Full Life-cycle Energy and Environmental Impacts of New Energy Vehicles in China

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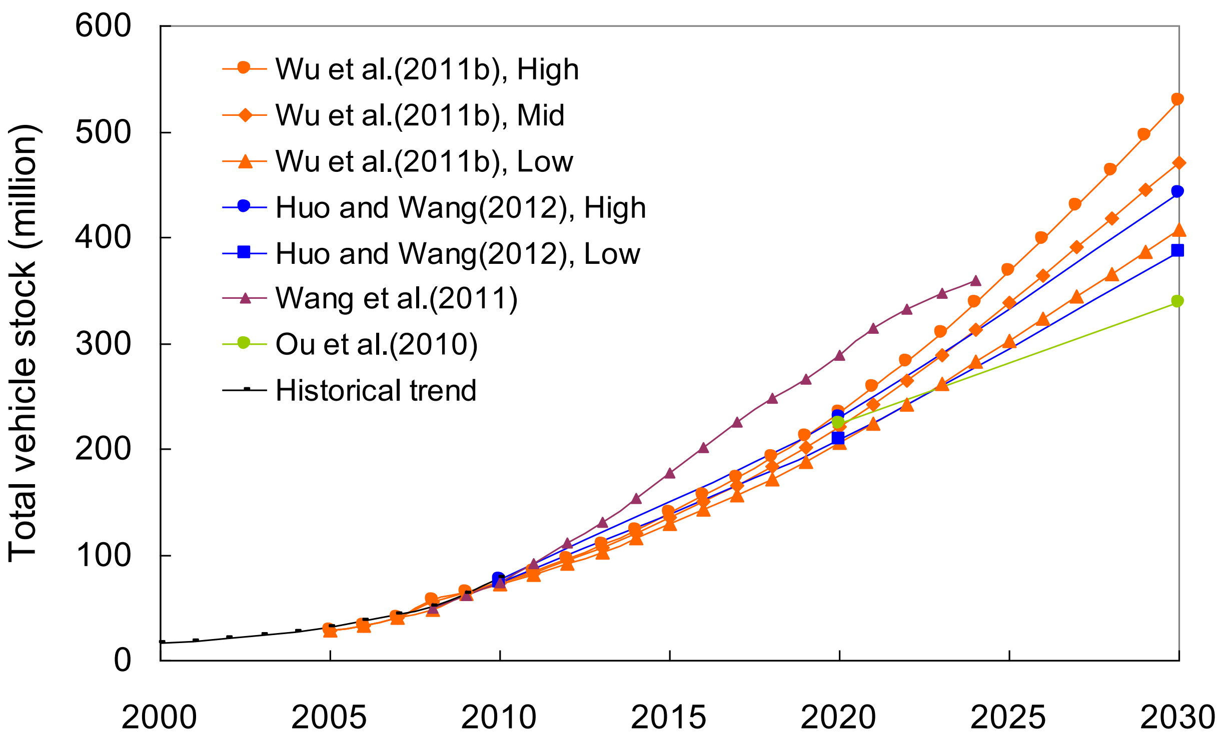
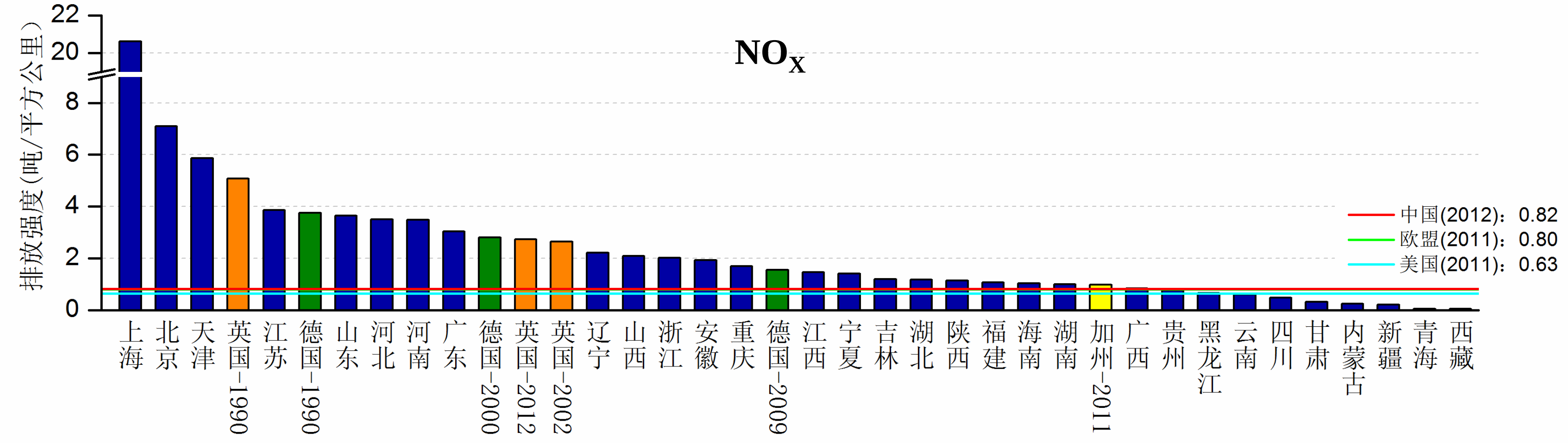
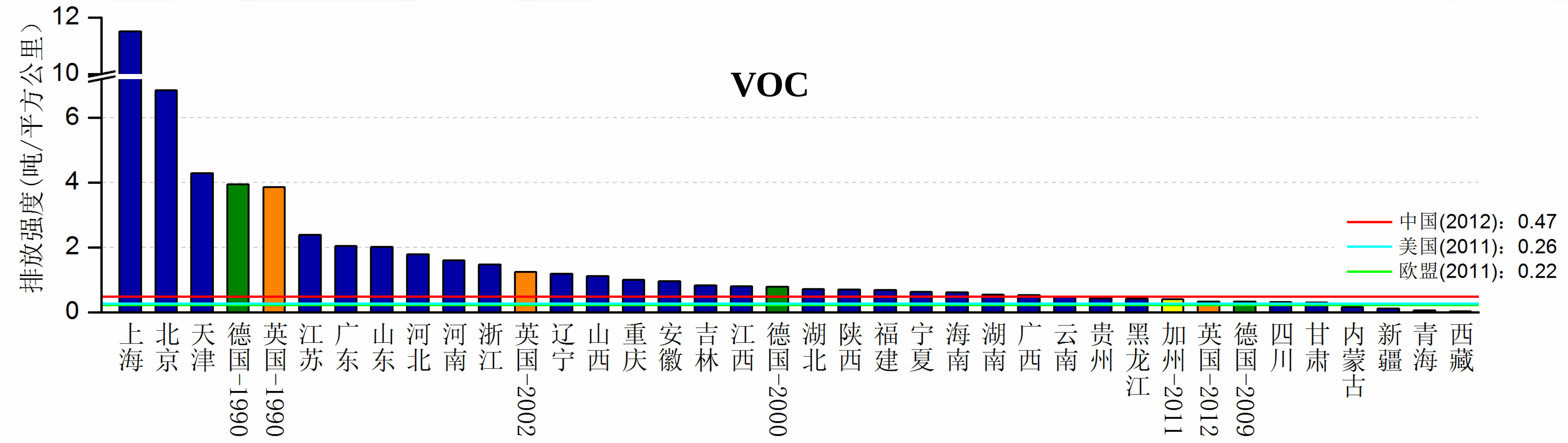
Leading auto market: challenges or opportunities?

Domestic and overseas studies showed that China's vehicle population will reach 200-250 million by 2020, 250-500 million by 2030! By 2025, China will become the large car owner in the world!



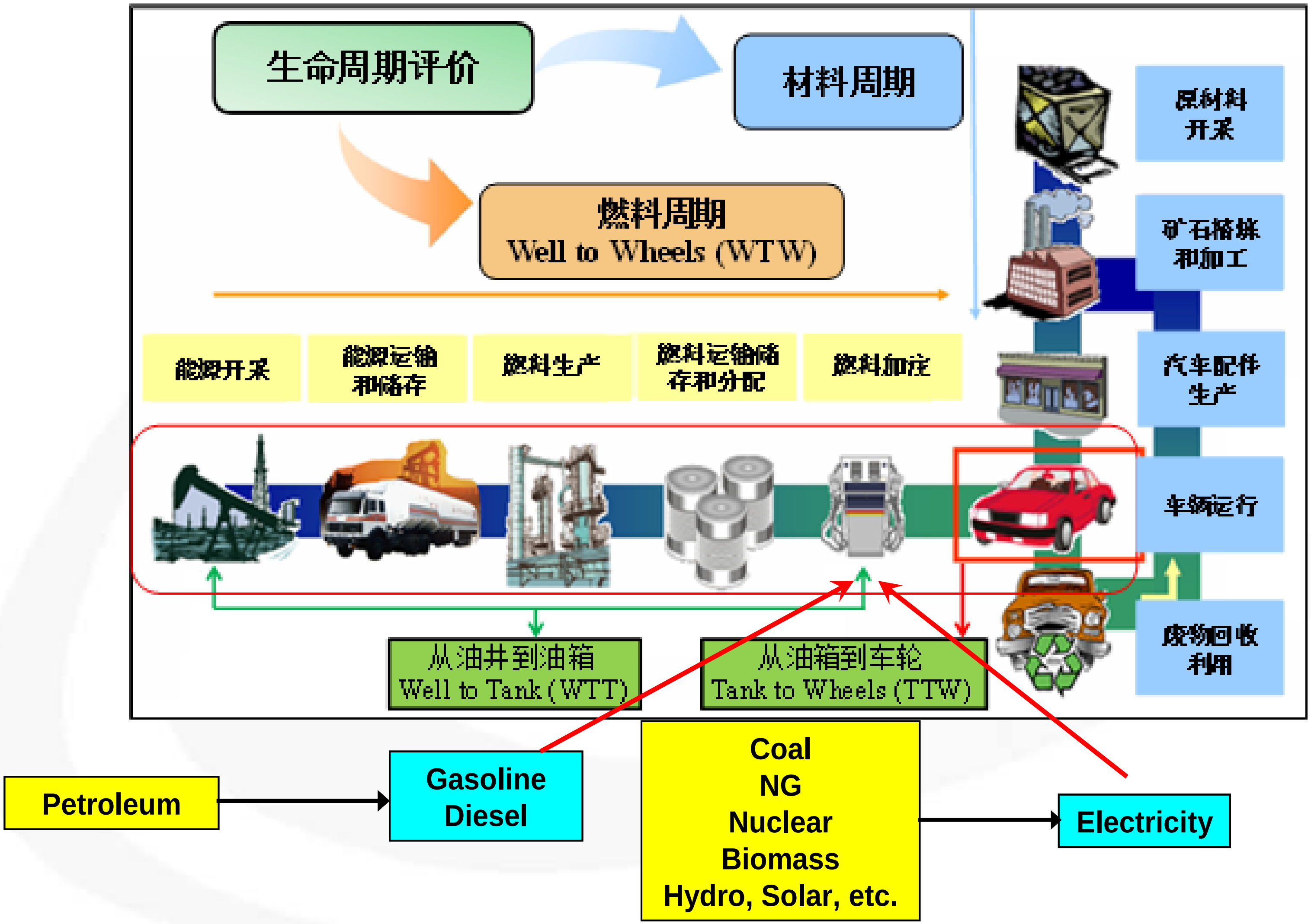
Vehicular emission intensities in Eastern China are much higher than those in developed countries





New energy vehicles are penetrating in China

LCA must be used to fully evaluate energy and environmental impacts of new energy vehicles



LCA needs extensive data related to fuel, material and usage

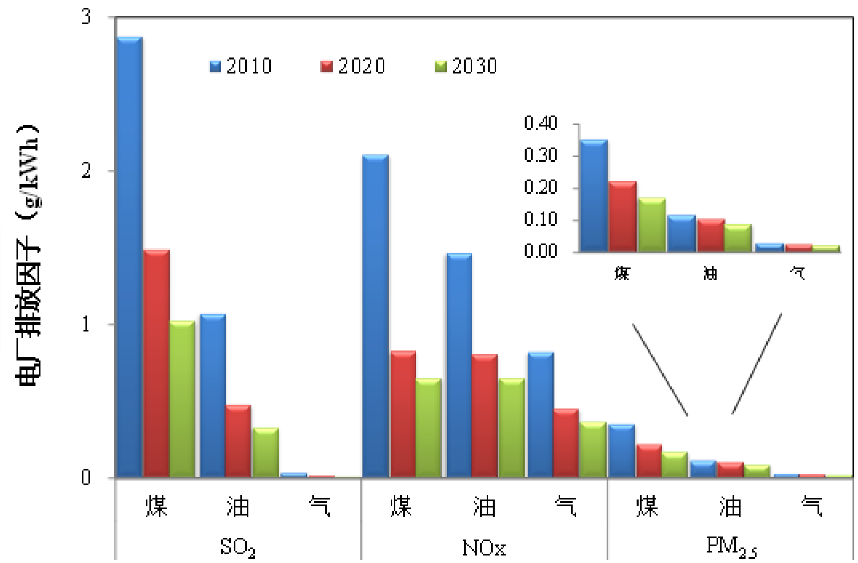
- **Vehicle fuel upstream (WTT) process energy consumption and emission data base**
  - ✓ Power generation process: regional electricity mix and thermal power generation efficiency
  - ✓ Power generation process: composition of key control technology and pollutant emission factor
  - ✓ Oil extraction and refining process: energy efficiency and emission factor
  - ✓ Natural gas extraction, production and transportation process: energy efficiency and emission factor
  - ✓ Other: energy consumption and emission factor of the transportation, storage and other processes of key raw materials and fuels
- **Vehicle operational period (TTW) energy consumption and emission database**
  - ✓ Traditional gasoline car/diesel vehicle: standard-based fuel economy and pollutant emission factor
  - ✓ HEV/PHEV/EV: improvement proportion of fuel economy and pollutant emission
  - ✓ Other: CNG bus fuel economy and emission factor
- **Vehicle use fuel life-cycle database (only involving energy consumption and CO_2 at current stage)**
  - ✓ Material composition of key vehicle parts
  - ✓ Extraction and smelting process of typical raw materials: iron & steel, copper, aluminum, lithium, nickel…
  - ✓ Production process of key vehicle parts: vehicle battery (lead-acid, ni-mh and li-ion battery)…
  - ✓ Energy consumption in recycling of vehicle use materials and vehicles

A series of important regulations and plans were released and their impacts to EVs need to be carefully examined

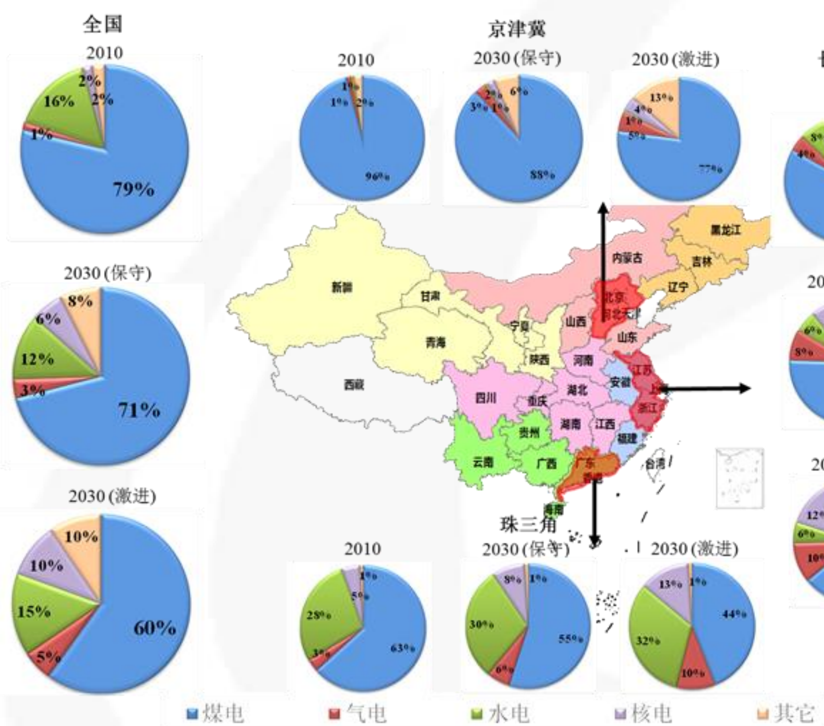
- ✓*Development Plan for the Energy-saving and New Energy Vehicle Industry (2012-2020)*
- ✓ *Phase 3/4 Fuel Economy Standard*
- ✓ *Total Quantity Control Target for the 12^{th}/13^{th} Five-year Plan Period (NOX and SO2)*
- ✓ Newly-revised *National Ambient Air Quality Standard*
- ✓ *National and Regional Action Plan for Air Pollution Prevention and Control*
- ✓ *National Emission Standard of Air Pollutants for Thermal Power Plants*
- ✓ *China V Gasoline/Diesel Oil Standard*
- ✓ *China V/VI Pollutant Emission Standard for Light-duty Vehicles/Heavy-duty Vehicles*
- ✓ *…*

Key parameters for upstream power generation in China

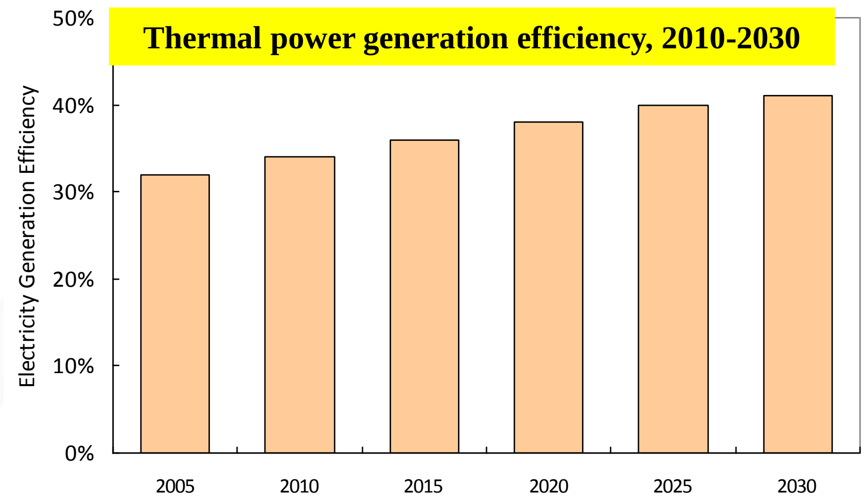
Thermal power emission factor, 2010-2030



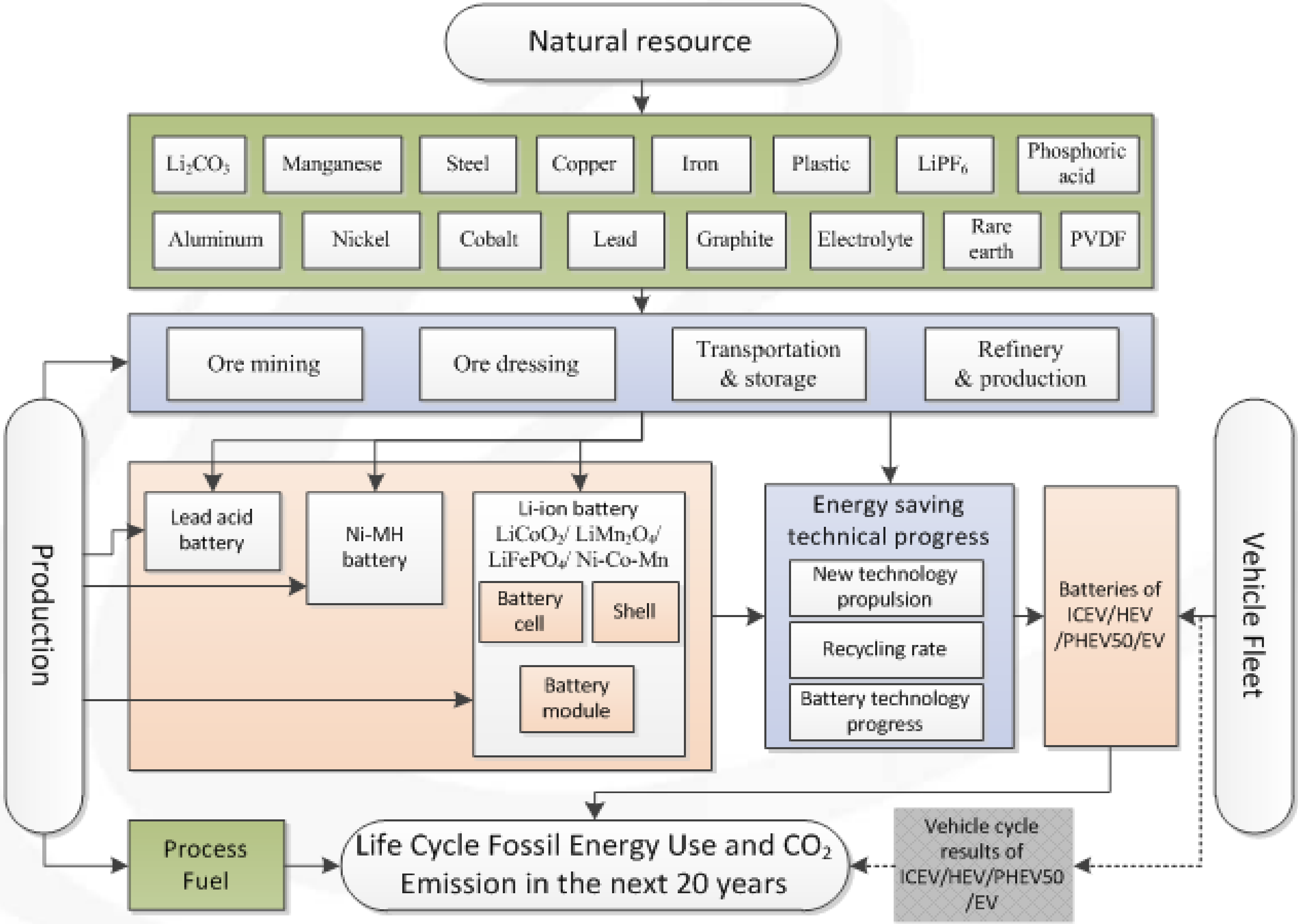
Electricity mix by region, 2010-2030



Thermal power generation efficiency, 2010-2030



Key parameters for upstream vehicle materials and components production and assembly



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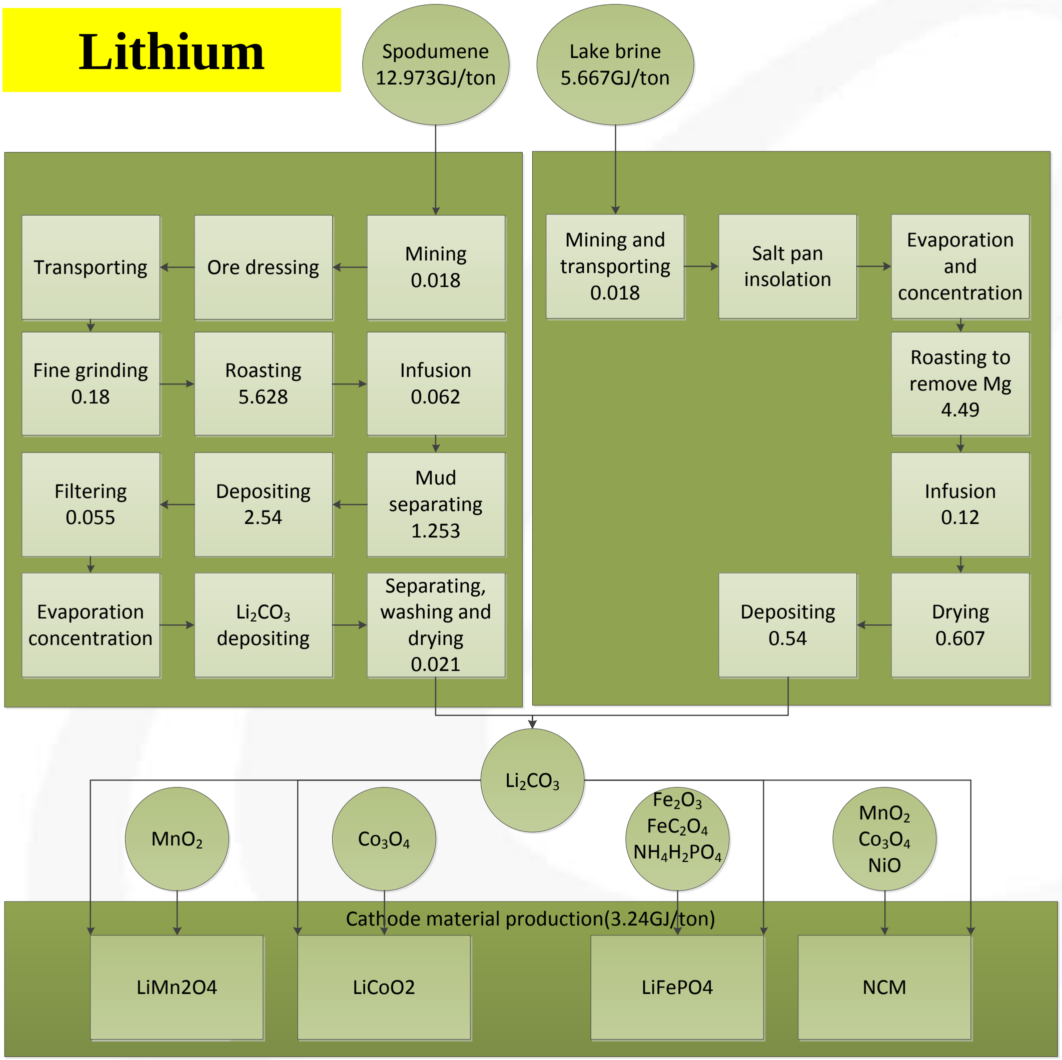
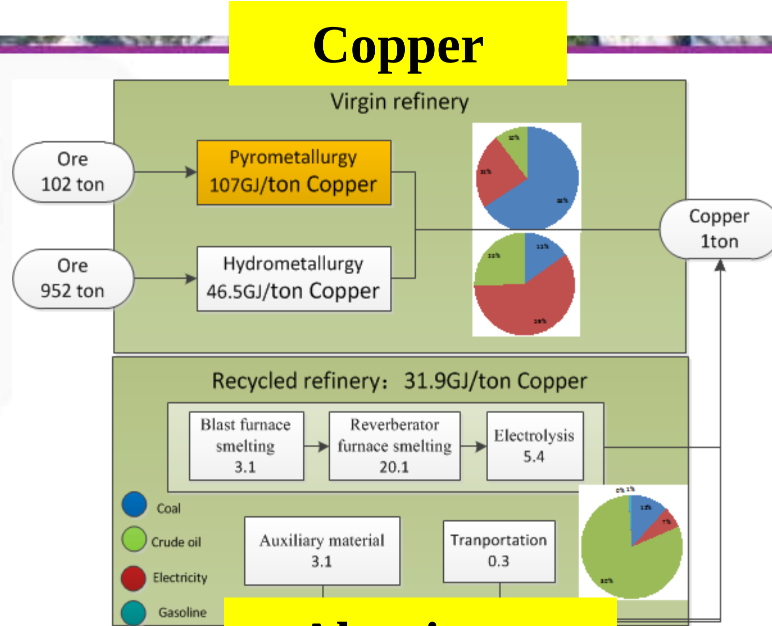
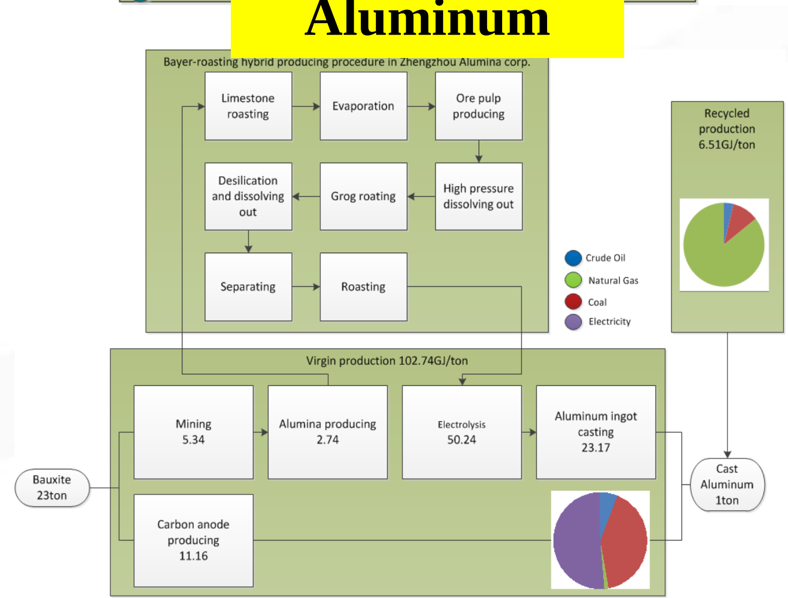
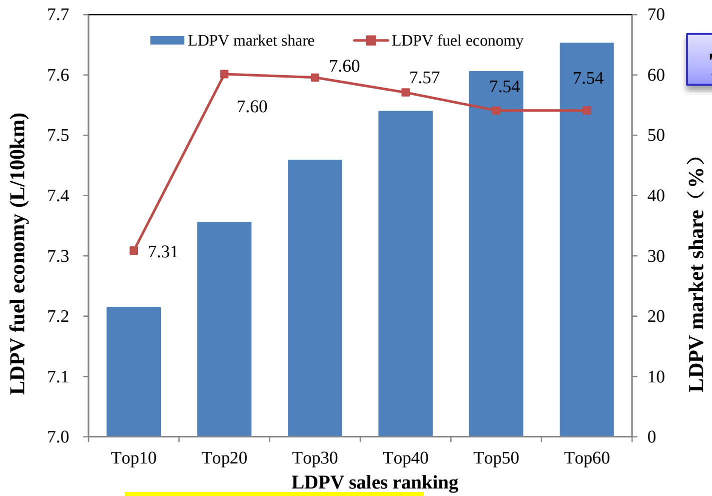






Key parameters for vehicle usage: 1) light-duty vehicle

Verified gasoline vehicle fuel economy



7.5L/100km

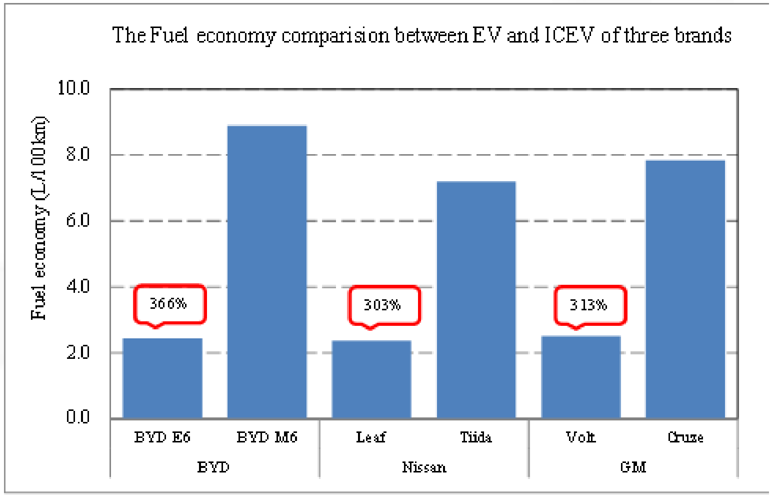
Real-road gasoline vehicle fuel economy

LDPV	Fuel economy（L/100km)	
	Scenario 1	Scenario 2
2010	8.7	8.7
2015	7.9	7.9
2020	7.3	6.5
2025	6.6	6.0
2030	6.4	5.5

HEV fuel economy

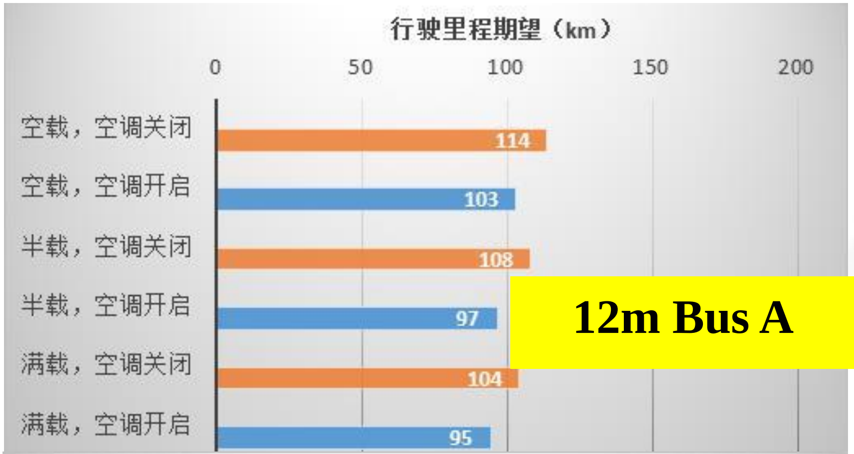
			Fuel Economy Improvement			Fuel Consumption Decrease		
Brand	Vehicle	Comparison Vehicle	User-Reported	Old EPA Combined	New EPA Combined	User-Reported	Old EPA Combined	New EPA Combined
Ford	Escape	Escape 2WD V6	65%	55%	50%	-39%	-36%	-33%
	Mariner	Mariner 4WD V6	53%	48%	42%	-35%	-33%	-30%
GM	Aura	Aura 3.6L 4-spd Auto	34%	27%	29%	-25%	-22%	-22%
	Sierra	GM Sierra 2WD 5.3L	31%	7%	6%	-24%	-7%	-6%
	Vue	Vue 2WD 6 cyl. Auto	28%	27%	30%	-22%	-21%	-23%
Honda	Accord	Accord 3L Auto.	-9%	32%	29%	10%	-24%	-22%
	Civic	Civic 1.8L Auto.	52%	48%	45%	-34%	-32%	-31%
	Insight	Civic 1.8L Auto.	138%	85%	62%	-58%	-46%	-38%
Nissan	Altima	Altima V6 Auto	35%	60%	55%	-26%	-38%	-35%
Toyota	Camry	Camry V6 3.5L Auto.	53%	54%	48%	-34%	-35%	-32%
	GS 450h	GS430	28%	28%	21%	-22%	-22%	-17%
	Highlander	Highlander 2WD 3.3L	38%	39%	37%	-27%	-28%	-27%
	LS 600hL	LS 460 L	10%	11%	11%	-9%	-10%	-10%
	Prius	Corolla 1.8L Auto.	47%	68%	59%	-32%	-40%	-37%
	RX 400h	RX 350 2WD	28%	34%	30%	-22%	-26%	-23%
Average			42%	42%	37%	-27%	-28%	-26%

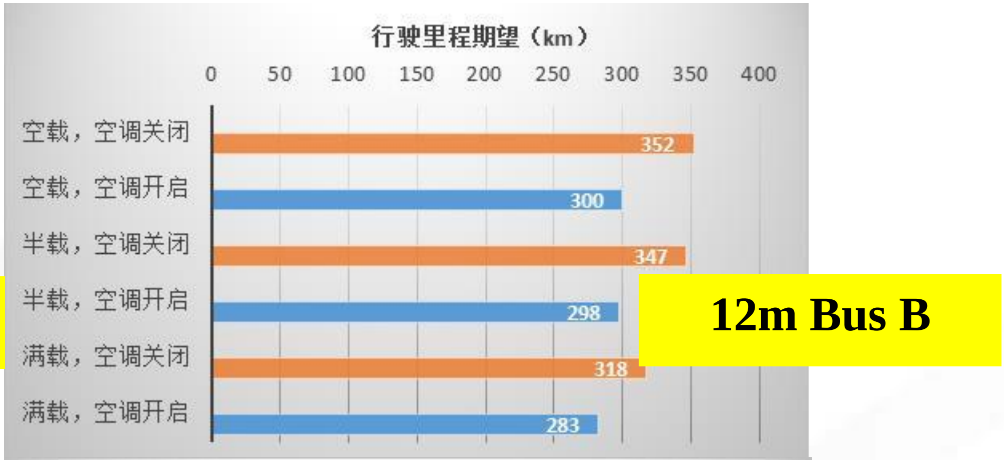
PHEV and BEV fuel economy

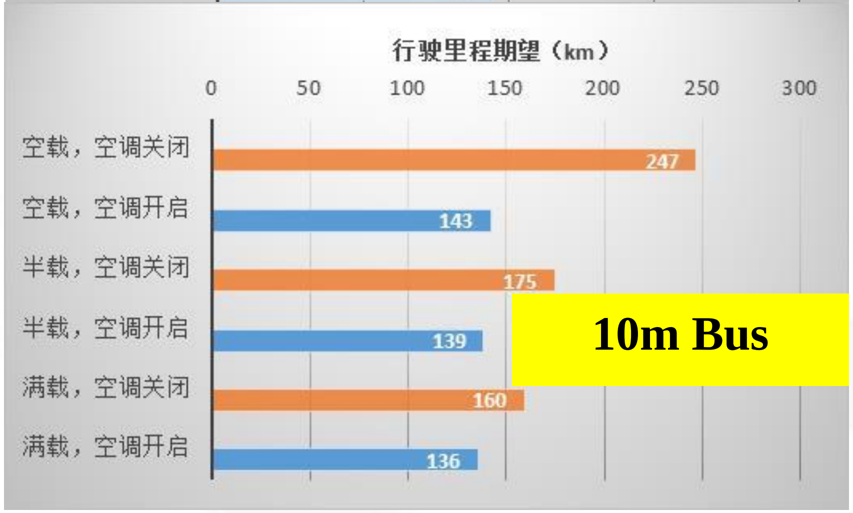


Key parameters for vehicle usage: 2) bus

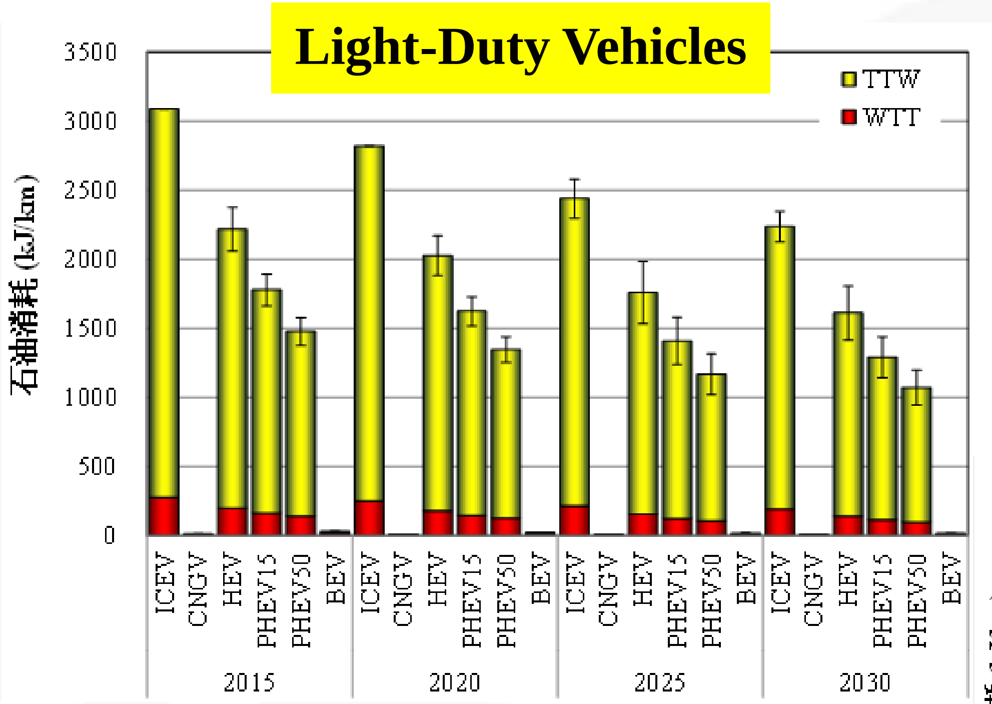
The comprehensive power consumption of most electric buses at full load and with air conditioner opened increases by 21-27% on average and the correspondingly single driving range drops by 17-21%; generally, the activation of air conditioner has a greater impact than that of full load.

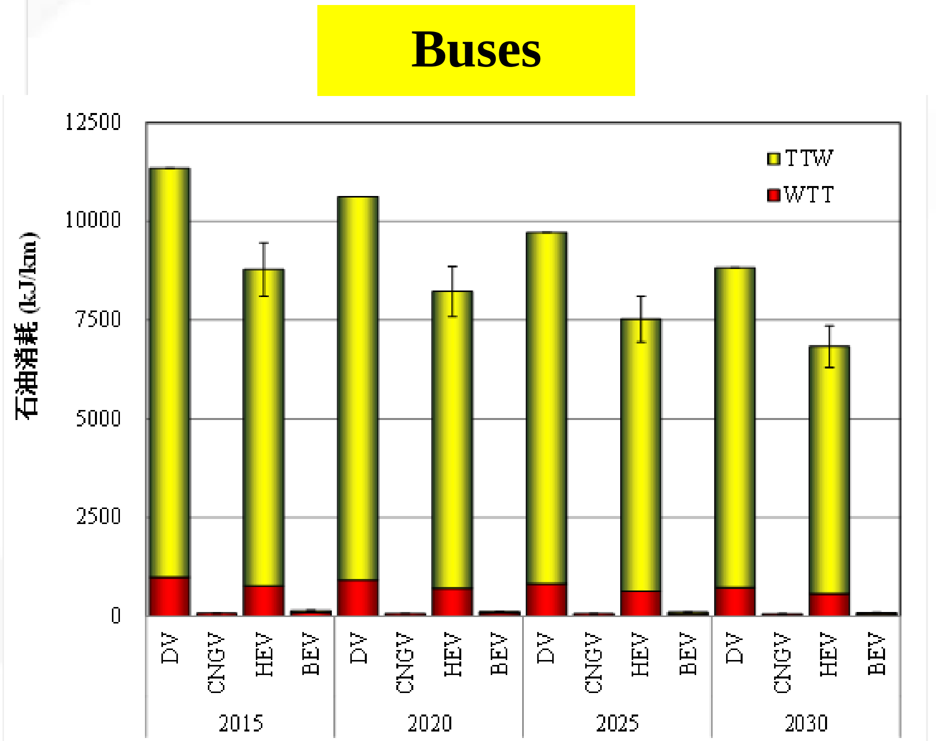




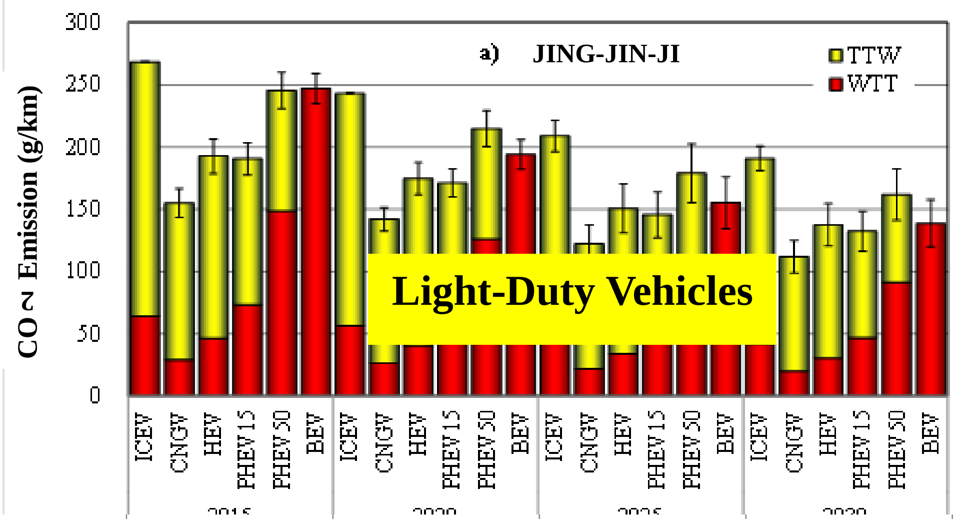


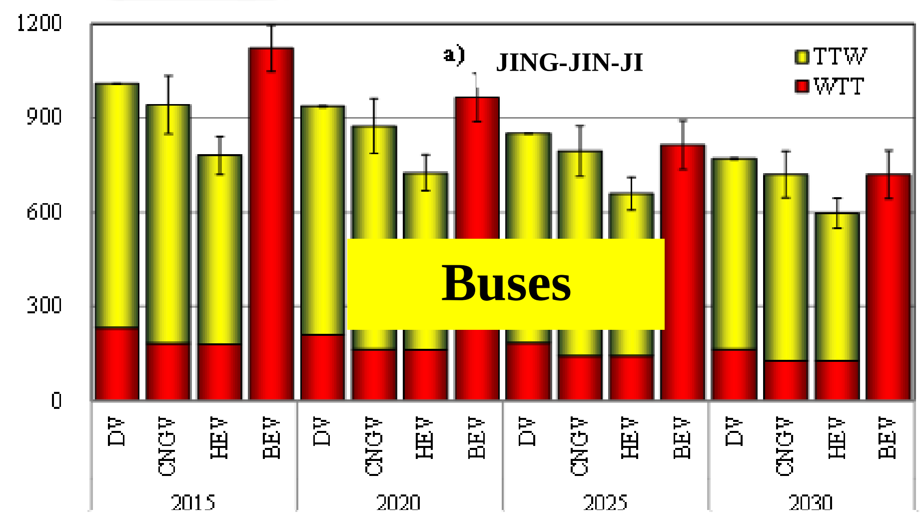
The promotion of EVs can greatly improve the oil energy security

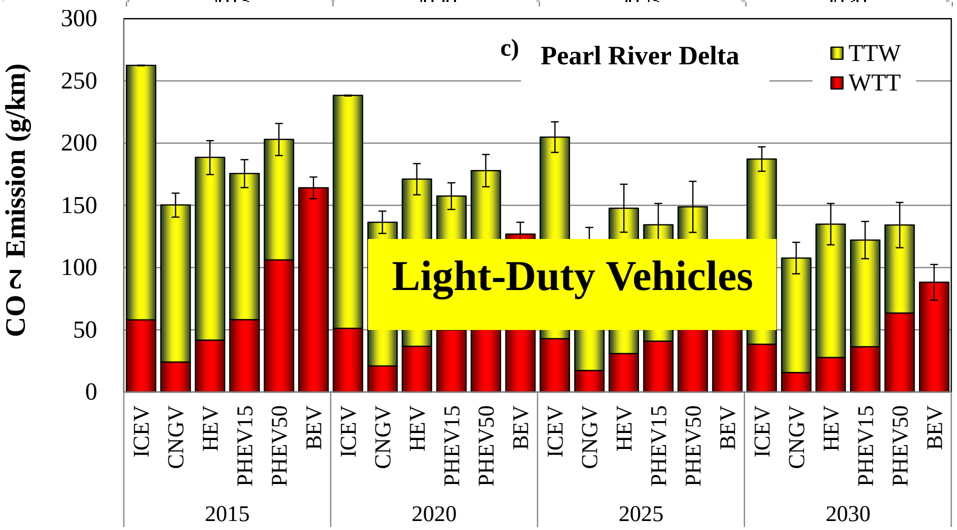


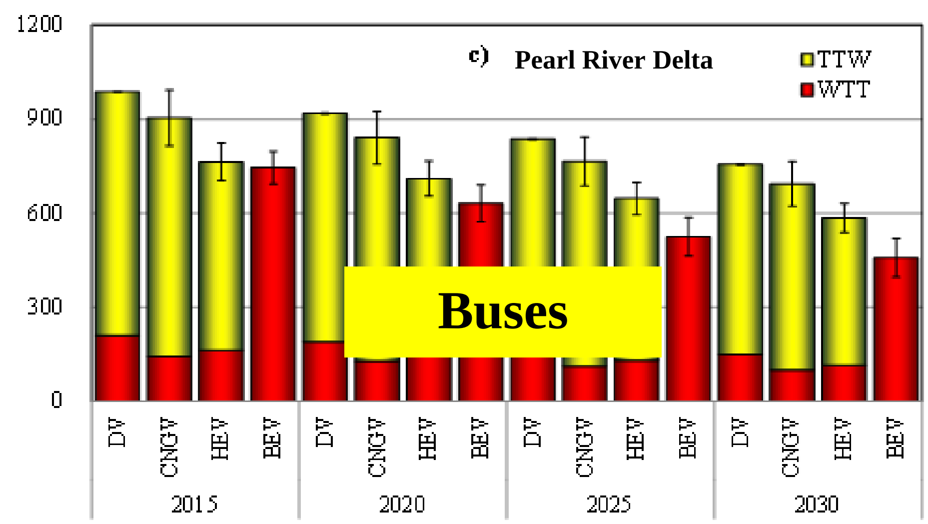


The benefit of CO_2 emissions for EV are strongly relevant to generation mix, coal technology, fuel economy, etc.

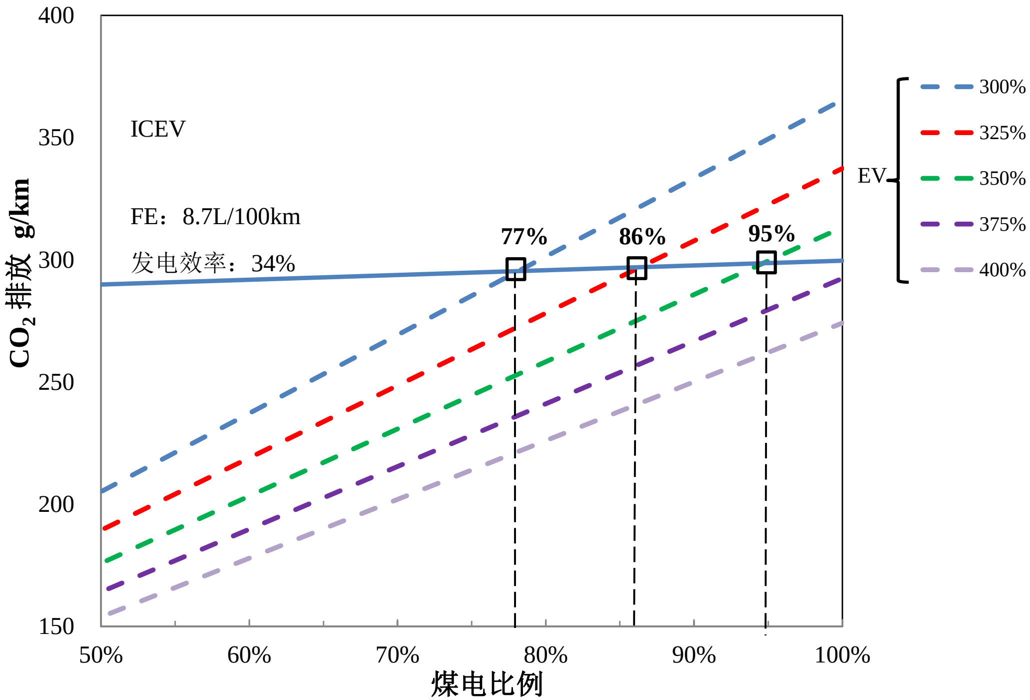


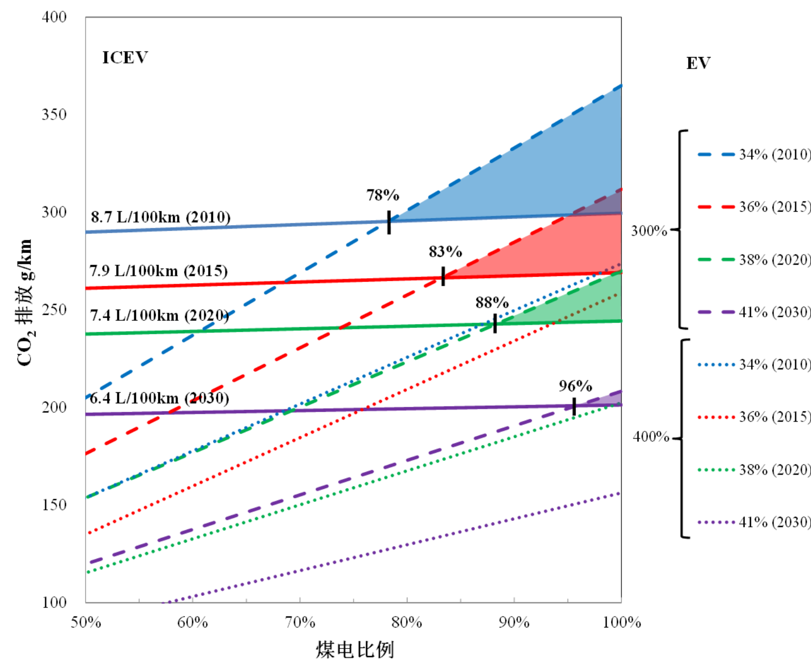






CO_2 breakeven of light-duty BEV vs. ICEV





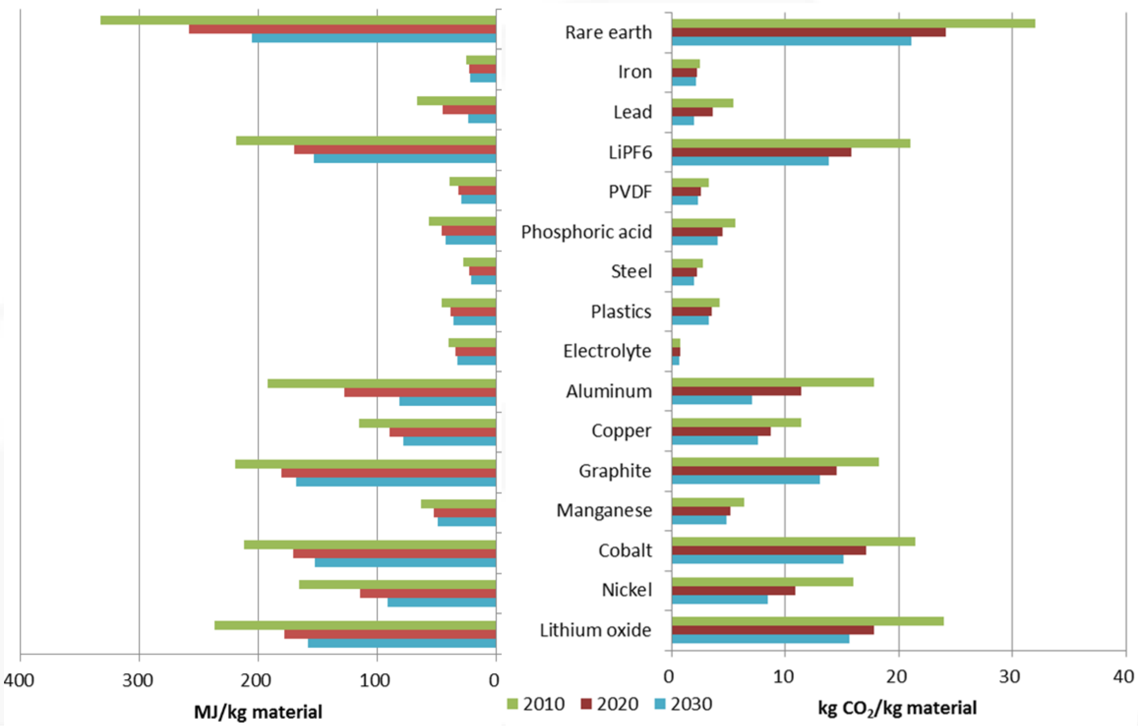
When power generation efficiency is 34% (2010 level),

(1) BEV'S FE is 300% of that of ICEV: the breakeven proportion of coal-fired power is 77%. Based on the existing electricity mix by region, the coal-fired power proportion in North China, Northeast China and East China is higher than 77% and ICEV is better than BEV; in other regions, BEV is better than ICEV;

(2) BEV's FE is 350% of that of ICEV: when the coal-fired power proportion is 95%, ICEV is consistent with BEV. Except for North China, BEV is better than ICEV in all other regions.

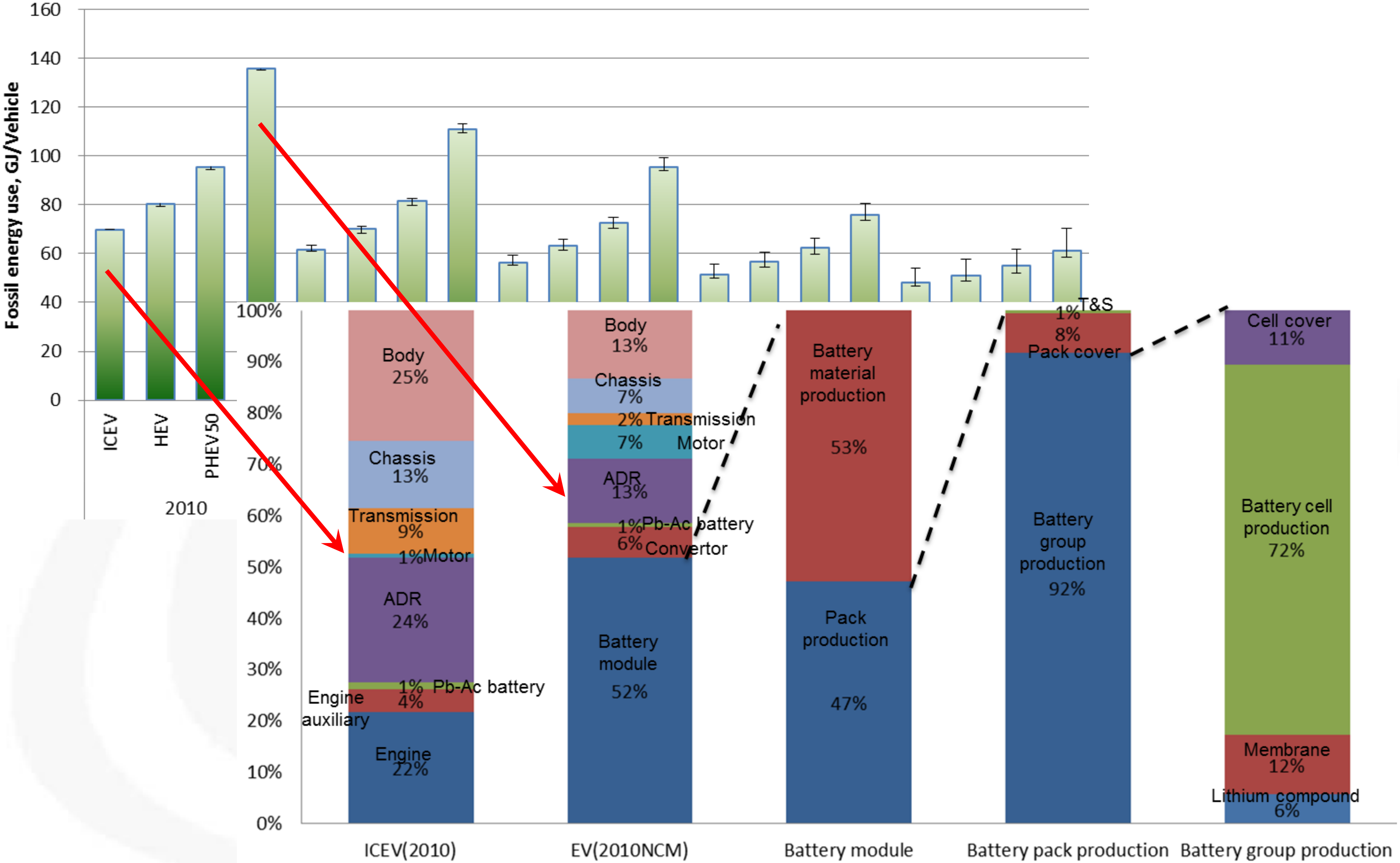
The CO_2 breakeven points between BEVs and ICEVs are relevant to several key parameters: fuel economy of ICEVs and BEVs, share of coal-fired power, and the generation efficiency of coal power.

Those vehicle materials with high energy intensity need to pay special attention

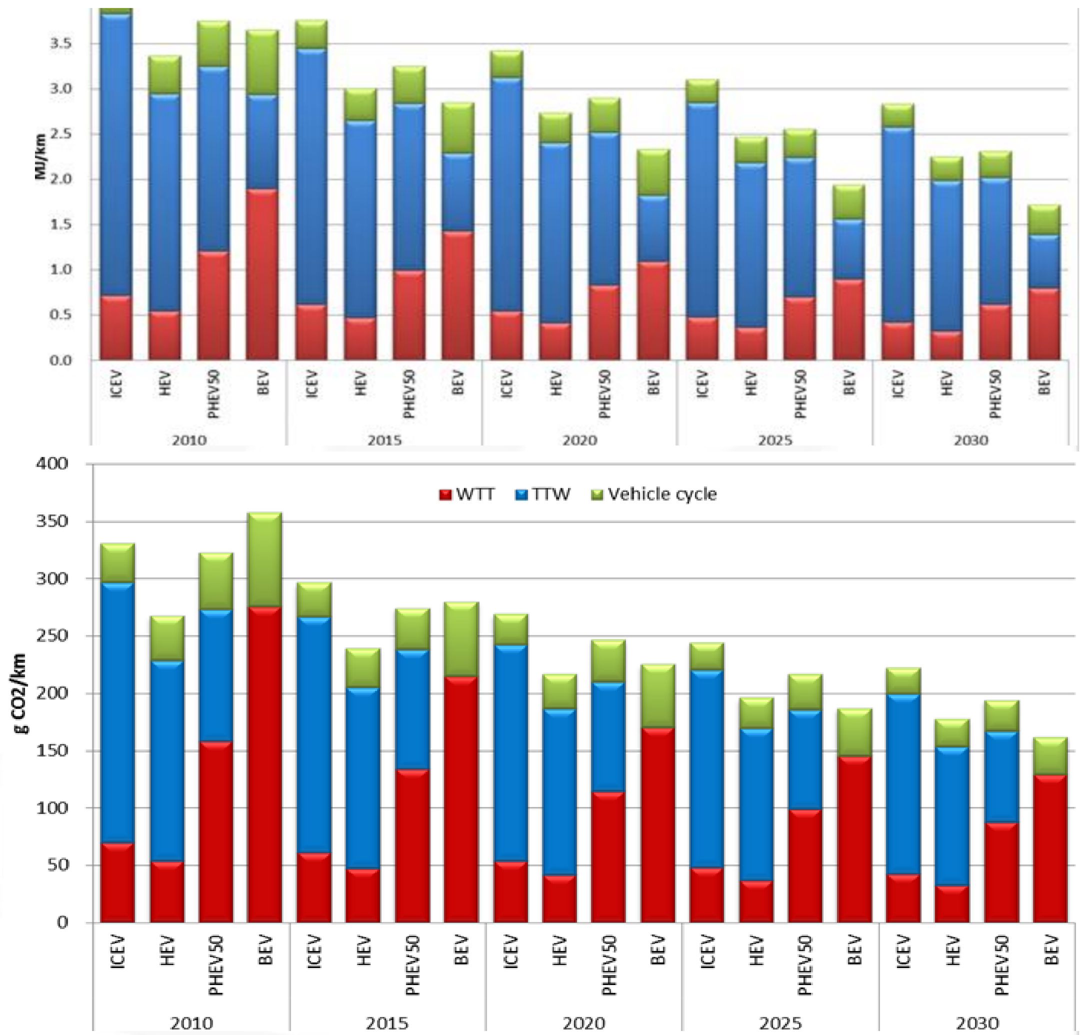


- In general, rare earth, aluminum, graphite, cobalt, LiPF6 and lithium oxide have relatively higher fossil energy use than other materials.
- Among cobalt, nickel and manganese, cobalt is the leading metal in both fossil energy use and CO_2 emissions.
- The fossil energy use and CO_2 emissions of almost all materials will continue to decrease due to the technology improvement. This is especially true for those materials with high energy intensity (e.g., Al).

Battery is the biggest contributor to total energy use of vehicle material cycle for BEVs



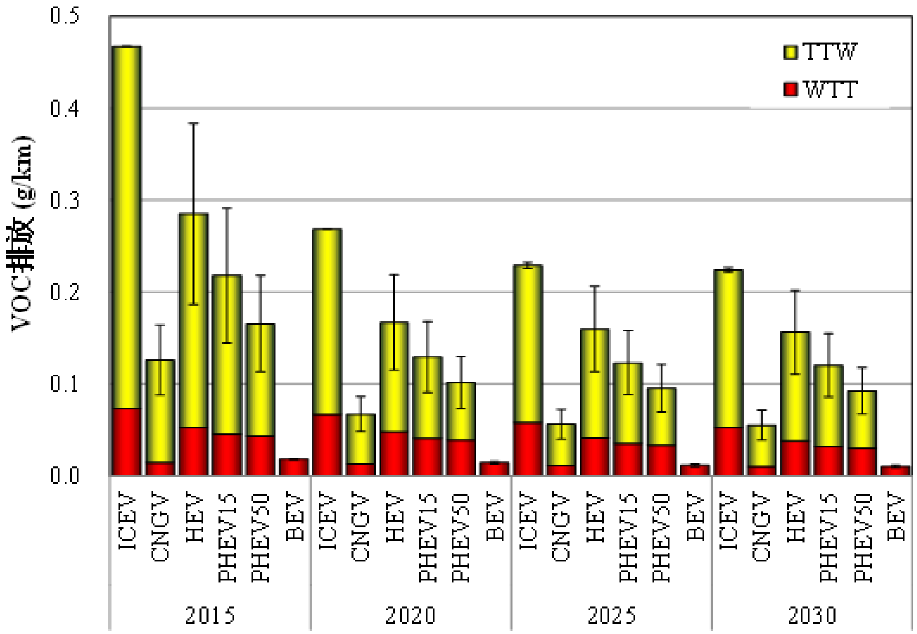
Currently full life cycle CO_2 use for BEV is not better than gasoline car, but after 2020 BEV will be much better



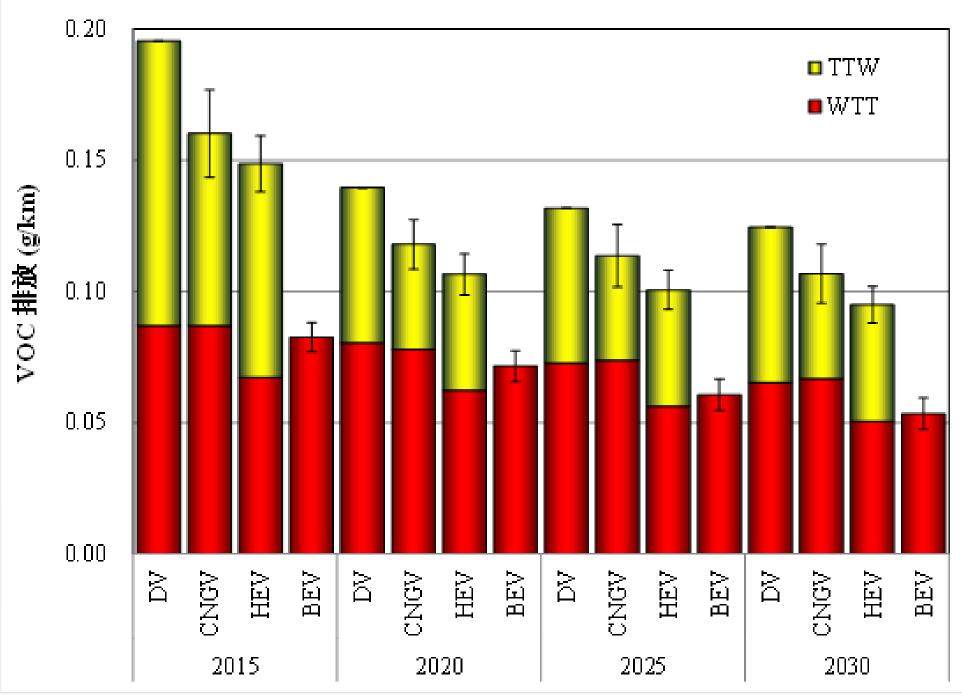
- All three electric vehicle technologies achieve savings in full life-cycle fossil energy use relative to ICEV.
- BEV will show more advantage in fossil energy use over ICEV in the future.
- At the current stage, BEV and PHEV50 could not achieve full life-cycle benefit in CO_2 emissions over ICEV.
- As technology improves in battery industry and more renewable power promotes in China, BEV will show advantage in CO_2 emissions over ICEV.

For those air pollutants (e.g., VOC) primarily from vehicle usage, BEV is the best technology

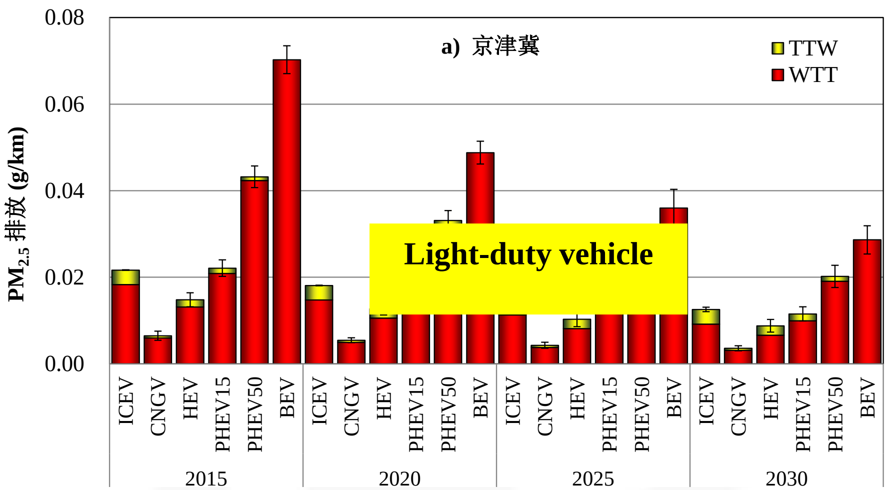
Light-duty vehicle

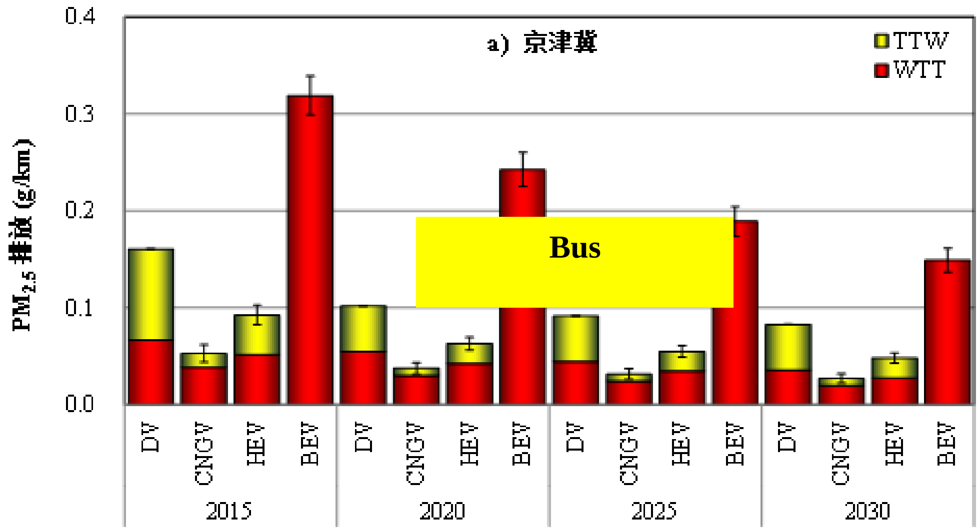


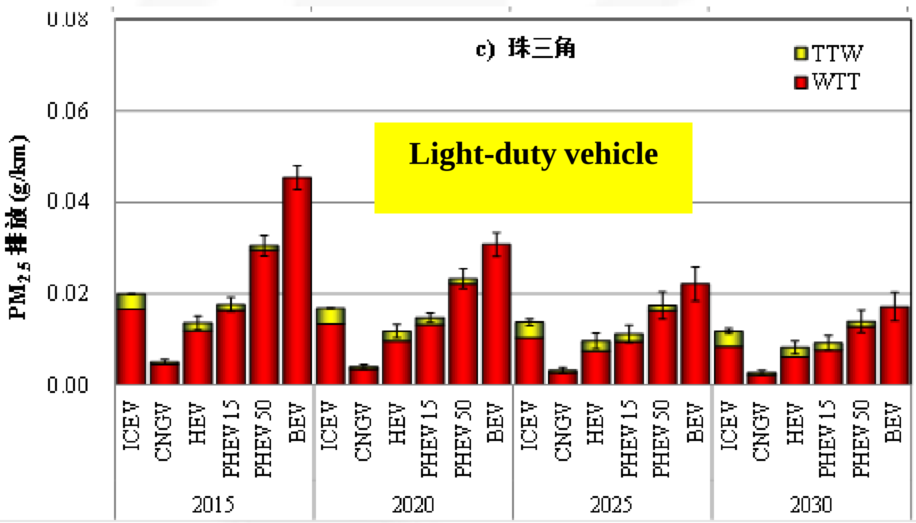
Bus

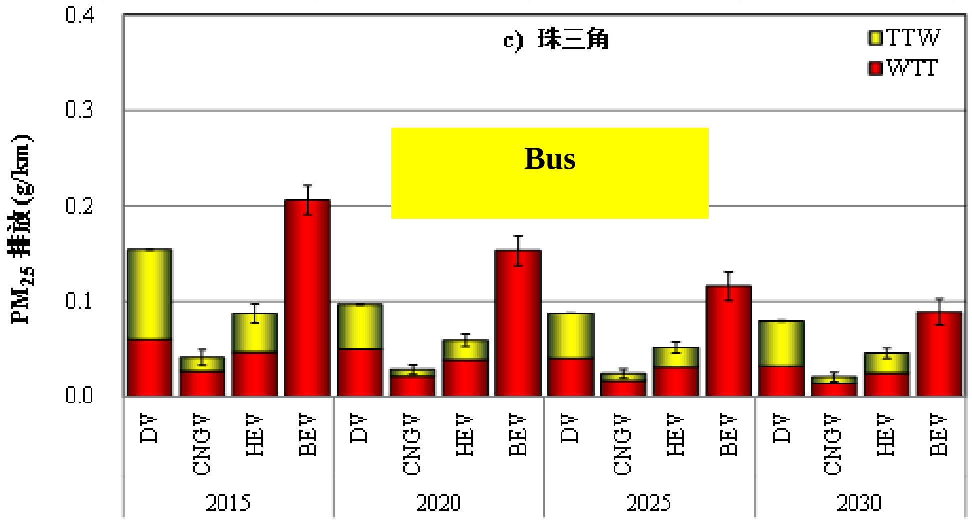


For those air pollutants (e.g., primary $PM_{2.5}$) primarily from upstream power plants, BEV will be worse than ICEV

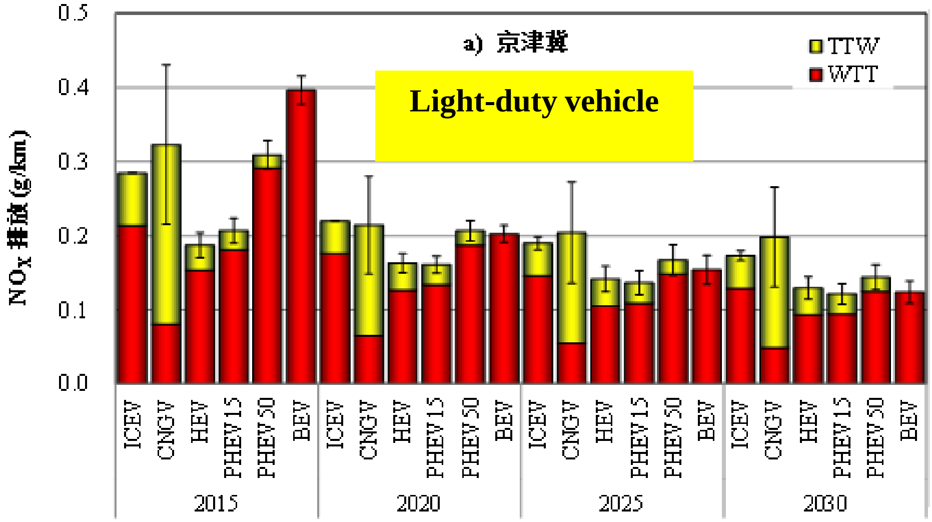


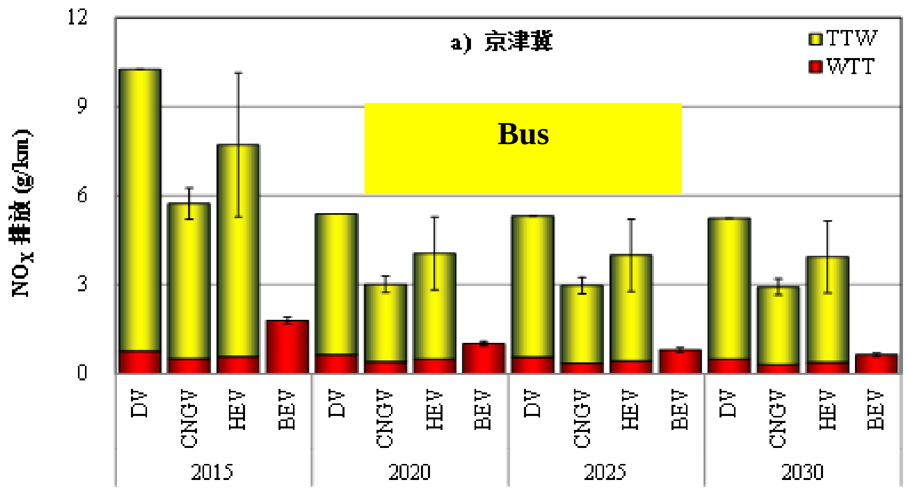


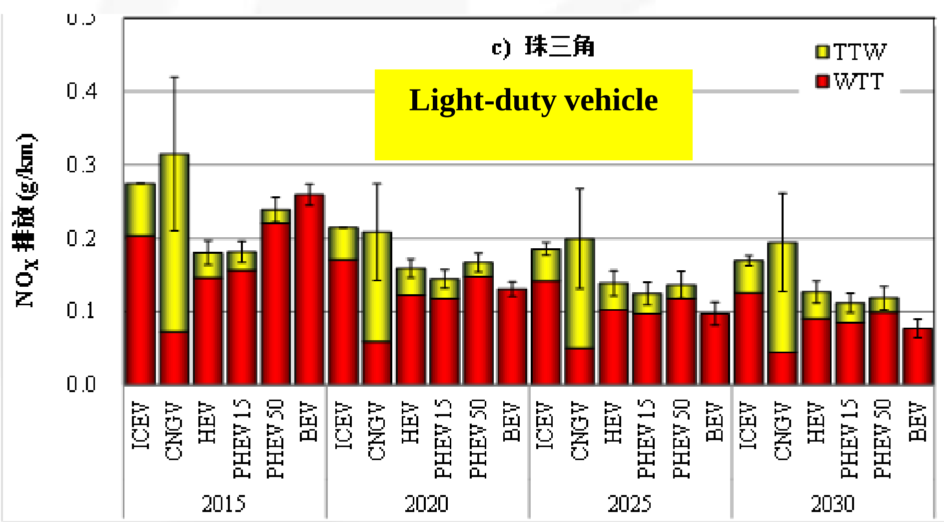


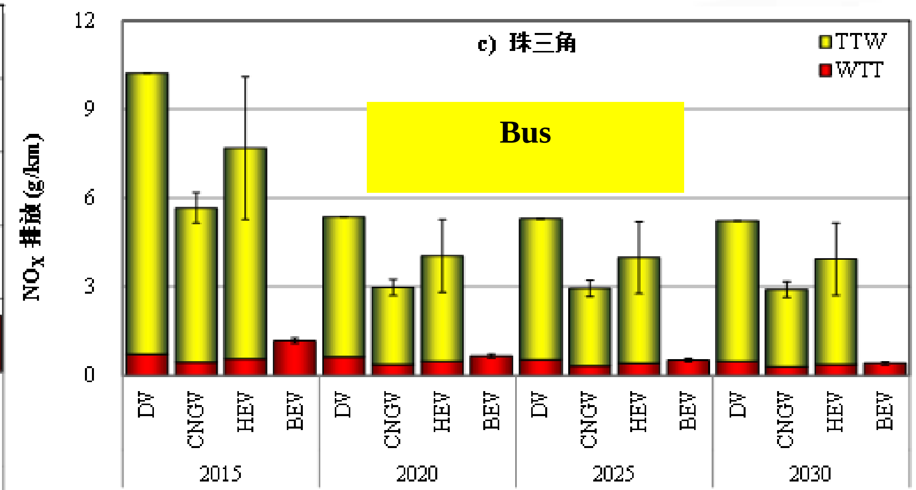


BEV bus can achieve the best NO_X reduction benefit; however, for BEV cars its NO_X reduction are mainly relied on the upstream cleaner power.









Conclusion and Policy Suggestion (1)

- **The promotion of EVs can greatly improve the oil energy security**
  - ✓ PHEV15/PHEV50 can reduce 40-50% petroleum consumption
  - ✓ BEV consume little oil

Conclusion and Policy Suggestion (2)

- **The benefit of fossil fuel use and CO_2 emissions for EV are strongly relevant to generation mix, coal technology, fuel economy, material energy efficiency, etc.**
  - ✓ **Petroleum consumption benefit>Fossil fuel use reduction>CO_2 emissions reduction**
  - ✓ The fossil fuel and CO_2 reduction benefit are BETTER in the cleaner electricity regions, while WORSE in the higher coal-share regions
  - ✓ The HEV and PHEV15 can achieve better reduction benefit on fossil fuel and CO_2 reduction in the near-term in higher coal share regions
  - ✓ Currently, full life cycle CO_2 use for BEV is not better than conventional ICEV, the upstream energy saving such as for vehicle materials need to pay special attention

Conclusion and Policy Suggestion (3)

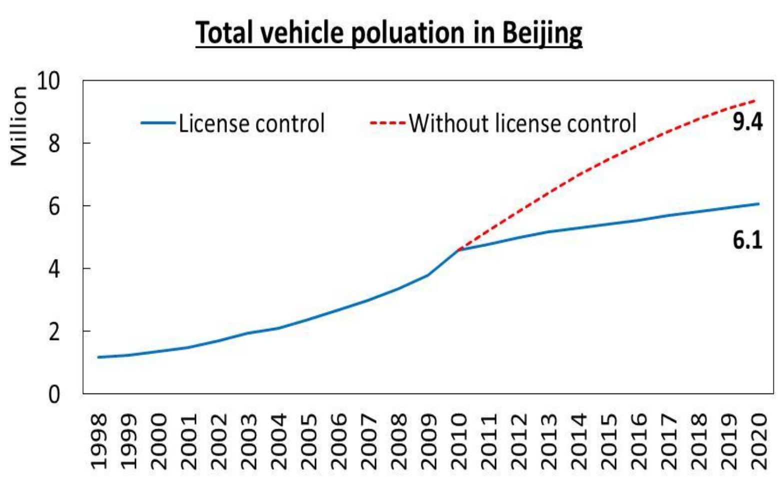
- **Before 2020: The BEVs could be treated as zero emission vehicle, considering the petroleum and emission reduction during TTW stage**
  - ✓ BEV: The fuel consumption, CO_2 emission and air pollutant emissions are zero.
  - ✓ PHEV: Set different reduction ratios for fuel economy and pollutant emissions based on the AER and VKT in China.
- **After 2020: We should balance the energy use, CO_2 and pollutant emissions for new energy vehicles from the perspective of life cycle.**

Conclusion and Policy Suggestion (4)

- **Promotion of BEV can reduce VOC and CO greatly, but will increase SO_2 and primary $PM_{2.5}$ in the near term. Therefore, a scientific evaluation of environmental and human health impacts of EVs in urban and regional scale needs to be conducted.**
- **The promotion of EV should:**
  - ✓ Increase renewable clean electricity (Solar energy and wind)
  - ✓ Use high efficient coal power technology (e.g., ultra-supercritical and IGCC)
  - ✓ Use high efficient vehicle material technologies
  - ✓ In the regions with high efficient APCDs (e.g., FGD/SCR/ESP/FF), promote EV preferentially

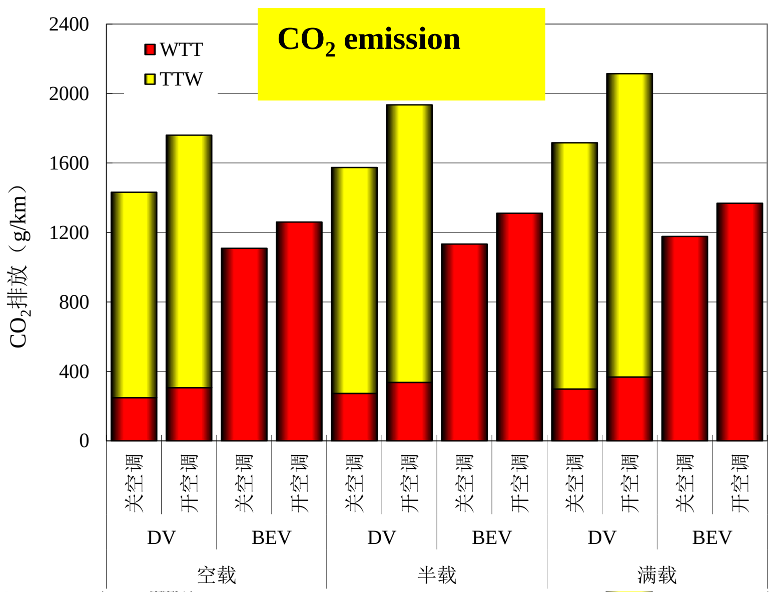
EV Promotion vs. Total Vehicle Quantity Control in Major Regions and Cities

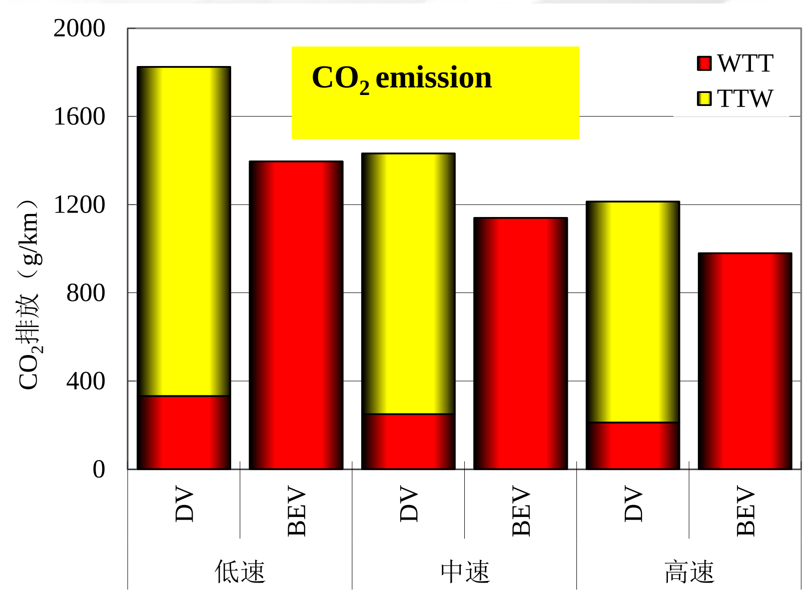
Vehicles are highly concentrated in large cities/metropolis areas and major regions in China. Going forward, **control on total vehicle quantity (ownership + activity level)** will become the top priority of vehicle emission control: **how to balance EV promotion and the alleviation of traffic congestion?**

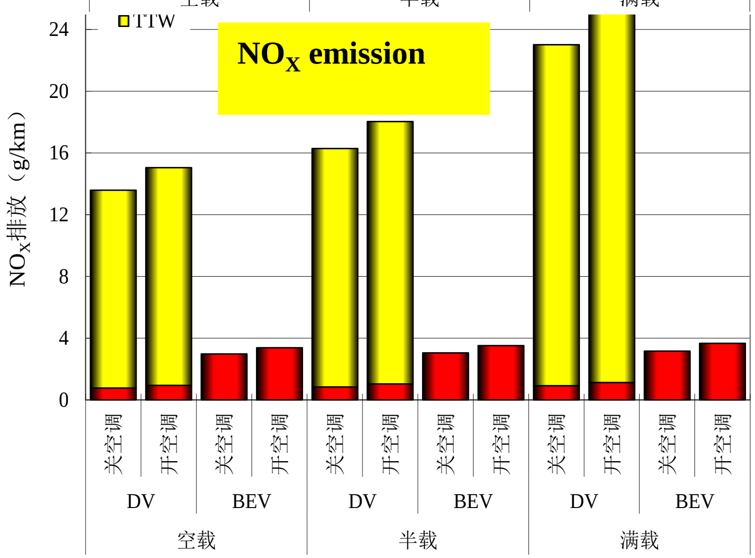


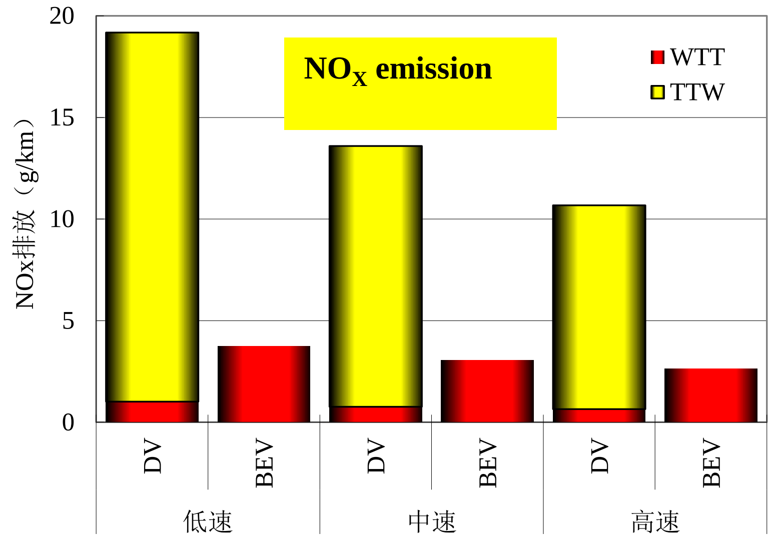
Note: cities marked in red have taken purchase restriction measures

Under most test conditions, electric buses tend to obtain greater energy saving and emission reduction advantage under low-speed congestion, activated air-conditioner or full load, and other “harsh” conditions









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Cummins

Thank you for your attention !

Questions ?

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