Overview of Renewable Energy & Electric Vehicle Development in China




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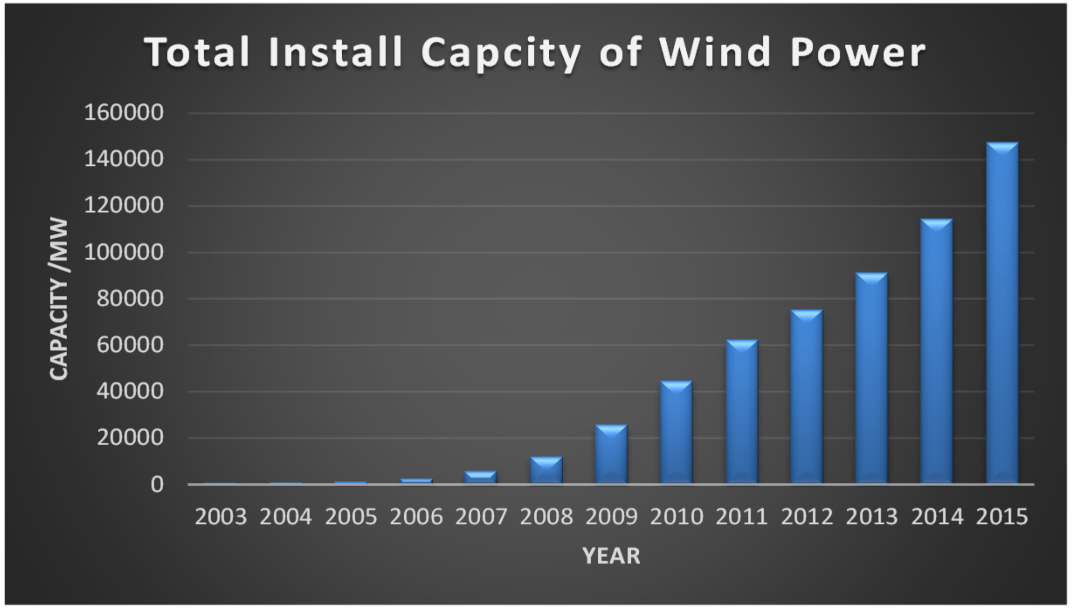
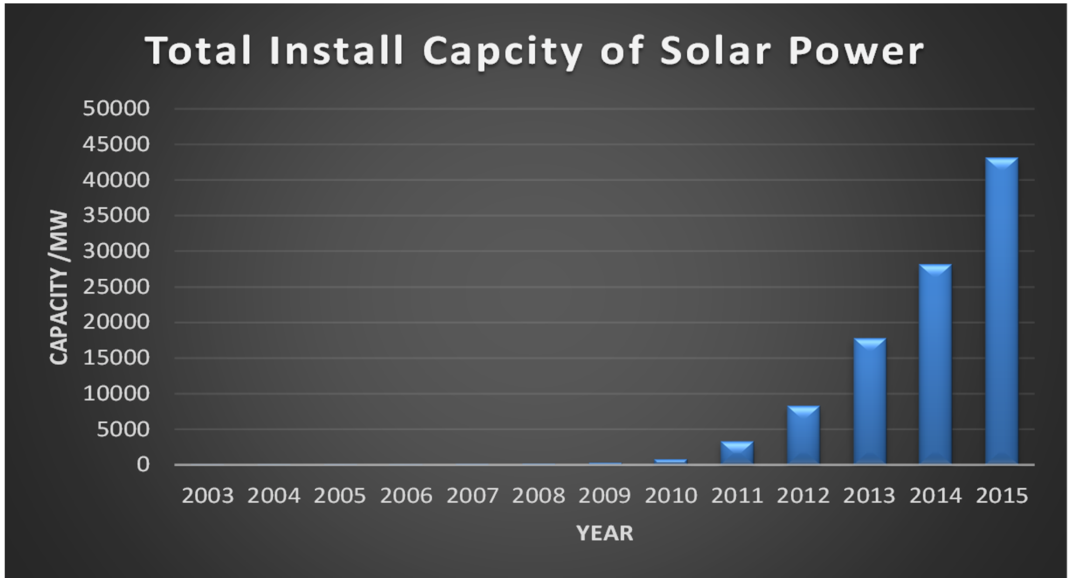
Contents

Contents

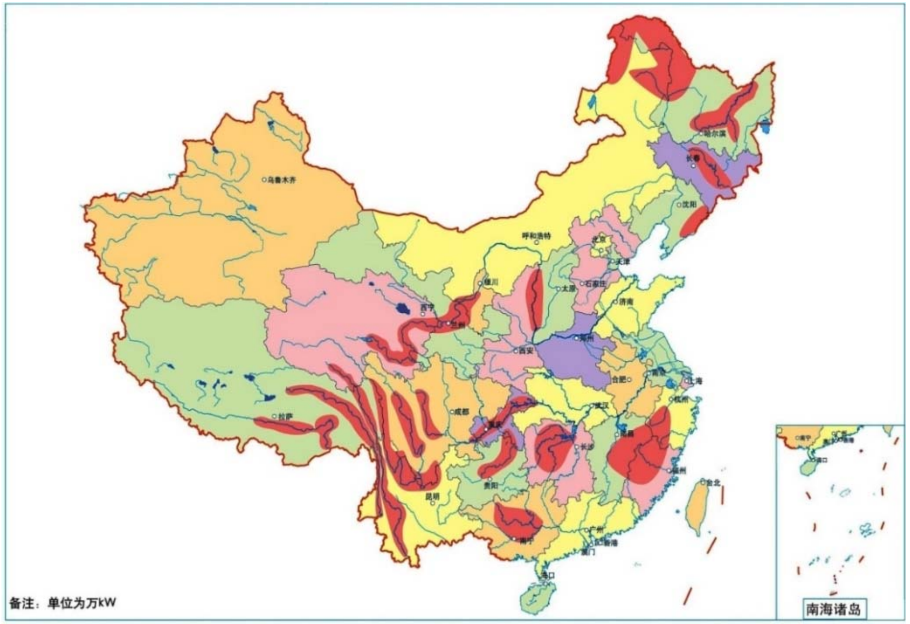
Renewable Power Generation

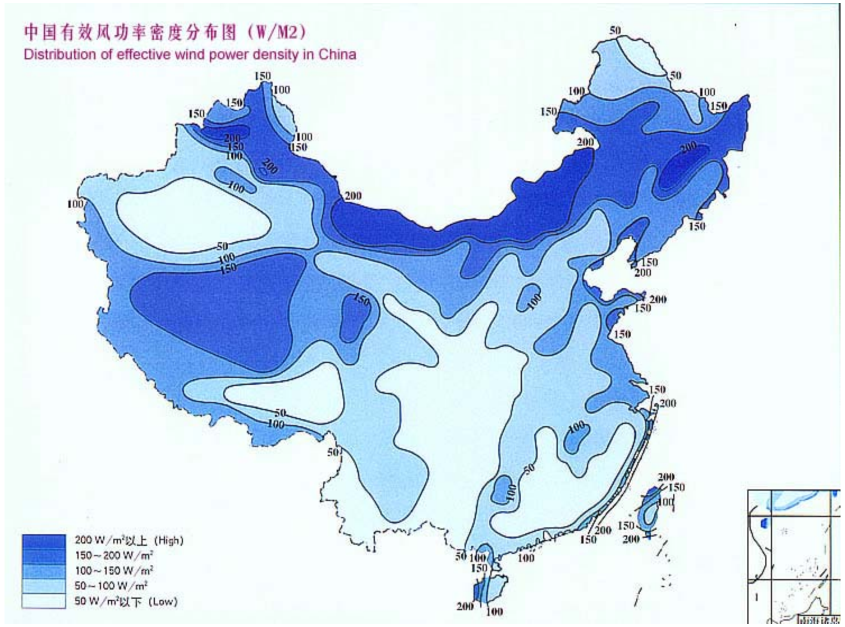




- Installed capacity of wind and solar power generation increased very fast in the past six years
- **Wind power** ranks number one from year 2012
- Installed **solar power capacity** outnumbers Germany from year 2015
- Fast increasing renewable generation poses great challenges to power system operation, especially in the "Three North Parts" of China

Renewable Power Distribution

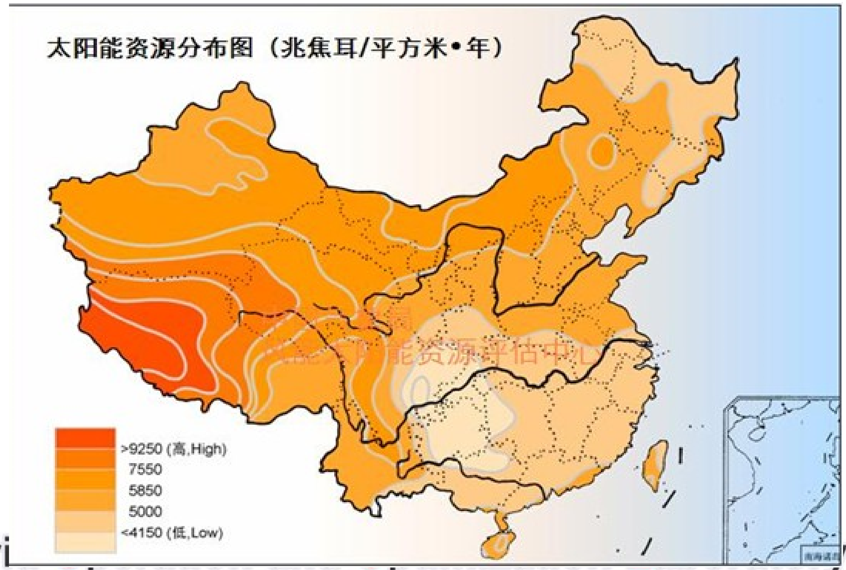




Hydro Power Distribution

Wind Resource Distribution

Solar Radiation Distribution

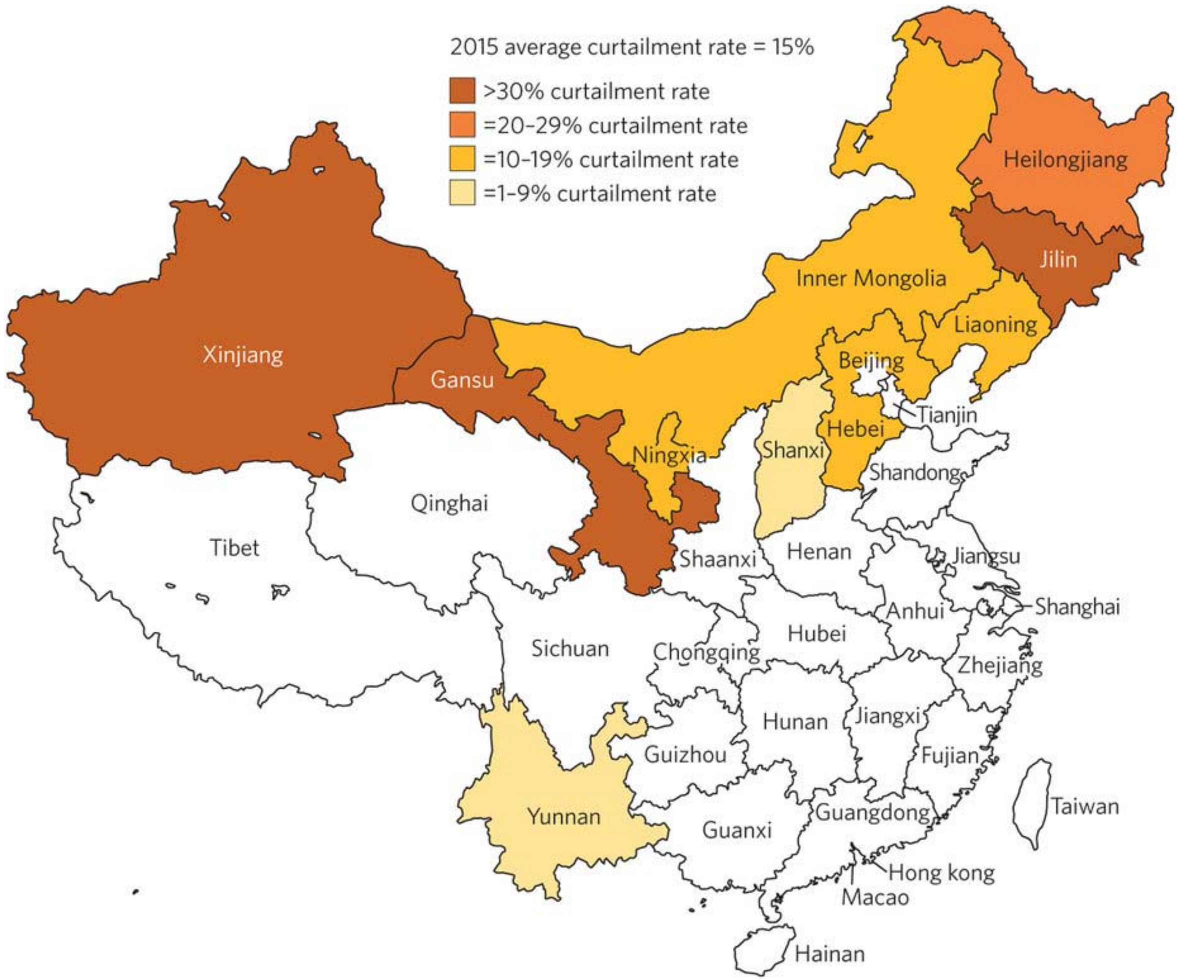


Installed capacity of wind power

Total accumulated installed capacity 2016

Serious wind spillage problem

Year	Curtailment (billion kWh)	Rate (%)
2012	20.8	**17**
2013	15	**11**
2014	13.3	**8.5**
2015	**33.9**	**15**
2016	49.7	**17.1**



Source: http://www.nature.com/articles/nenergy201676/figures/1

Serious wind spillage problem

- Amount of wind energy spilled

Year	2012	2013	2014	2015	2016
Spilled energy (billion kWh)	20.8	15.0	13.3	33.9	49.7
Percentage (%)	17	11	8.5	15	17.1

Wind spillage in several provinces (2016)

Province	Spilled energy (billion kWh)	Percentage （%）
Gansu	10.3	43.1%
Xinjiang	13.7	38.4%
Ningxia	1.9	13.1%
Shaanxi	0.2	6.6%

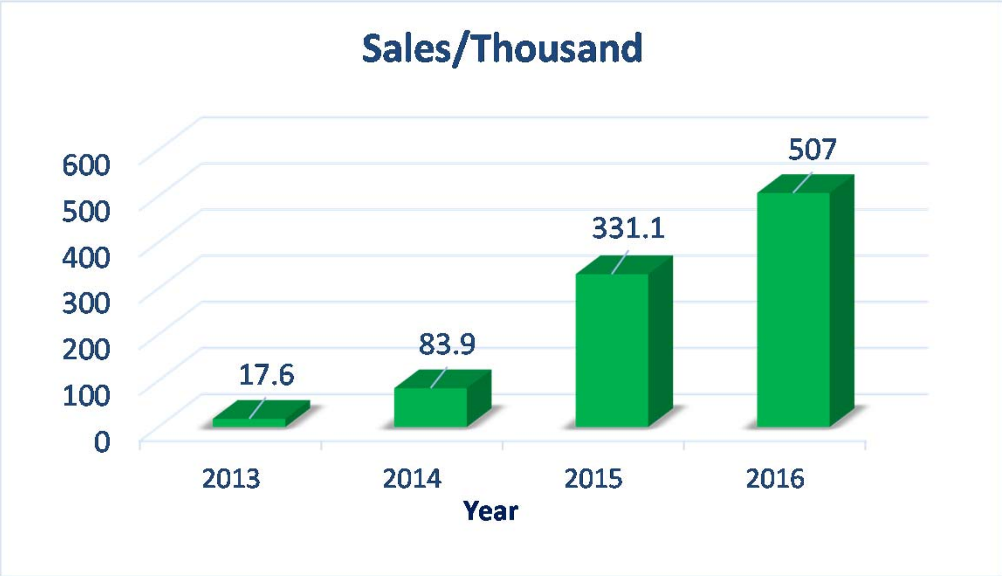
Background for EV development

- Environment
  - Air **pollution** is serious, esp. in big cities
- Energy Security
  - More than half of the oil consumed is **imported**
  - Renewable energy generation
- Auto Industry
  - China is the biggest auto market
  - Promote the implementation of new technology



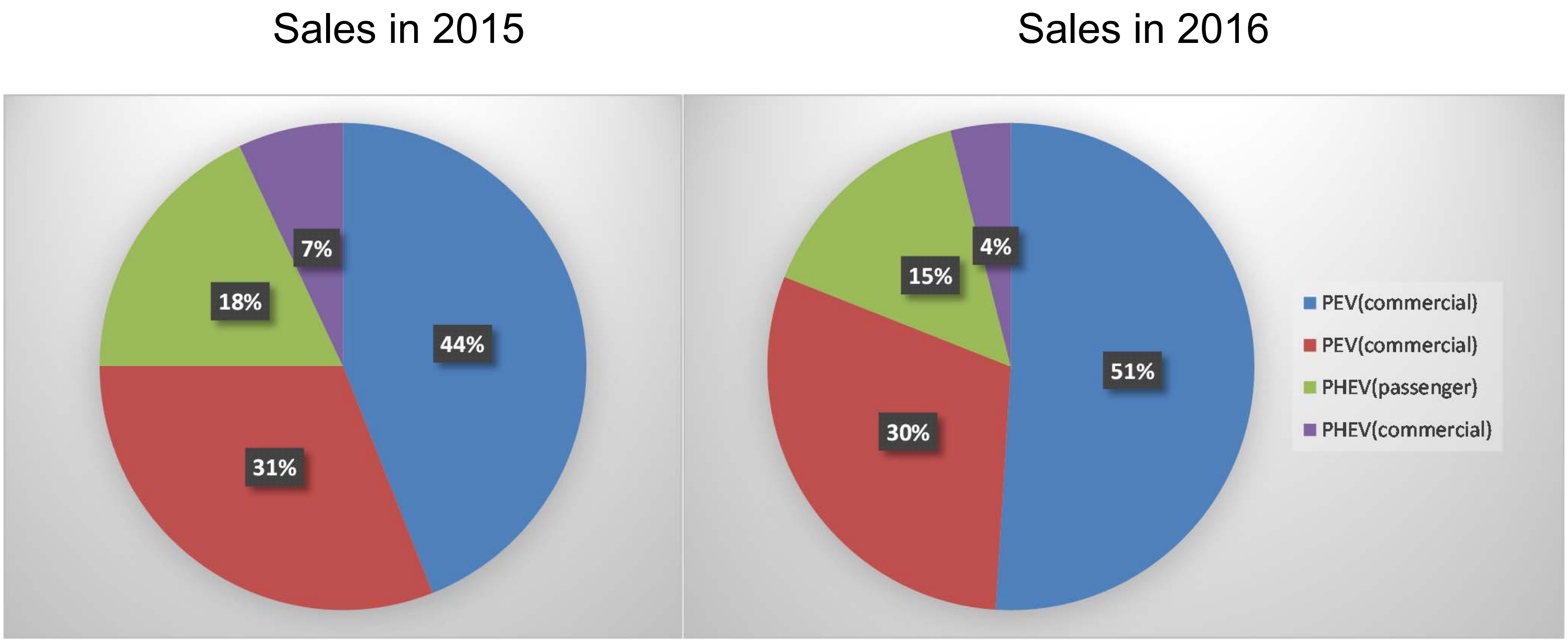
Efforts by Government and Results

- In Nov 2007, NRDC released "rules on the production admission administration of new energy automobiles"
- In Jan 2009, several departments and NRDC launched "Ten Cities and One Thousand EVs" program
- In June 2010, subsidy is provided for private EV buyers.
- In Feb, 2014, Beijing initiated a vehicle plate program for EVs only.
- Over **300%** increase of EV vehicle registration in 2015 compared to 2014.



EV production and sale

Pure EV Passenger car	Sale/thousand
Year 2015	147
Year 2016	263



Source: China Association of Automobile Manufactures

EV Subsidy by Central Government

New Energy EV Subsidy Standard (2013-2020)									
Vehicle type	Range /km	2013	2014	2015	2016	2017	2018	2019	2020
Pure EV	2013-15 (80≤R<150)	3.5	3.325	3.15					
	2016-2020 (100≤R<150)				2.5	**2**	2	**1.5**	1.5
	150≤R<250	5	4.75	4.5	4.5	**3.6**	3.6	**2.7**	2.7
	R≥250	6	5.7	5.4	5.5	**4.4**	4.4	**3.3**	3.3
PHEV	R≥50	3.5	3.325	3.15	3	**2.4**	2.4	**1.8**	1.8
FCEV	-	20	19	18	20	**20**	20	**20**	20

Purchase cost comparison

Cost comparison PHEV, BEV and conventional vehicle in Shanghai 2016

Category	BYD Qin PHEV (NEV >50km range)	BAIC EV200 BEV (NEV >150km range)	Comparable conventional vehicle (BYD F3)
Price before subsidy	209,800 RMB (approx. 31200 USD)	208,900 RMB (approx. 28,000 USD)	65,900 RMB (approx. 9800 USD)
Purchase tax	0	0	3,295RMB
National Subsidy	-24,000 RMB	-36,000 RMB	0
Local Subsidy	-12,000 RMB	-18,000 RMB	0
Number plate auction	0	0	Approx. 84,500 RMB
Total customer costs (after benefits)	**173,800 RMB (approx. 25800 USD**	**154,900 RMB (approx. 23100 USD)**	**153,695 RMB (approx. 23,000 USD)**

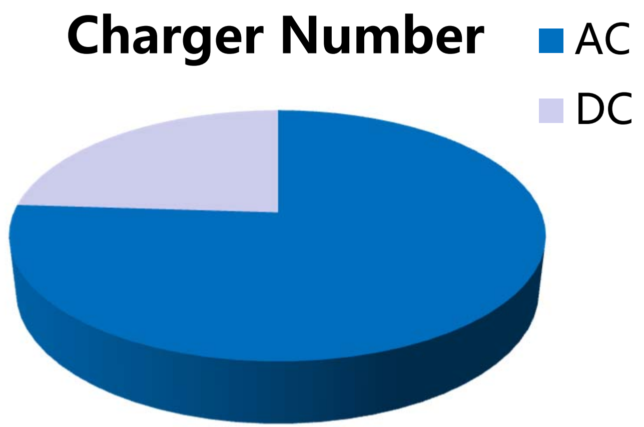
(Exchange rate RMB/EUR=0.136)

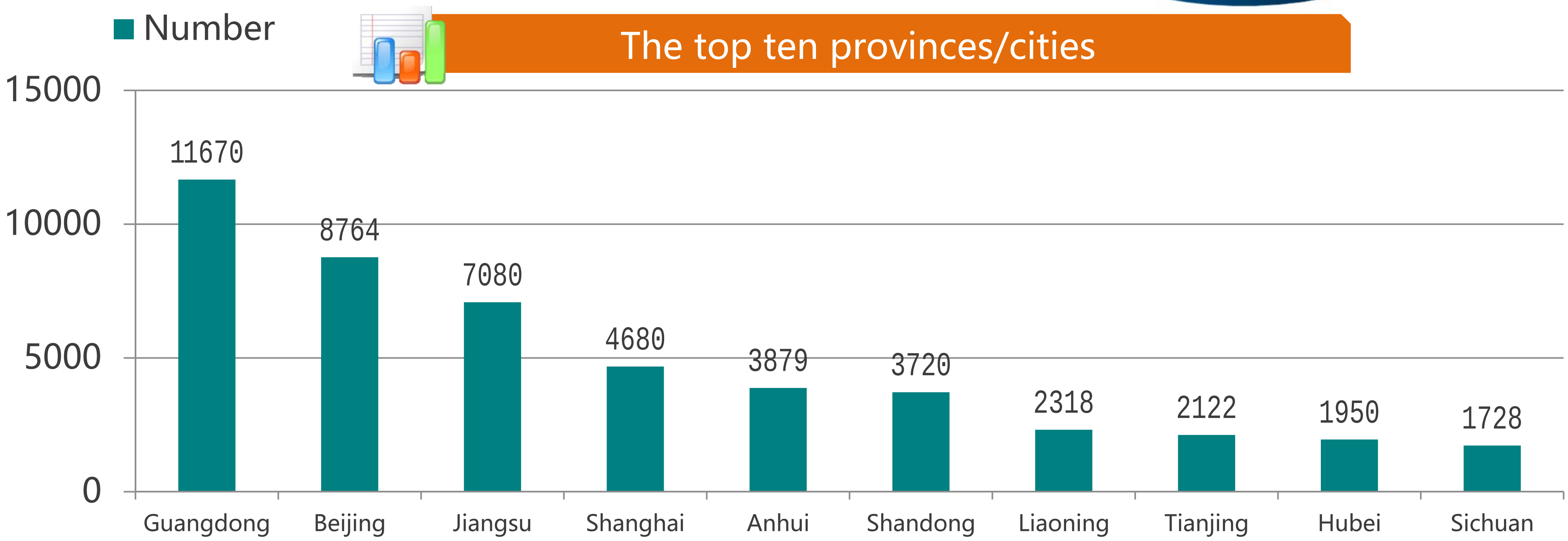
Source: NDRC et al., 2015; MOF et al., 2015; SMPG, 2016.

Contents

Charging infrastructure development

To Jan. 2016， the total number of public charging ports is 58,758 (AC 38,312 , DC 12,101 , Combo 8,345); private owned number is 50,241 (AC 50,233 ，DC 8).





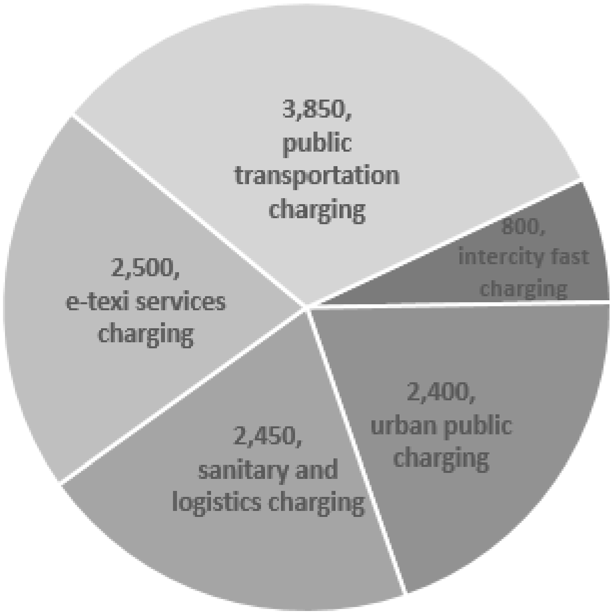
数据来源：中国电动汽车充电基础设施促进联盟_简报_总第2期

Charging infrastructure development

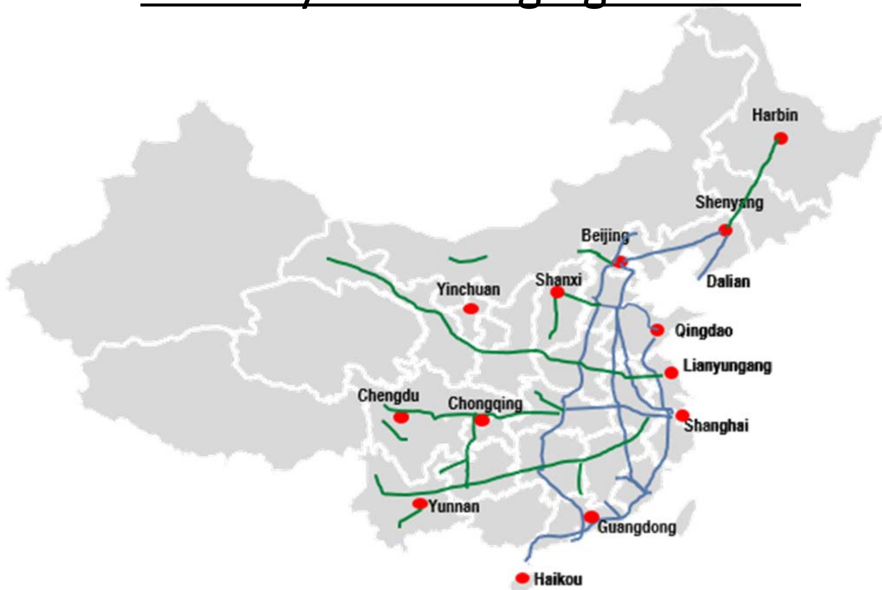
Centralized charging and swapping stations

- **12,000** centralized charging and swapping stations are planned by 2020.

<u>Category and target</u>



<u>Intercity fast charging network</u>



Highway with fast charging network.

Pilot city or province with governmental charging infrastructure deployment.

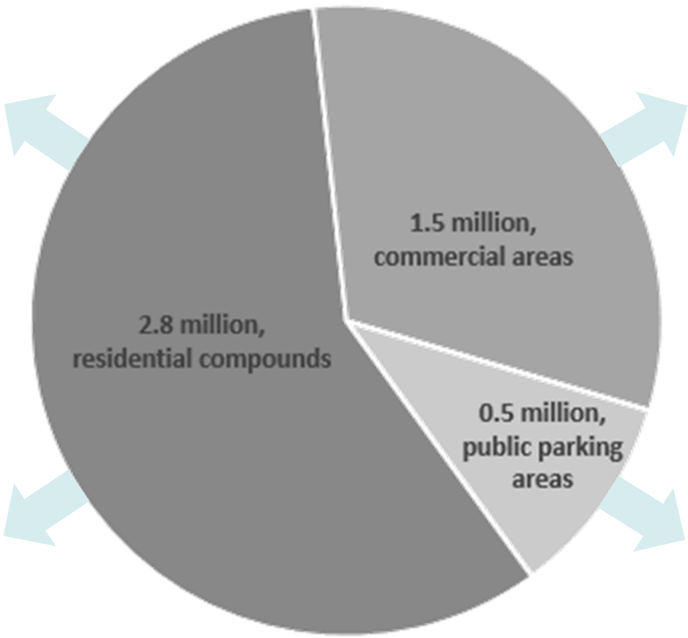
Source: NDRC et al., 2015.

Charging infrastructure development

Distributed charging pillars

- **4.8** million distributed charging pillars are planned by 2020.

Category and target



Source: NDRC et al., 2015.

Charging infrastructure development

Charging infrastructure implementation

Newly-built constructions rules (2016)

- **100%** parking lots in compounds should be enabled for charging installations (parking lot).

- **10%** parking lots in public constructions (larger than 20,000m^2) have to equip with charging devices.

Short term solution

- Co-use power supply of illumination equipment, such as street light.

Long term goal

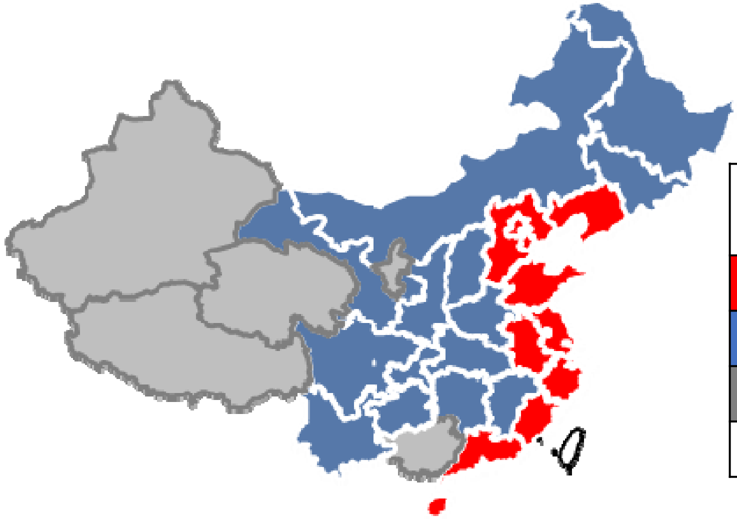
- Develop mechanical and multi-storey parking garages with charging facilities.

Source: MOHURD, 2015.

Charging infrastructure development

Nationwide development

- Nationwide development and provincial targets are planned.



Nationwide target amount

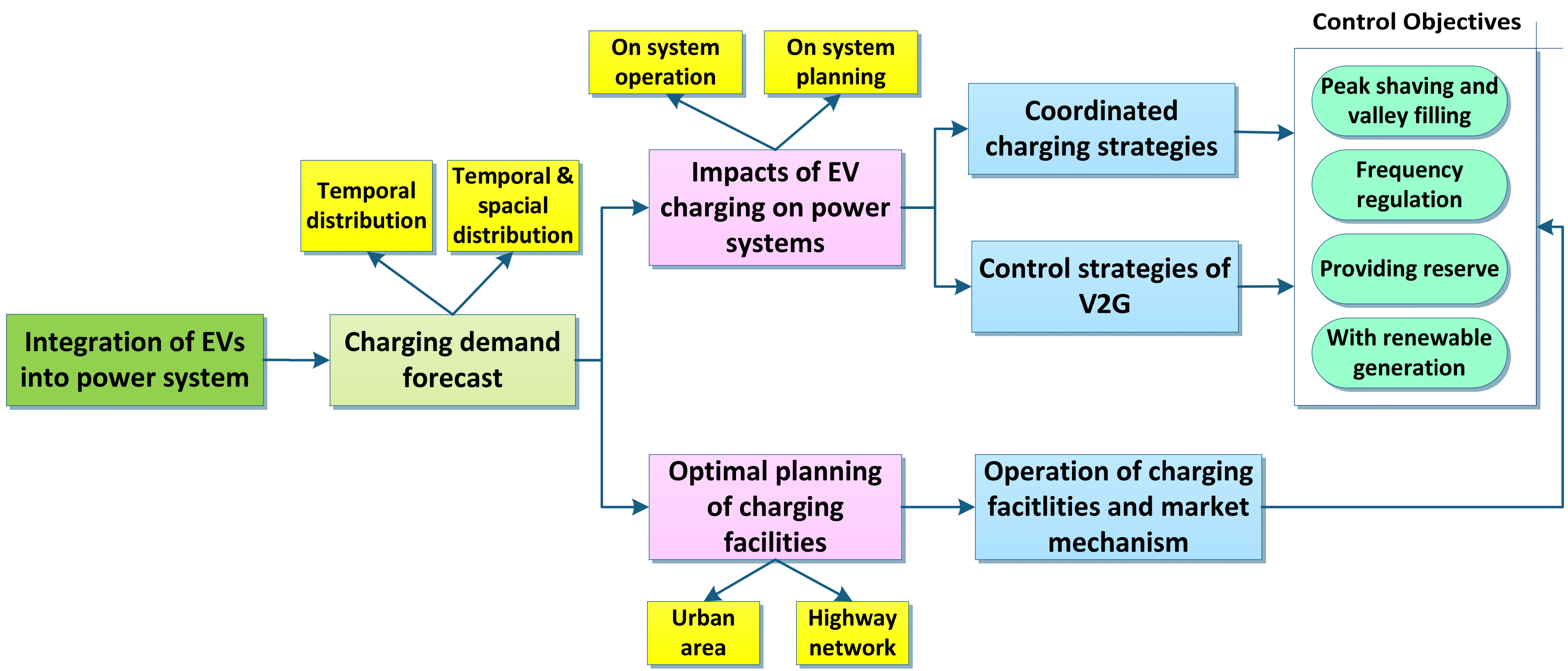
Region	No. of province	Charging station target by 2020	Charging pillar target by 2020
Acceleration area	12	7,400	2.5 million
Demonstratio area	14	4,300	2.2 million
Promotion area	5	300	0.1 million
Total	31	12,000	4.8 million

- Deployment of charging infrastructure in Beijing:
  - The "public-private partnerships" is encouraged and subsidized with maximum 30% of total investment.
  - Regulated charging service fee is introduced and directly related to 92 octane gasoline price.

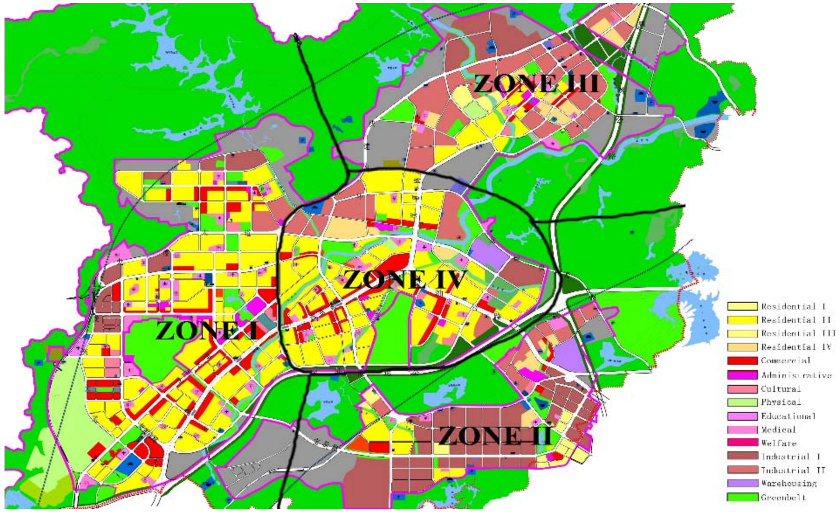
Source: GOSC, 2015; NDRC et al., 2015; BMCDR, 2015.

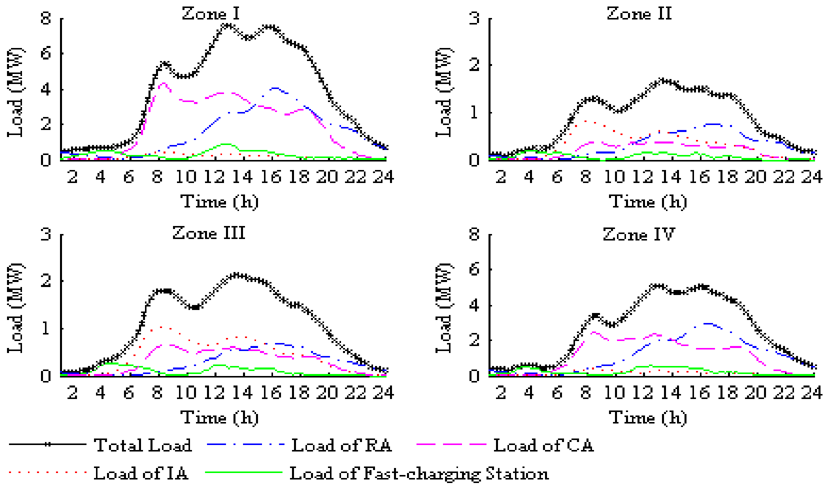
Contents

Research work overview

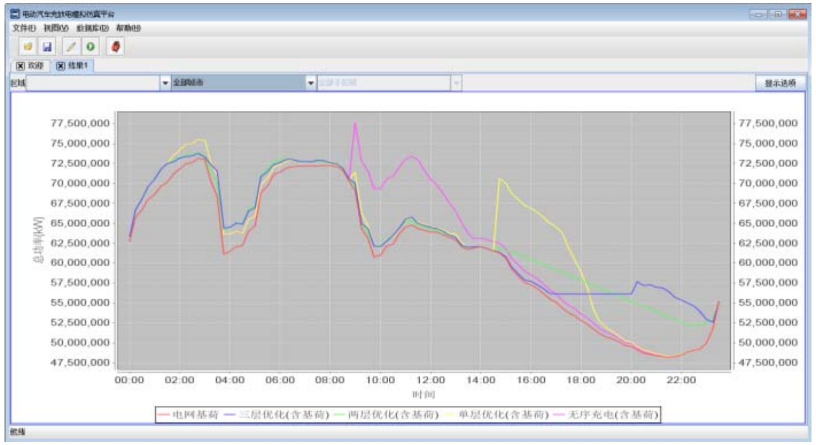


Charging load forecast and facility planning

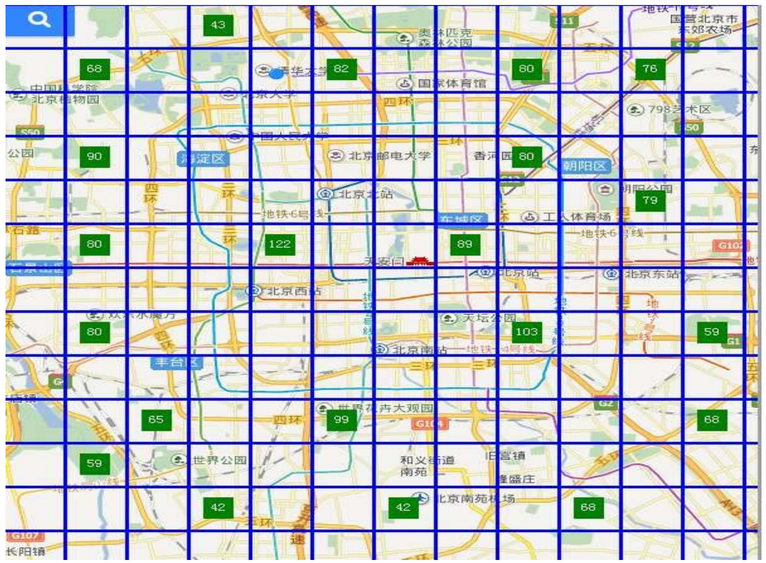




Spatial and temporal distribution of PEV charging load forecast

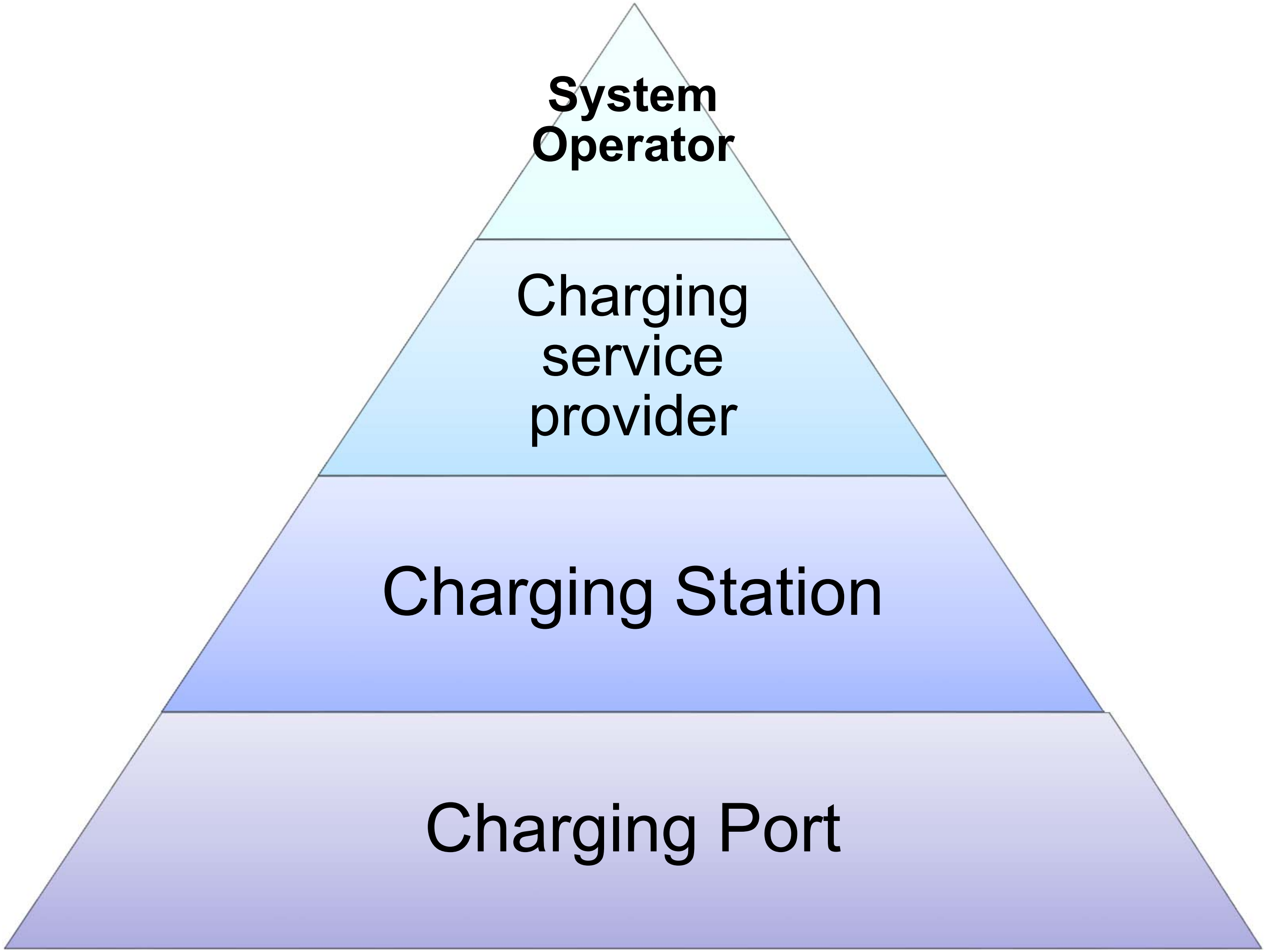


Charging load forecast

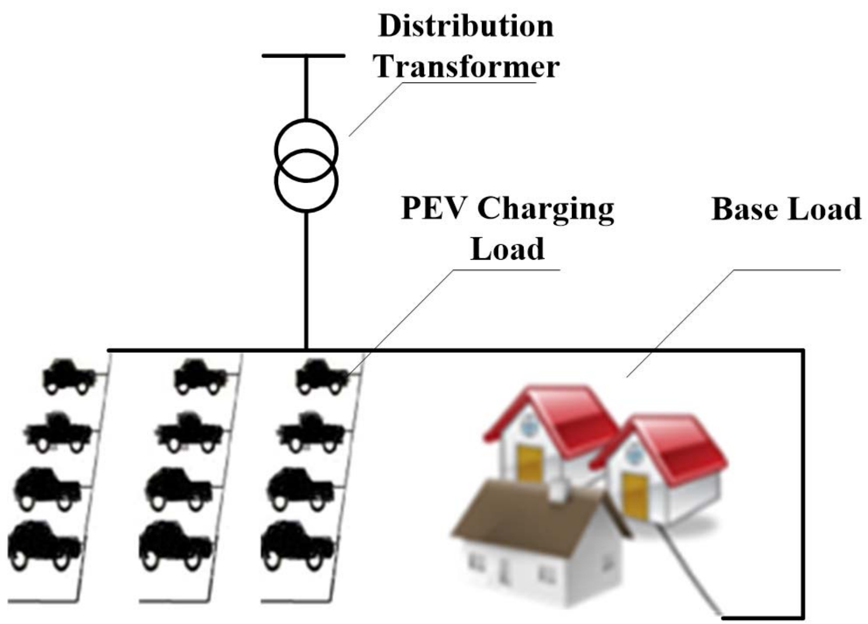


Charging station planning

Research work on coordinated charging

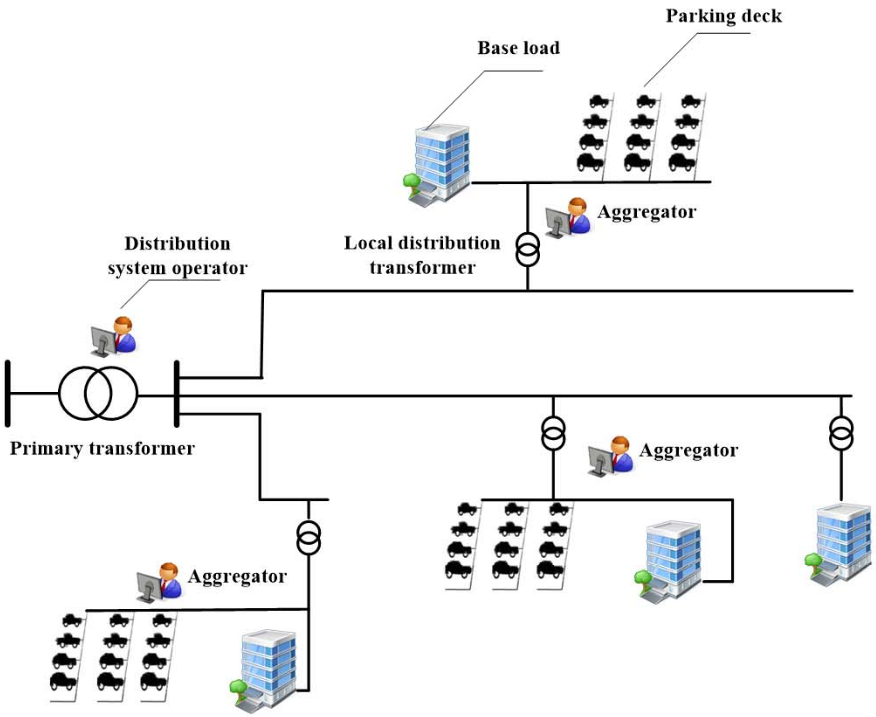


Smart Charging – station level



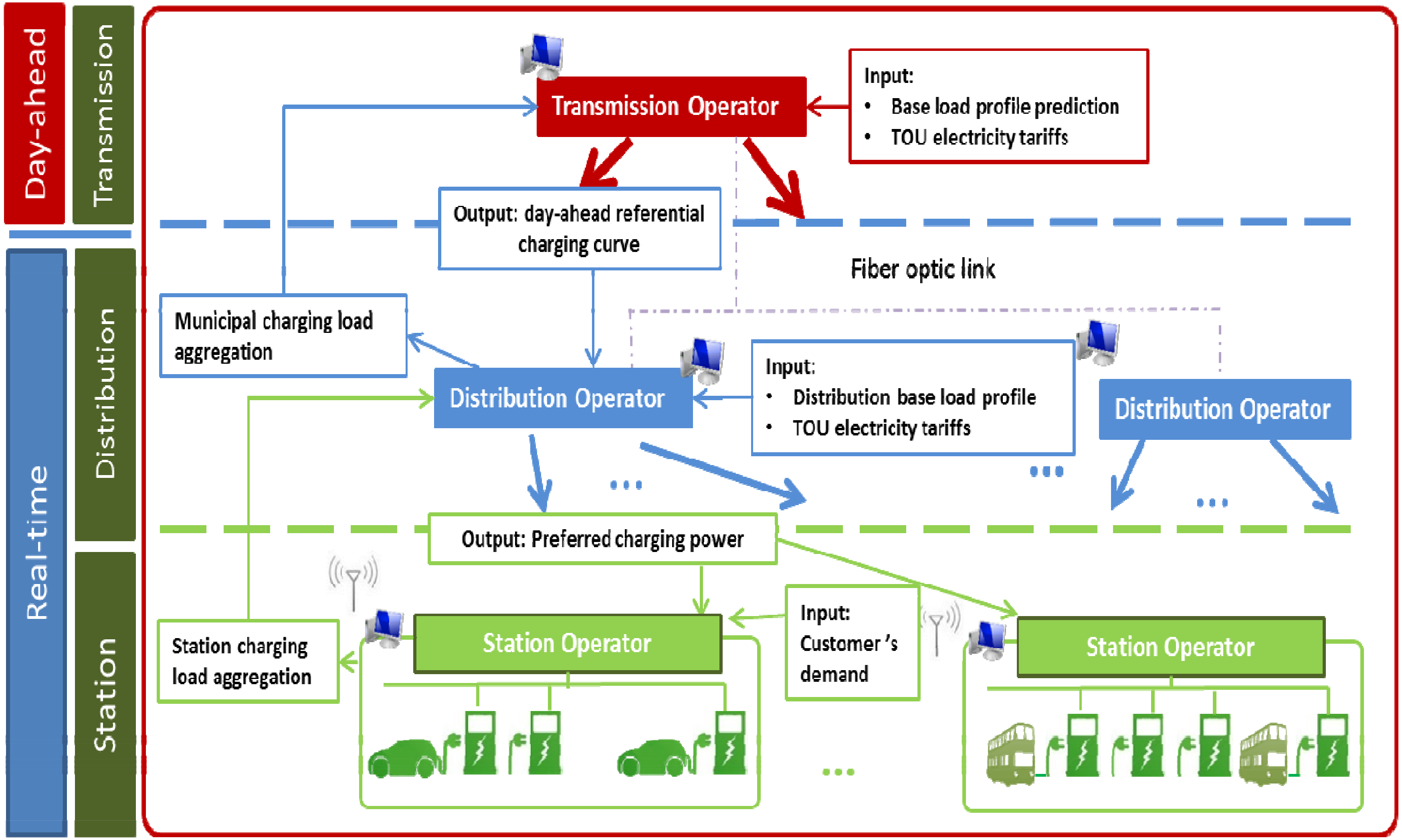
- Charging stations or parking lots with charging piles for PEVs
- The charging load and base load are connected to the distribution transformer
- Charging process of each EV is optimized to flatten the load profile and make more profit for the charging station while capacity constraint of the transformer is hold

Smart Charging – multiple stations



- A schematic illustration of the distributed charging system in an urban area
- Proposed hierarchical control framework for PEV charging coordination across multiple stations or aggregators
- A charging load aggregation method is put forward considering real-world PEV charging and distribution transformer constraints

Smart Charging – Three Levels



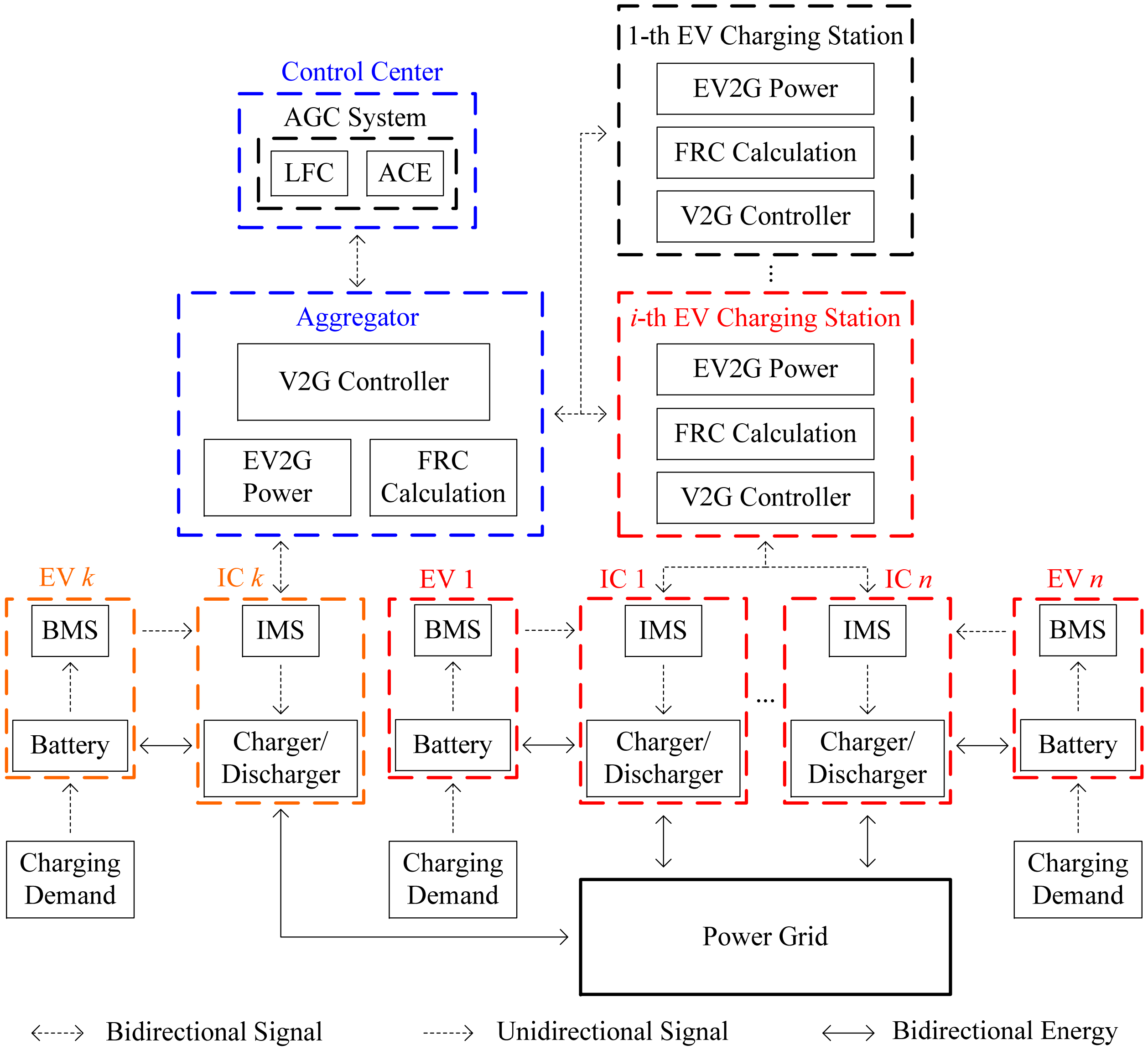
V2G for Primary Frequency Control

- Objective and Constraints
  - Smoothing frequency fluctuation
  - Meeting Charging demands
    - Charging EVs
    - Holding battery SOC

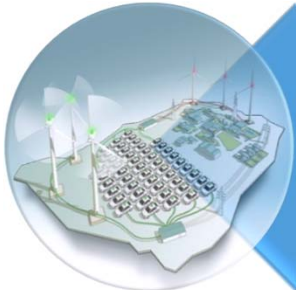
- Our Solution Method
  - Frequency droop control
    - Responding frequency signal
    - Considering SOC level
  - Tradeoff between achieving charging demands and frequency droop control

Hui Liu, Zechun Hu, Yonghua Song, and Jin Lin, “Decentralized Vehicle-to-grid Control for Primary Frequency Regulation Considering Charging Demands,” IEEE Trans. Power Systems.

EV Participating AGC



Coordination of EV and renewables



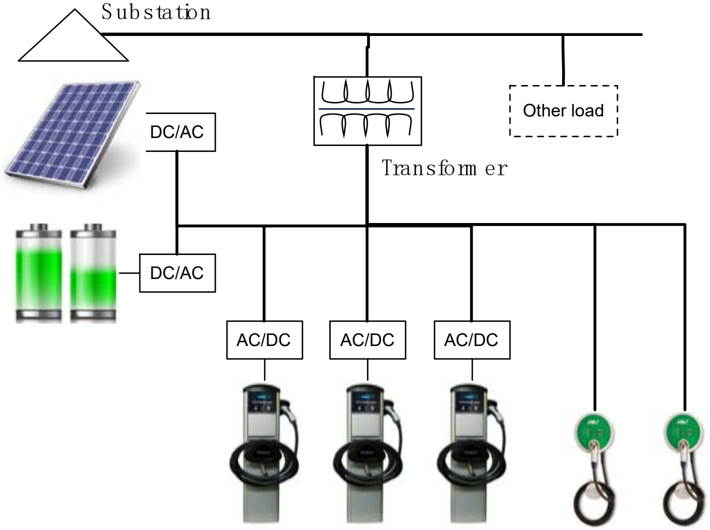
Coordinate with wind farm/PV plant, reduce the wind/solar curtailment

Coordinate with distributed generation resources

Application of EV in micro-grids（reduce the curtailment and secure system operation）

Coordination of EV and renewables

- From charging station to charging network
- From planning to operation



Coordinated EV charging: A key to open two locks!

Thank You!