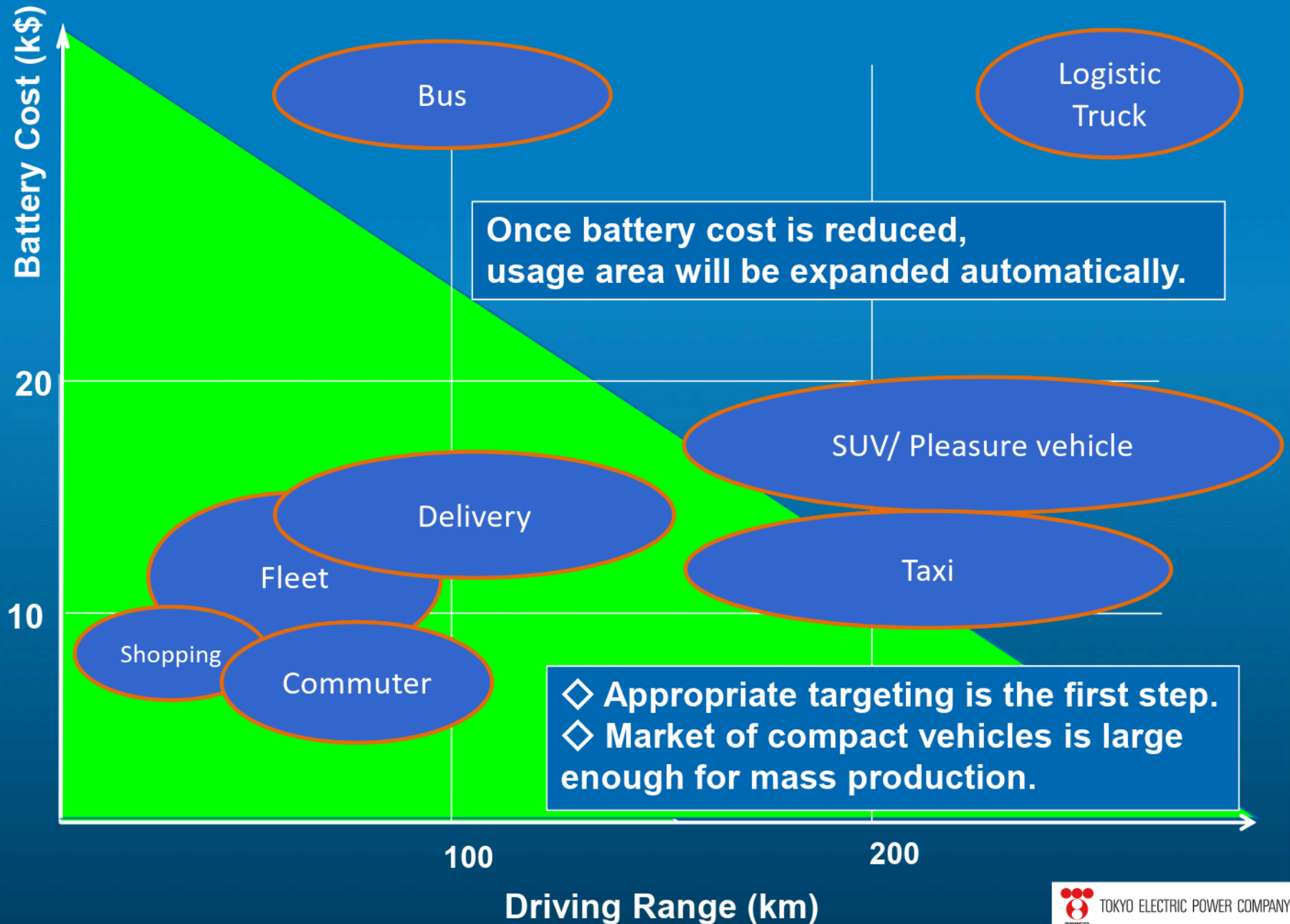
Battery type NMH

Battery weight 450kg

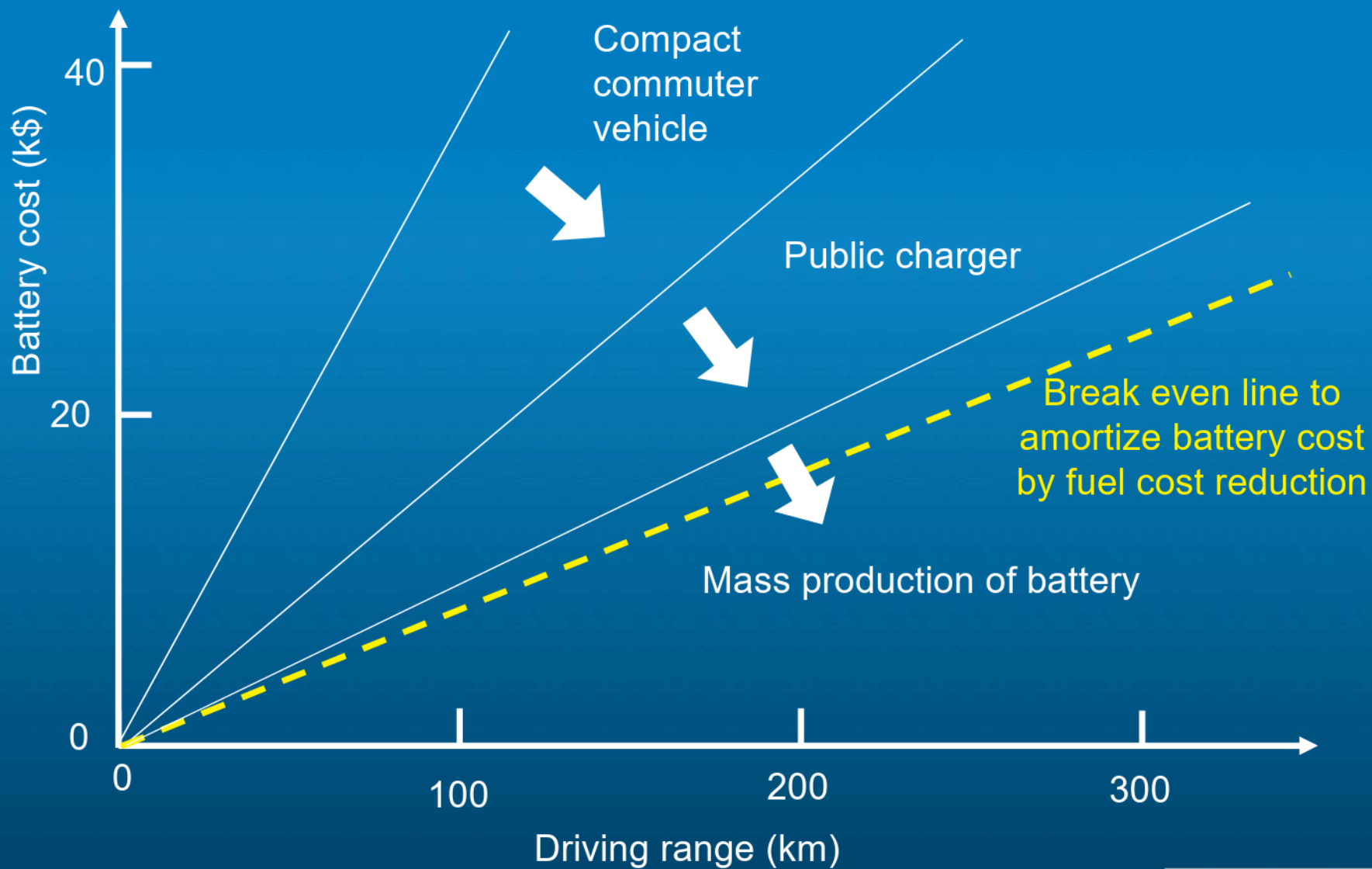
Bad news: Battery cost was extremely expensive then the vehicle cost was higher than the its price.

Good news: TEPCO employees were satisfied with 100km driving range .

Compact vehicle is a good target for initial stage

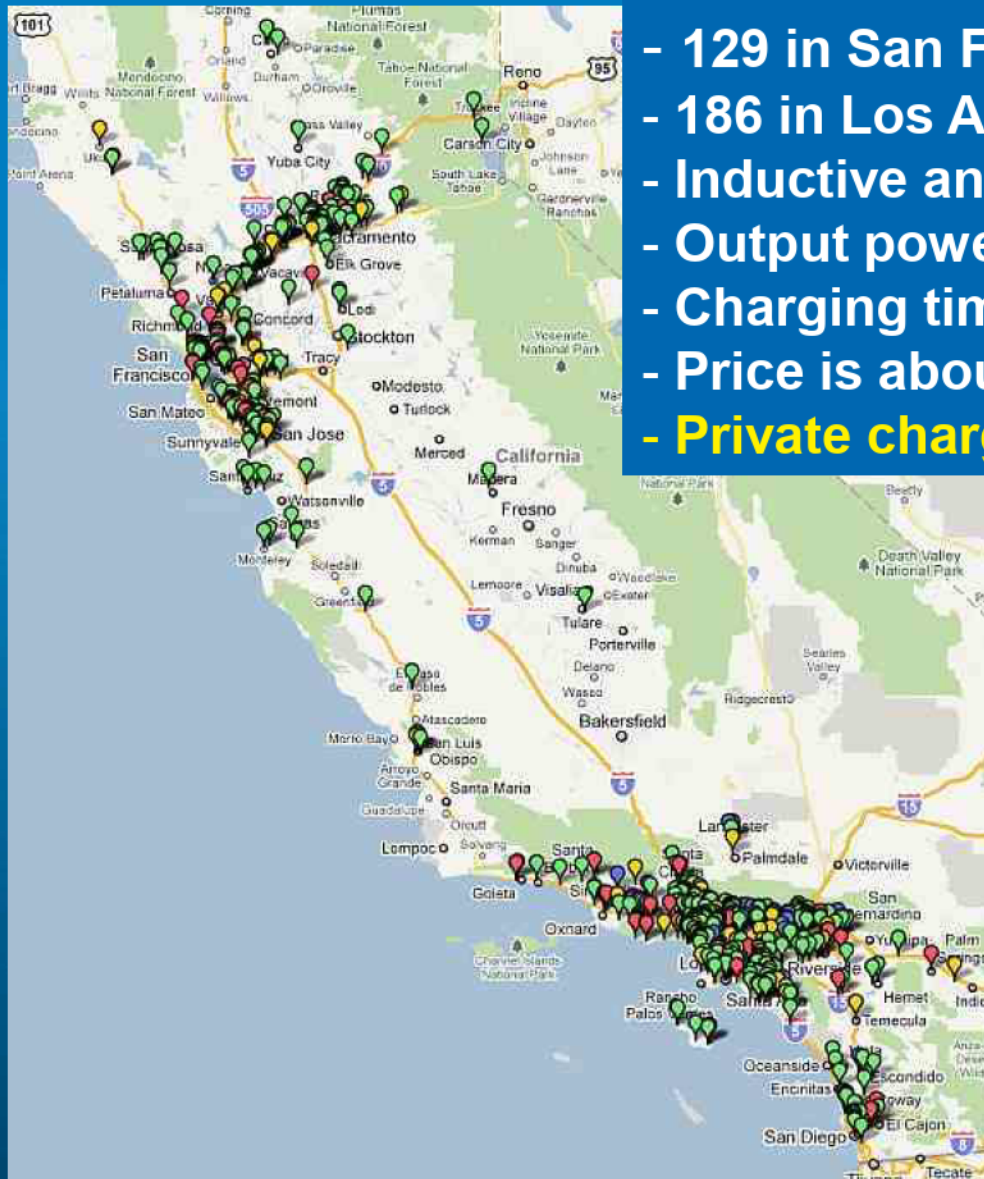


Use public charger to reduce battery amount



Findings from 1990's public chargers

Public charging stations in California



- 129 in San Francisco and Bay Area
- 186 in Los Angeles County
- Inductive and conductive are mixed
- Output power is around 5kW
- Charging time is around 2hrs for 70km
- Price is about \$3,000 without installation cost.
- **Private charger design is same of public one.**



Inductive



Conductive

Charging stations in San Francisco

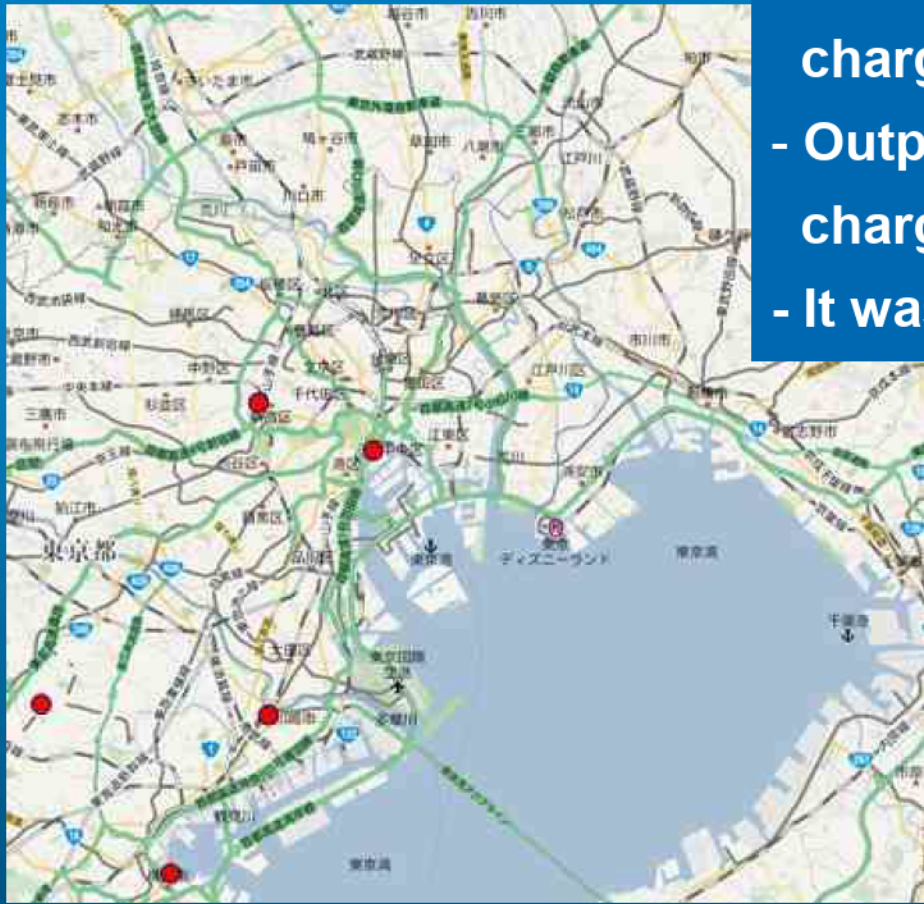


5km

- City of San Francisco is one of the most concentrated areas of public chargers.
- Less than one charging station in one square km.
- It is difficult to find a charging station near the place where drive wants to park.

Charging station in Greater Tokyo area

- In 1990's, there were only 6 inductive charging stations in Greater Tokyo area.
- Output power was around 2.5kW and charging time was around 4hrs for 70km.
- It was **intolerable waiting time.**



50km



Quick charger is suitable for public use

↑ Fast
Charging Speed

Cost is important for private and office use since number of equipments should be same of number of vehicles.



Charging speed should be fast enough.

← Private → Location → Public

Private

Public



Home

Office

Slow

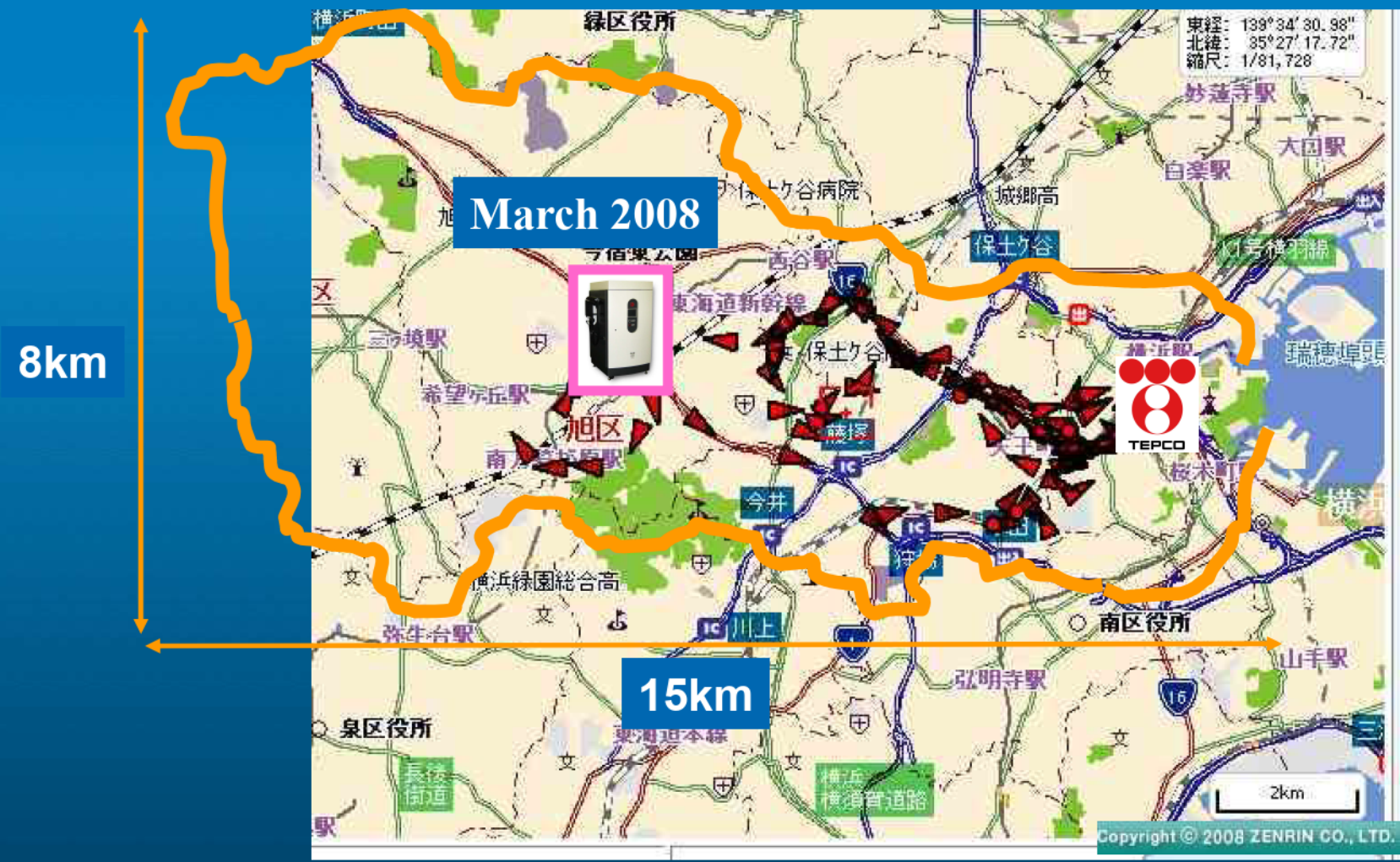


People don't use slow charging station in public.

Findings from experimental EV implementation to TEPCO branch office in 2007~2008

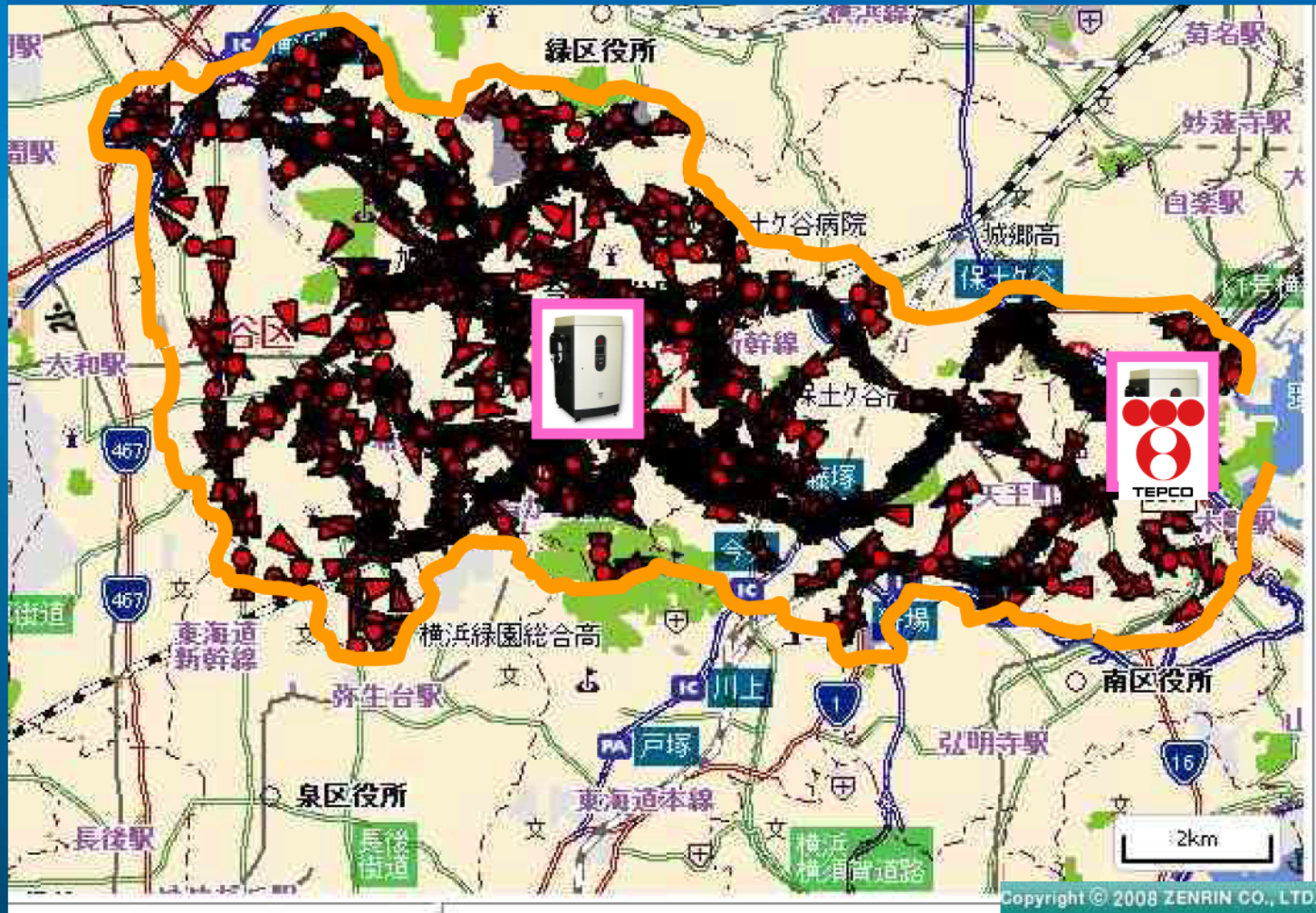
Before quick charger installation (October 2007)

Drive mileage in October 2007 was 203km.
Driver understood EV performance but they were reluctant to use it.



After quick charger installation (July 2008)

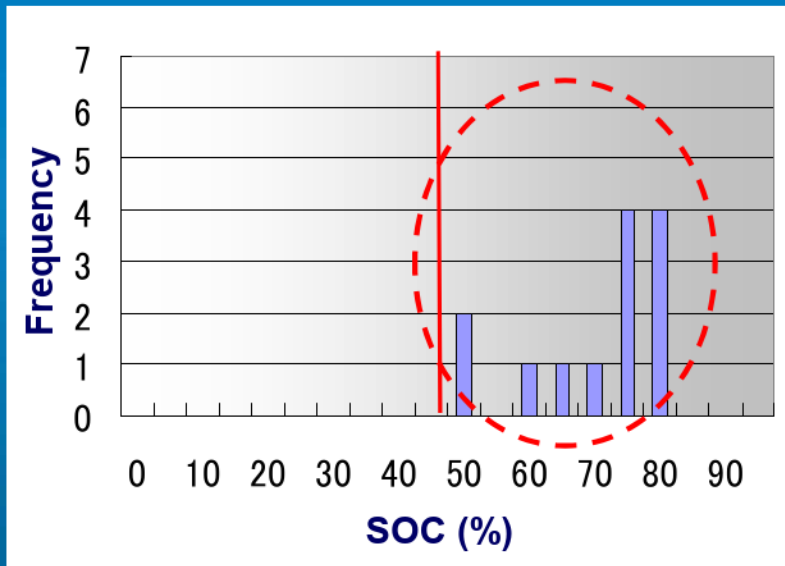
Drive mileage in July 2008 was drastically increase to 1472km. Quick charger removes drivers range anxiety effectively.



Quick charger extracts battery performance

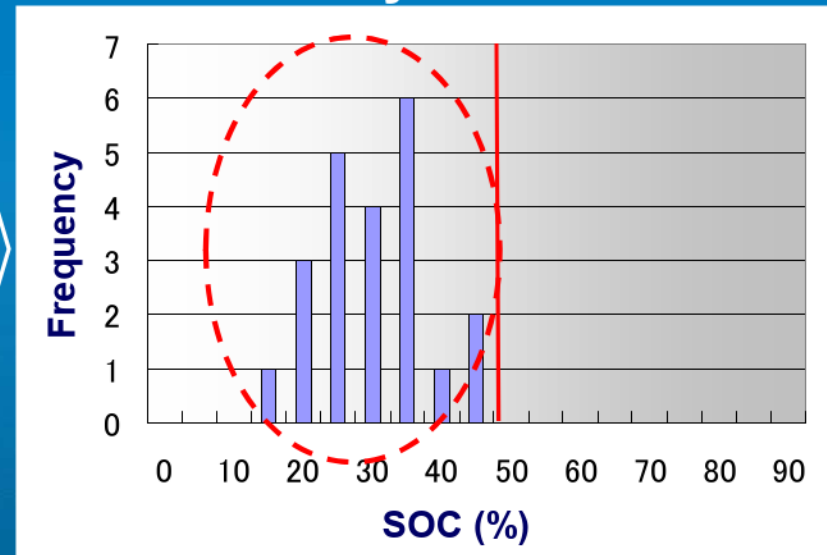
SOC distribution when EV came back to the office

October 2007



After
Quick
Charger
located

July 2008



Battery SOC were higher than 50%

Battery SOC were less than 50%

- Drivers feel easy because they can recharge whenever they need.
- Drivers use quick charger **only few times** and use electricity in the battery.

Basic strategy to expand EV market

Compact EV and public quick charger

Current circumstance

100km driving range means ~ \$15,000 battery cost.
How to minimize the on-board battery is key issue.

Strategy for the first step

1. **Target on compact commuter vehicles** in early stage of market penetration.
2. **Deploy public quick chargers** to remove drivers range anxiety.

Necessary number of quick chargers is small because drivers use normal charging usually.

Specifications of new electric vehicles

			
Name	Plug in Stella	iMiEV	Leaf
Maker	Subaru	Mitsubishi Motors	Nissan
Passengers	4	4	5
Weight [kg]	870	1,080	-
Driving range [km]	80	120	(160 in test mode)
Battery [kWh]	9.2	16	24
Charging Method	AC 1φ : 100~230V DC: 400V 125A 5min for 40km 10min for 60km	AC 1φ : 100~230V DC: 370V 125A 15min for 60km 30min for 100km	AC 1φ : 100~230V DC: 400V 125A

Several charger makers have started production

					
Hasetec	Takaoka	Takasago	Nittetsu Elex	Kyuki	ABB
\$35,000	\$35,000	\$35,000	\$35,000	\$44,000	—

Installation cost is approximately \$20,000.

5 makers had already started sales and more makers will join soon.

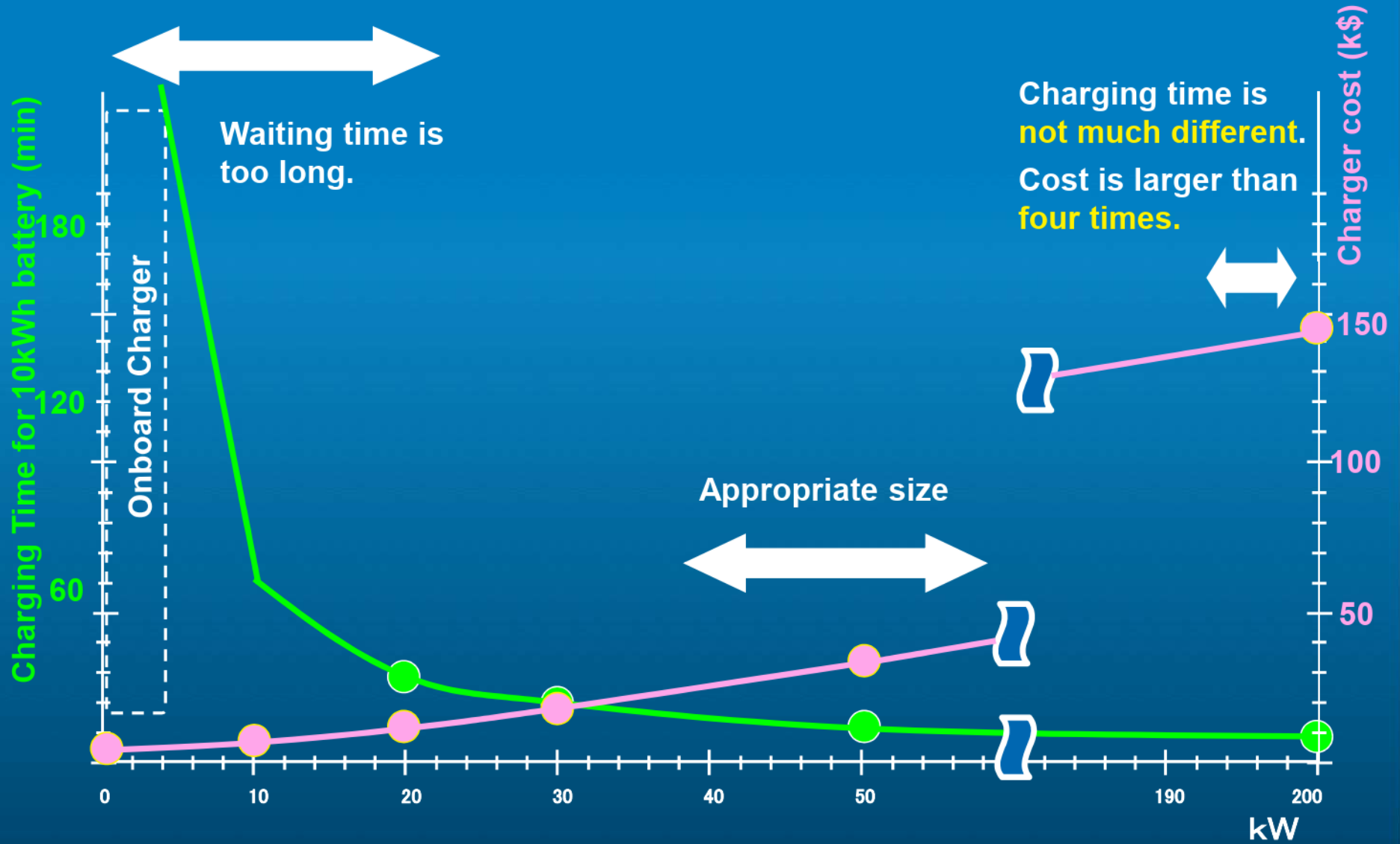
Real price is \$15,000 ~ \$25,000 in 2010.

How much kW is good for public charger?

How much kW is suitable for public quick charger?

- Public chargers are for commuter passenger vehicles.
Not for super EV which can drive 400km in one charge.
Not for big truck and heavy bus which is more than 10t.
- Passenger Vehicles (1t)
Battery size is around **20kW** for 140km driving range .
50kW charger can supply 60km driving electricity in **10min**.
- Truck and Bus (10t)
Battery size is more than **130kWh** for 100km driving EV.
400kW charger is necessary to recharge battery within 20min.
- Super EV (Driving range is 400km)
Battery size is more than **50kWh**.
200kW charger is necessary to recharge battery in **15min**.

Cost/Benefit of charging infrastructure



Specification of developed quick charger



Specifications

- Type: Switching type
constant current power supply
- Input: 3-phase 200V (200~430V)
- Output power: 50kW (10~100kW)
- Maximum DC output Voltage: 500V
- Output current: 125A (20~200A)

Target charging time

- 5 minutes for 40km driving range
- 10 minutes for 60km driving range
- Depend on battery performance

Price \$20,000~\$25,000

Characteristics of CHAdeMO charger

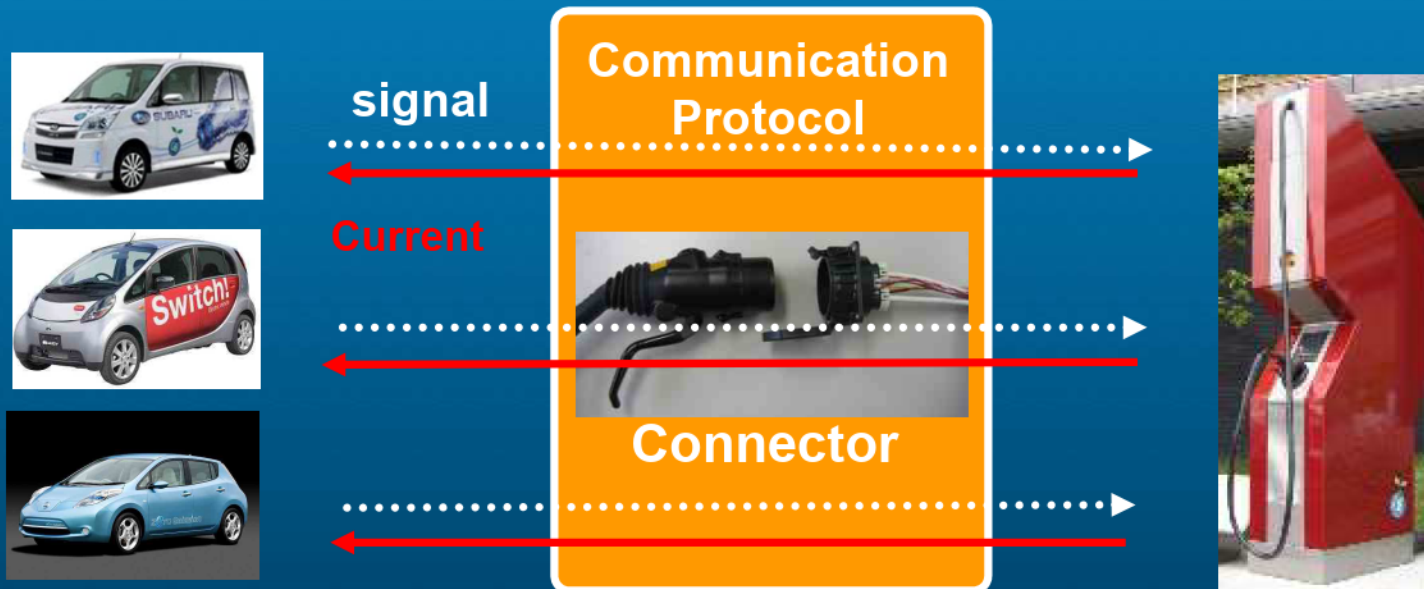
What is CHAdeMO protocol?

<Problem>

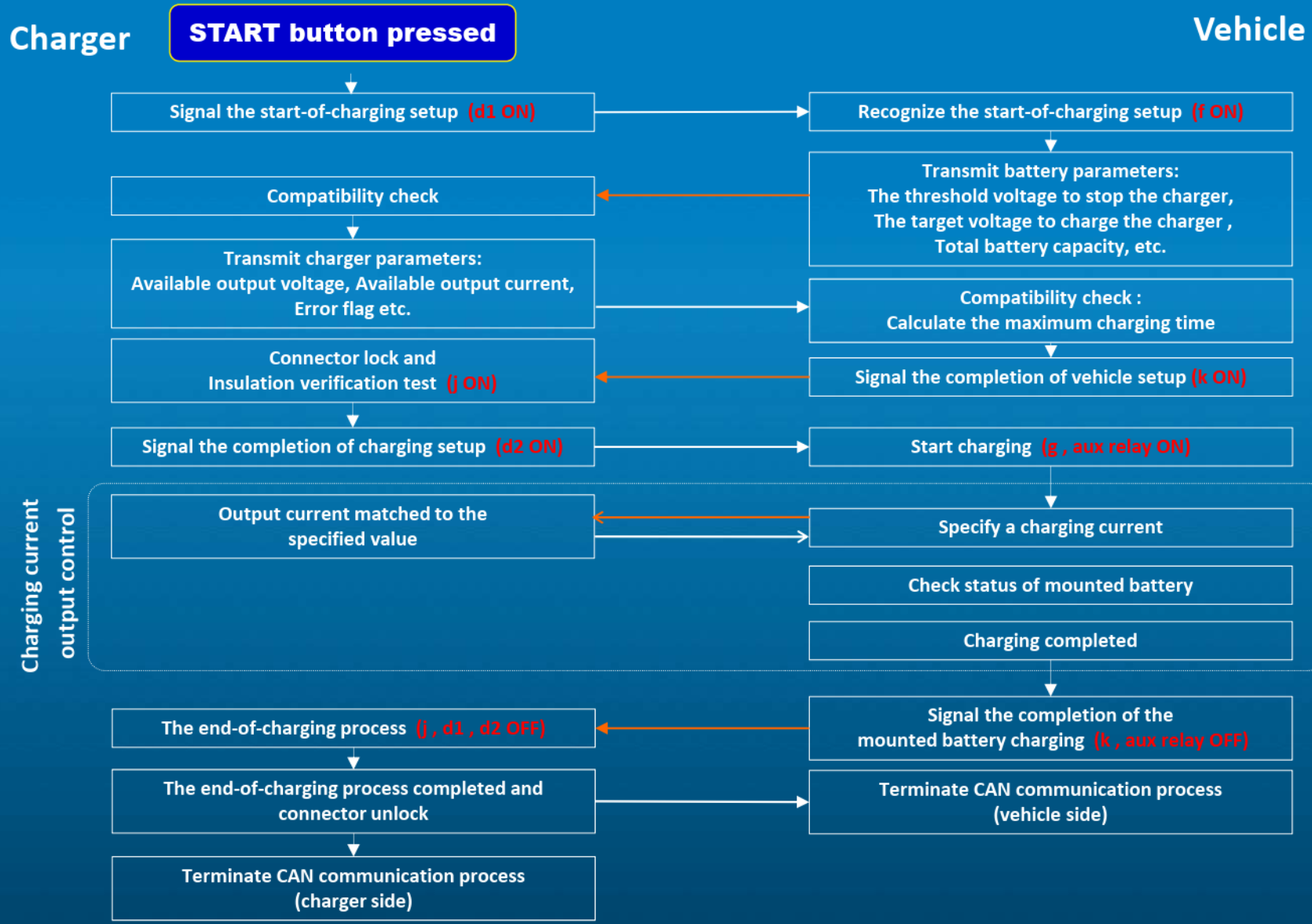
- Optimal charging pattern depends on **battery characteristics and condition**.
- Standardization may disturb battery improvement.

<Solution>

- **EV computer decides** optimal charging current base on its battery condition.
- Charger supplies DC current following order from EV computer.



Charging sequence flowchart



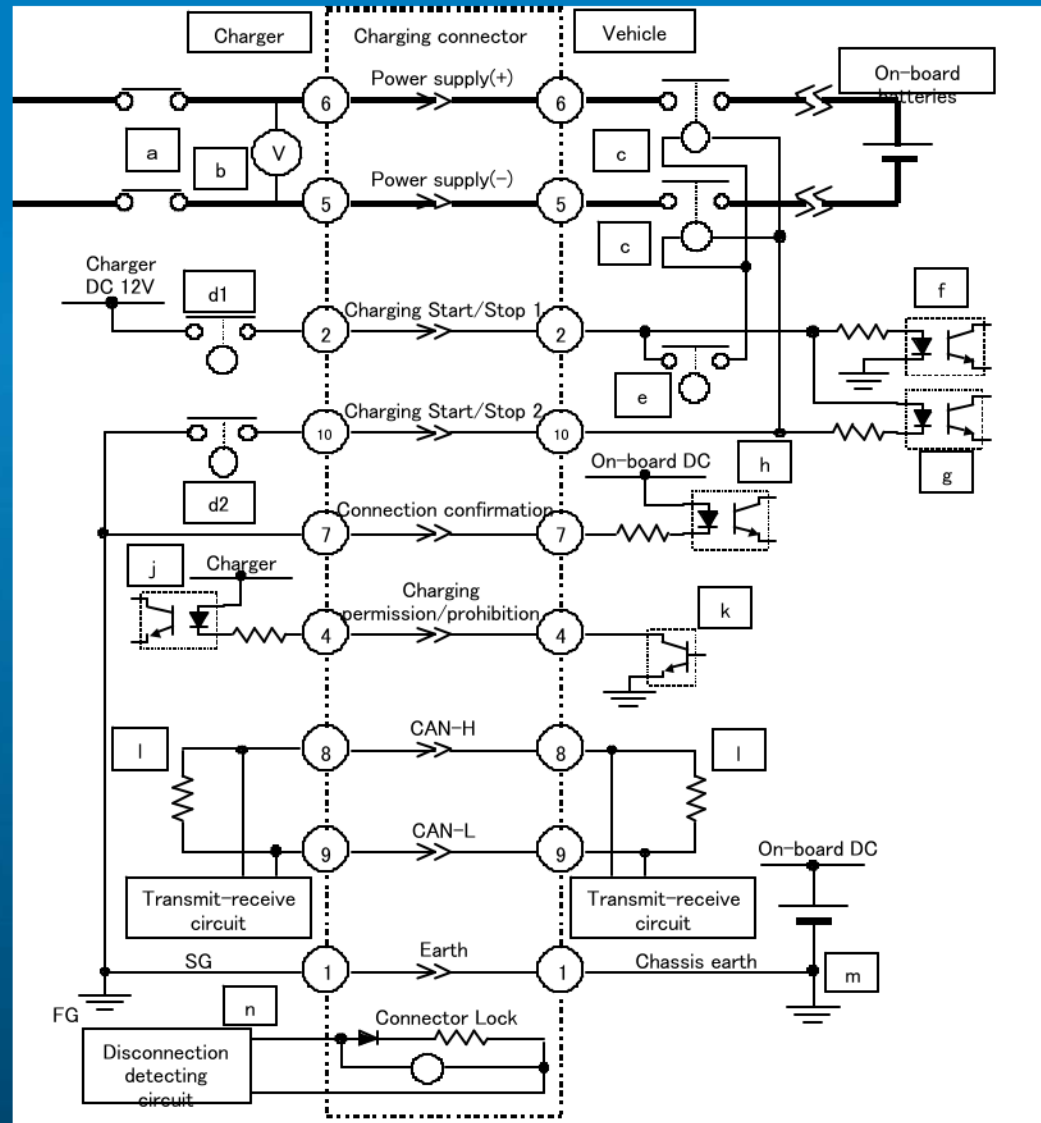
Vehicle and charger interface circuits

Main DC circuit

Sequence control circuit

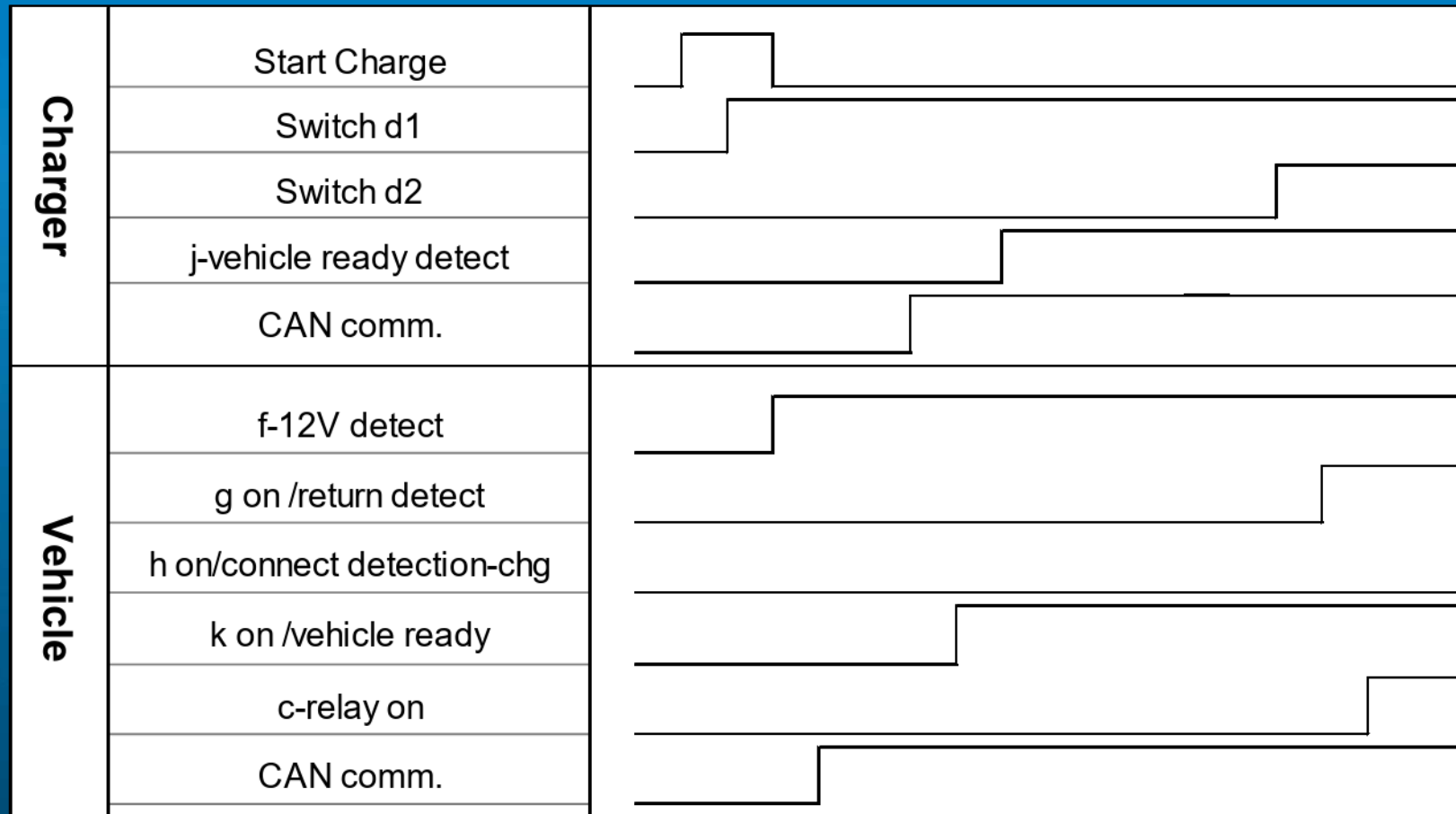
CAN communication bus

Reference GND and Isolation monitoring line



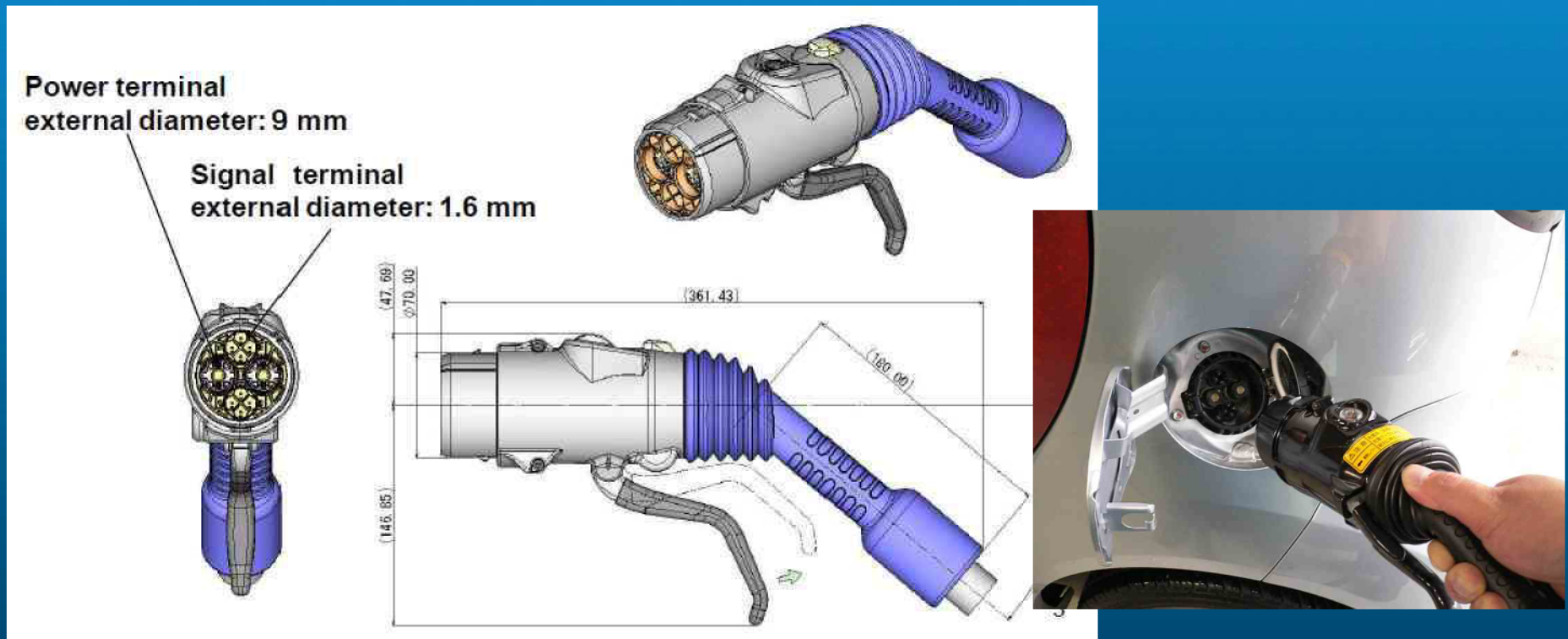
Definition of Control / Comm. Sequence & Timing

Ex.) Charging preparation process

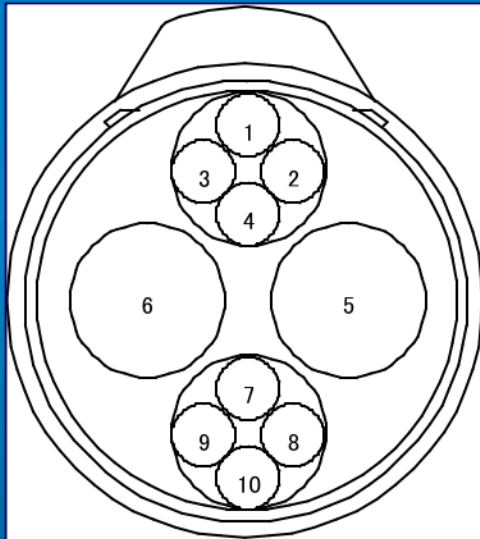


CHAdeMO proposing DC Connector

- Maximum current: 200A
- Getting feedback from field use, the design is improving.
- Detail dimension of interface geometry is open to public, then any maker can fabricate compatible connector.



Connector pin-layout and assignment



Connector surface

Pin No.	function / assignment	Pin diameter (mm)	Wire size (mm ²)
1	Reference GND for insulation monitor	1.6	0.75
2	Control EV relay (1 of 2)	1.6	0.75
3	(not assigned)	1.6	—
4	Ready to charge control	1.6	0.75
5	Power (supply) line-negative	9.0	150A: 42.4 200A: 53.5
6	Power (supply) line-positive	9.0	150A: 42.4 200A: 53.5
7	Proximity detection	1.6	0.75
8	Communication +	1.6	0.75
9	Communication -	1.6	0.75
10	Control EV relay (2 of 2)	1.6	0.75

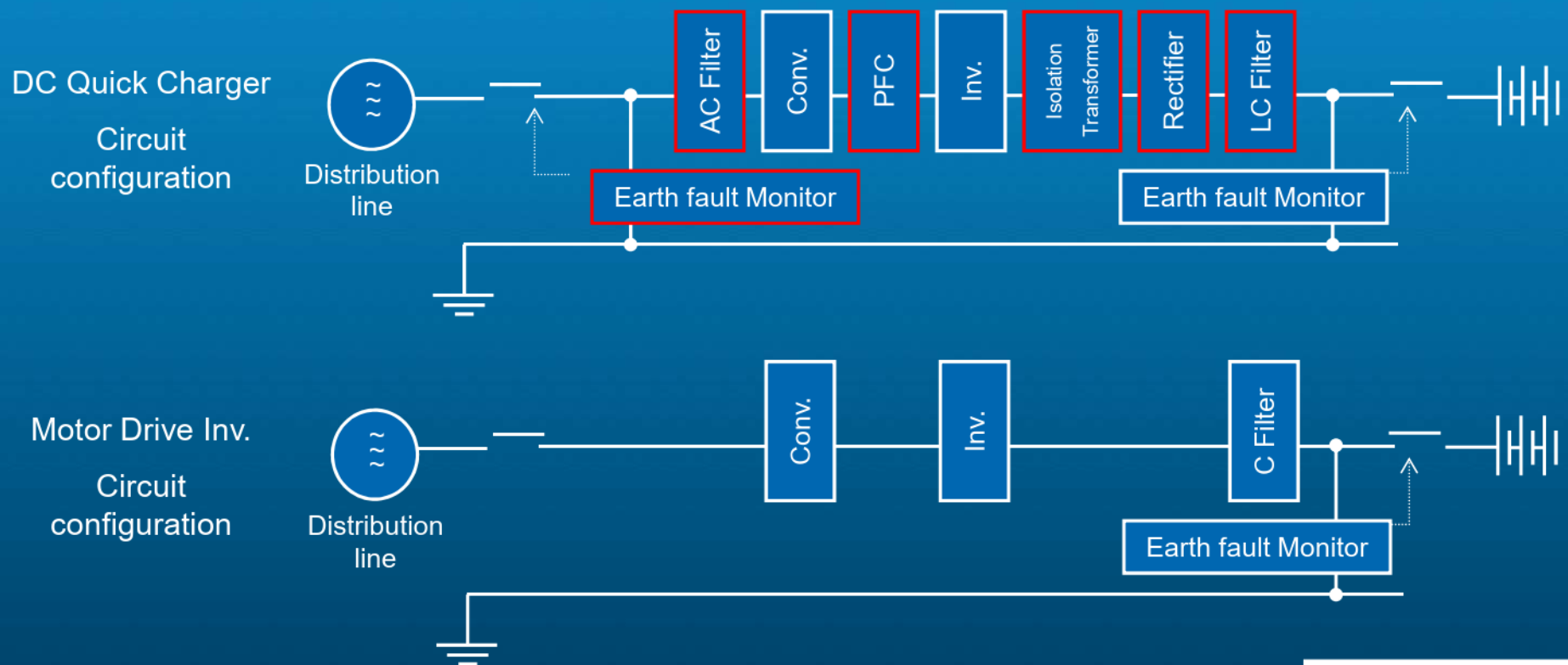
Comparison with other proposal

DC off board charger vs. Motor drive inverter



DC off board charger vs. Motor drive inverter

Element	Objectives	QC	MDI
AC Filter	Protect distribution line from higher harmonics distortion.	○	×
PFC	Conversion efficiency improvement.	○	×
Isolation Transformer	Operator and battery protection.	○	×
LC filter	Battery protection by getting rid of ripple from output current.	○	×
Ground fault monitor	The user is protected from the electric shock.	○	△



DC off board charger vs. Motor drive inverter

DC Off board Charger



On board
Charger

Motor Drive
Inverter

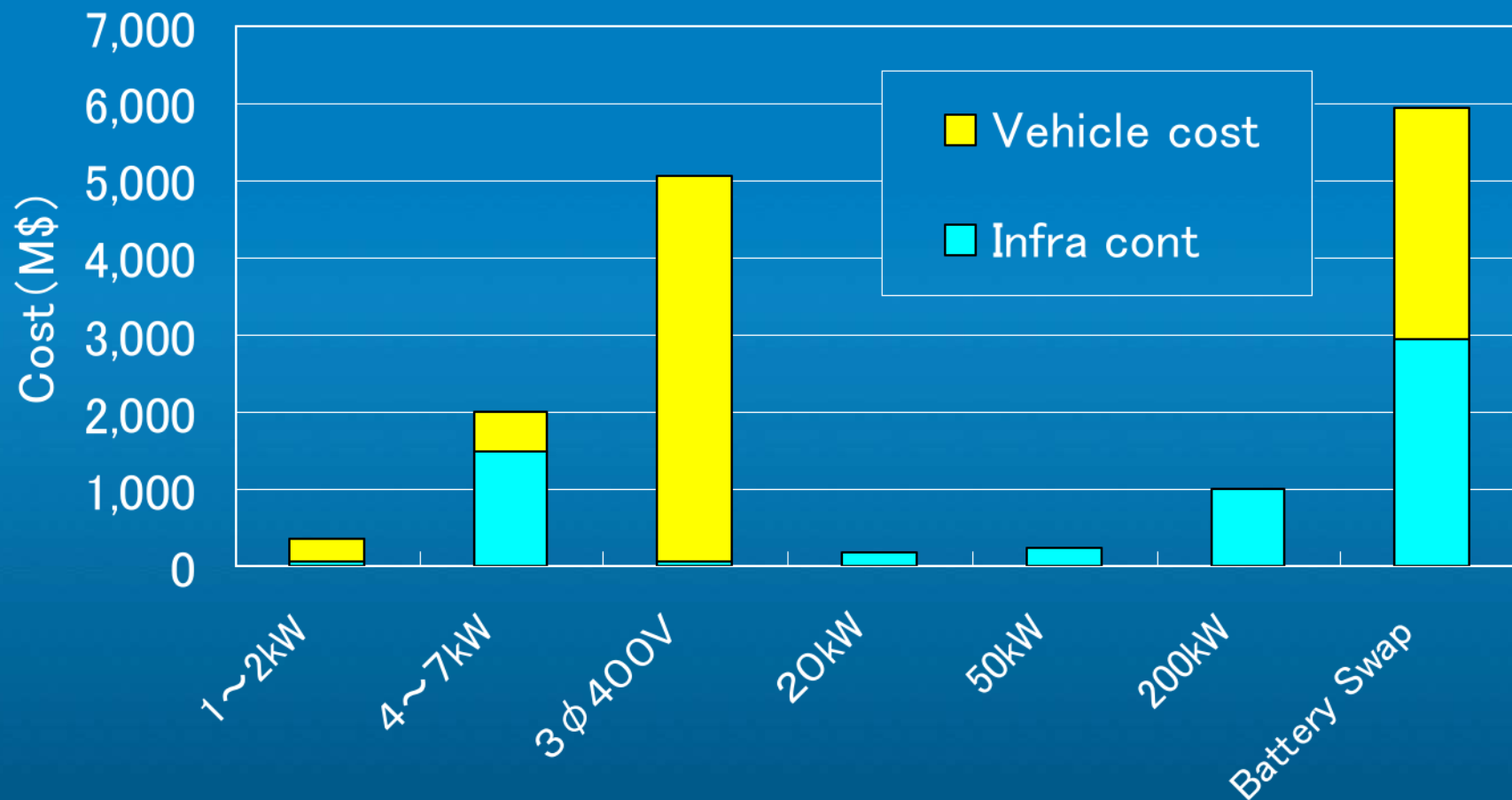


Better Place Model (Battery Exchange)



**Cost of battery exchange system is ~\$500,000.
Battery inventory pushes up total cost.**

Total cost of charging equipments



Charger number

← 100,000 units → ←

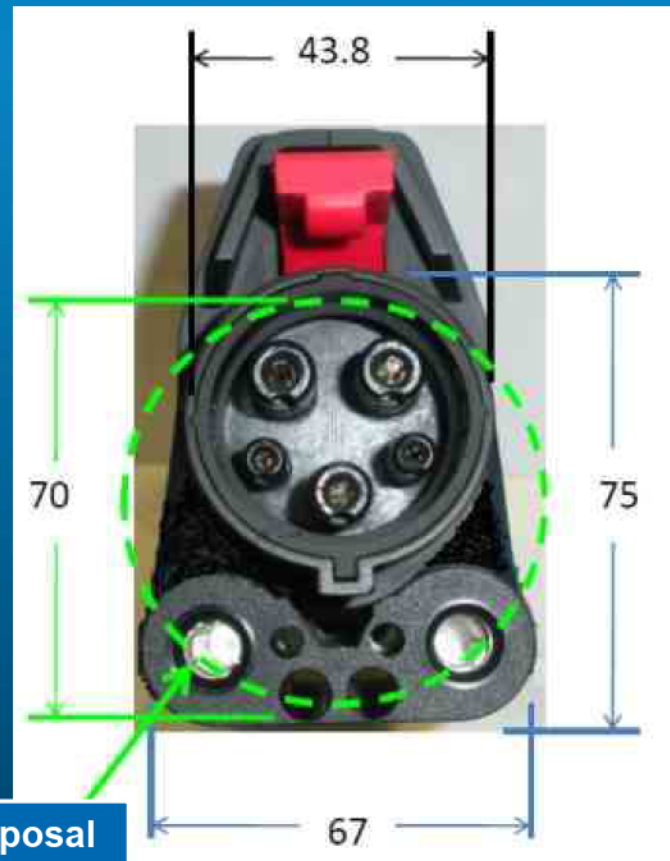
5,000 units

→

Based on million units of EV

Combo Connector

- Combo connector size is bigger than JARI proposed connector. Especially, real size becomes much bigger based on same number of signal lines as JARI proposed connector.
- Combo connector is heavier, then difficult to handle.
- Single trouble of socket disables both AC and DC power supply.



JARI proposal

REMA proposal

Three candidates of AC connector in IEC standard

- There are three different AC connector designs in IEC standard.
- MENNEKES connector is design to supply up to 44kVA



SAE AC standard



MENNEKES



Italy proposal

Who will install quick chargers?

TEPCO branch office



**64 quick chargers are installed.
It will be 100 by the end of 2010.**



**310 EVs are already deployed.
210 EVs will be deployed in 2010.**

Kanagawa prefecture office



Operation started on
June 2008



Shin-Marunouchi Building



Operation started
on September 2008



Operation started
on April 2009



Operation started
on September 2009

AEON shopping mall



Operation started on
September 2008

Public parking lot



Operation started on
October 2008

Metropolitan highway parking area



Operation started on
October 2008

Tokyo University of Marine Science and Technology



Operation started on March 2009

Gas station



Operation started on
March 2009



Operation started on
July 2009

Mitsubishi Motors & Nissan Headquarter



Operation started on
June 2009



Operation started on
August 2009

Location of quick chargers in Japan

184 chargers are in service

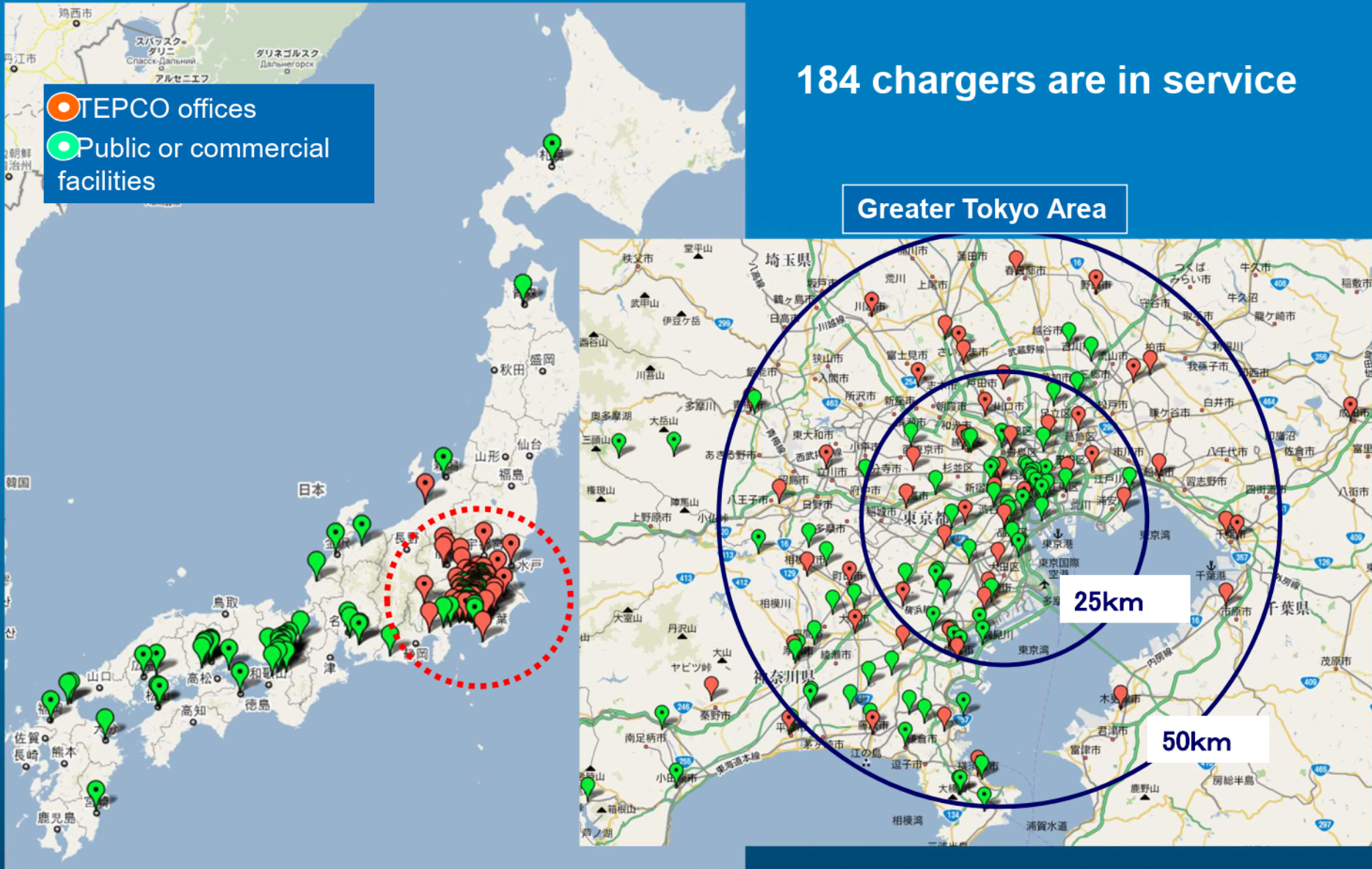
Greater Tokyo Area

25km

50km

1400km

- TEPCO offices
- Public or commercial facilities



Summary

- Home or working place

Normal electrical outlet of AC 100V ~230V

Drivers have enough time for recharging.

Number of charging spots should be more than millions.

It should be easy and cheap infrastructure.

- Public place

DC quick charger

It relieves drivers psychological obstacle.

Mainly it is for emergency and sometime for range extender.

Number of DC charger is small since drivers don't use them often.

CHAdeMO DC charger is currently available safe and reliable design.