中国新能源汽车推广的节能和CO_2减排影响
Full Life-cycle Energy Use and CO_2 Emissions of New Energy Vehicles in China

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轻型汽车节能法规与技术路径国际研讨会

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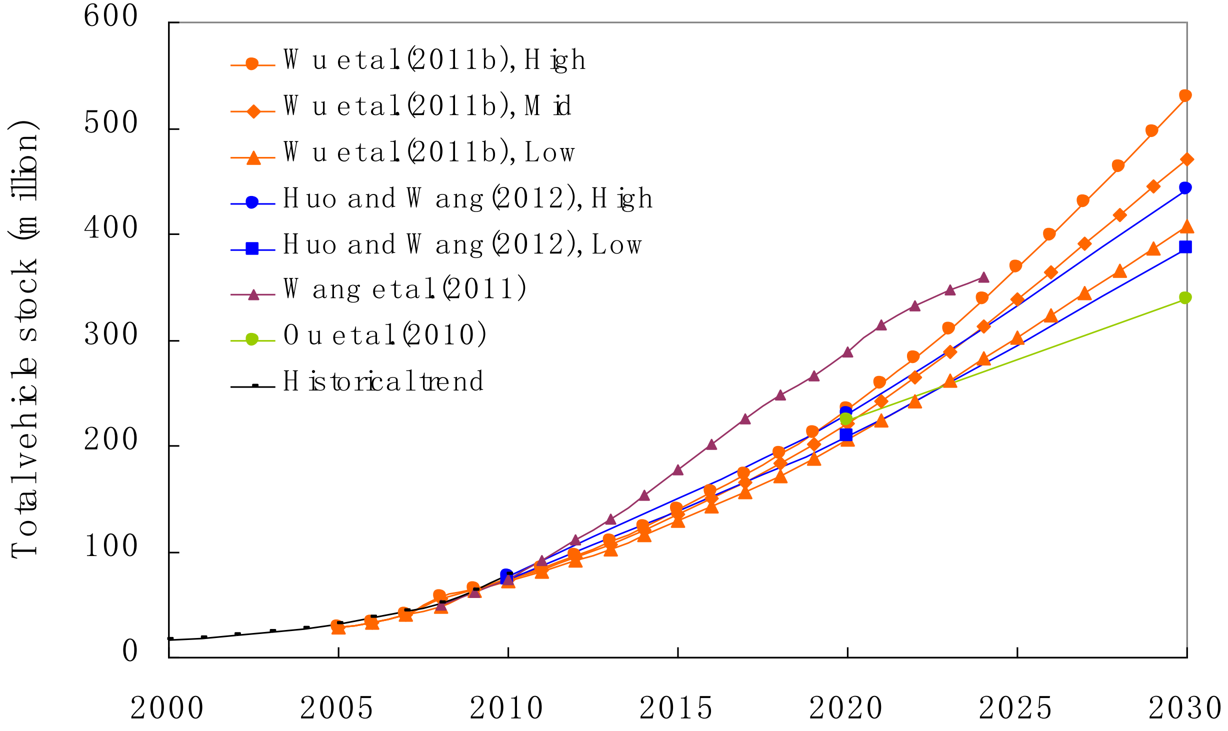
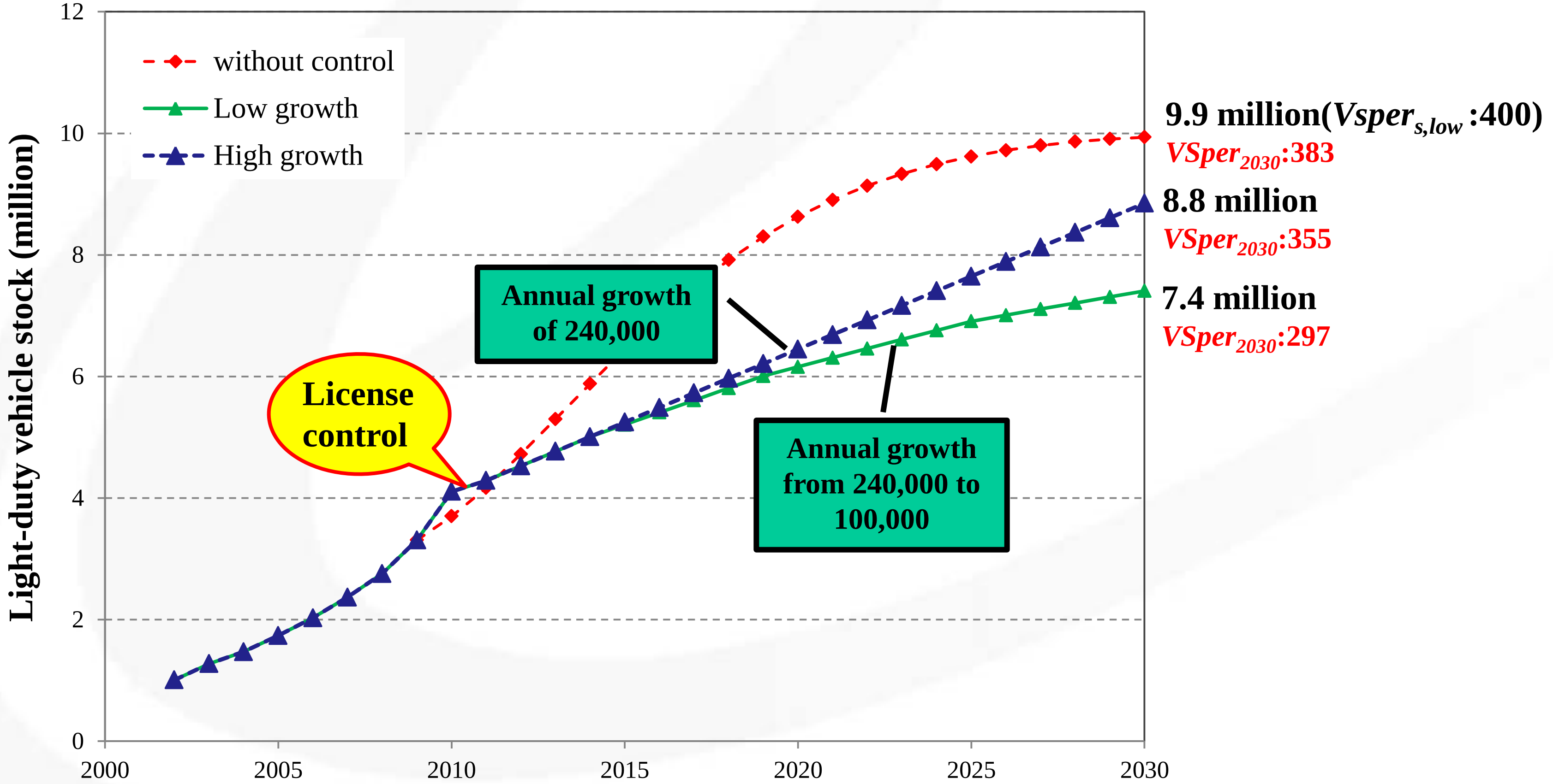
中国正在快速进入汽车时代：挑战和机遇？
Leading auto market: challenges or opportunities?

国内外多项研究均显示：**2020年**我国汽车保有量将达到**2.0-2.5亿辆，2030年**达到**3.5-5.0亿辆**！**2025年前后**将成为**全球汽车保有量最大**的国家！



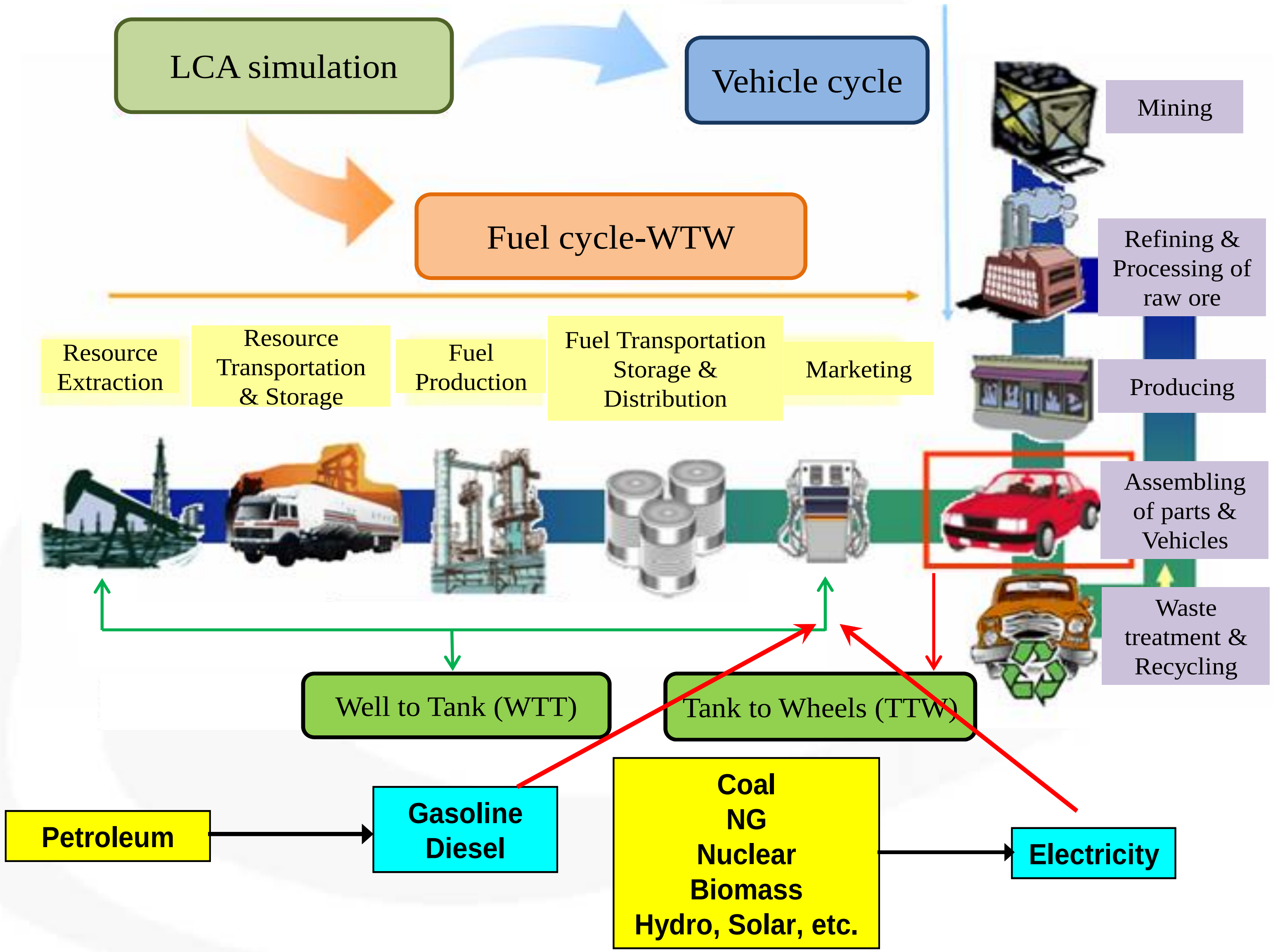
The trend in future auto stock is changing for Beijing and other megacities

Due to the current "license control" policy, estimated trend for Beijing is rather different.



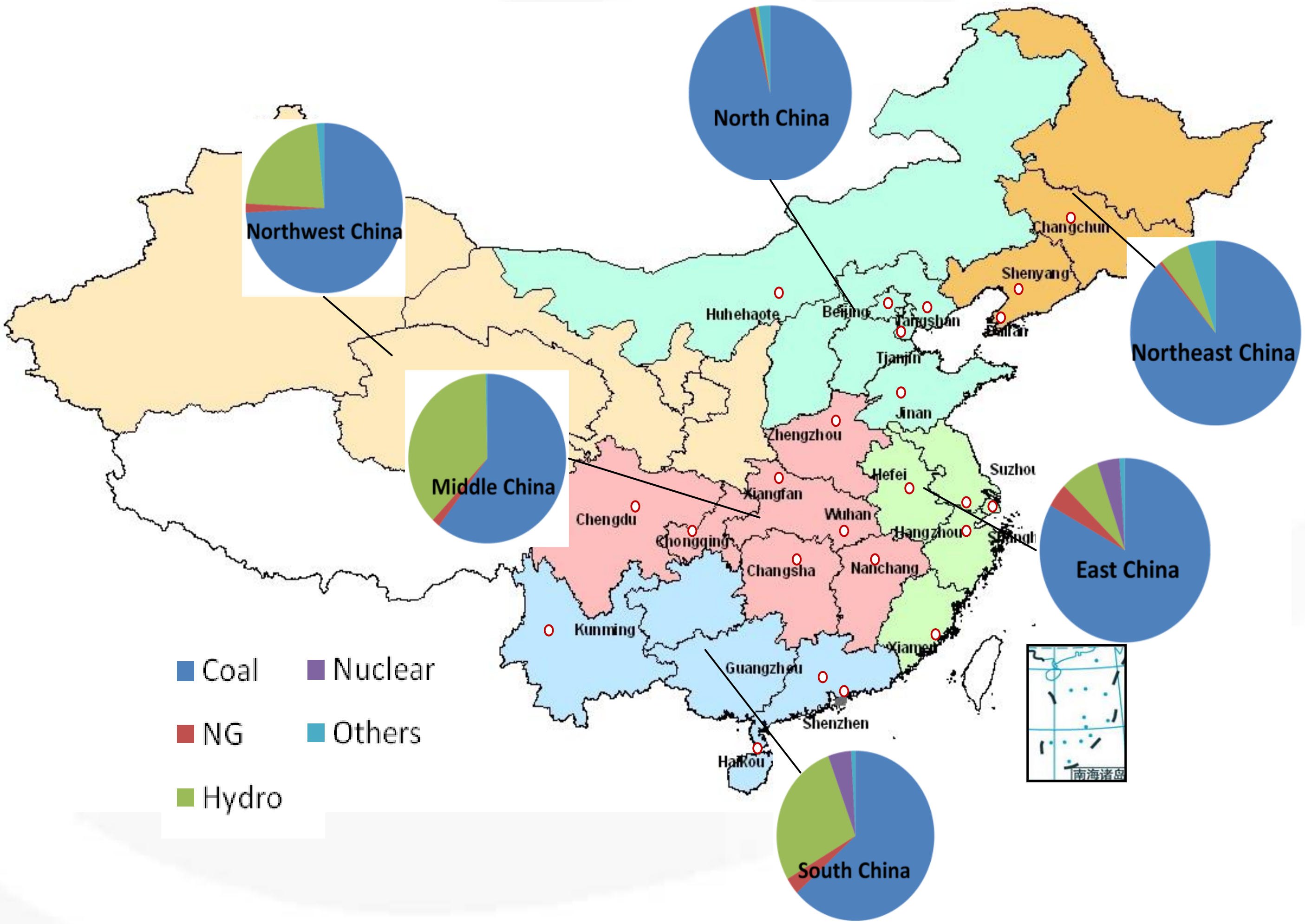
New energy vehicles are penetrating in China

LCA needs to be used to fully evaluate energy and CO_2 impacts of new energy vehicles

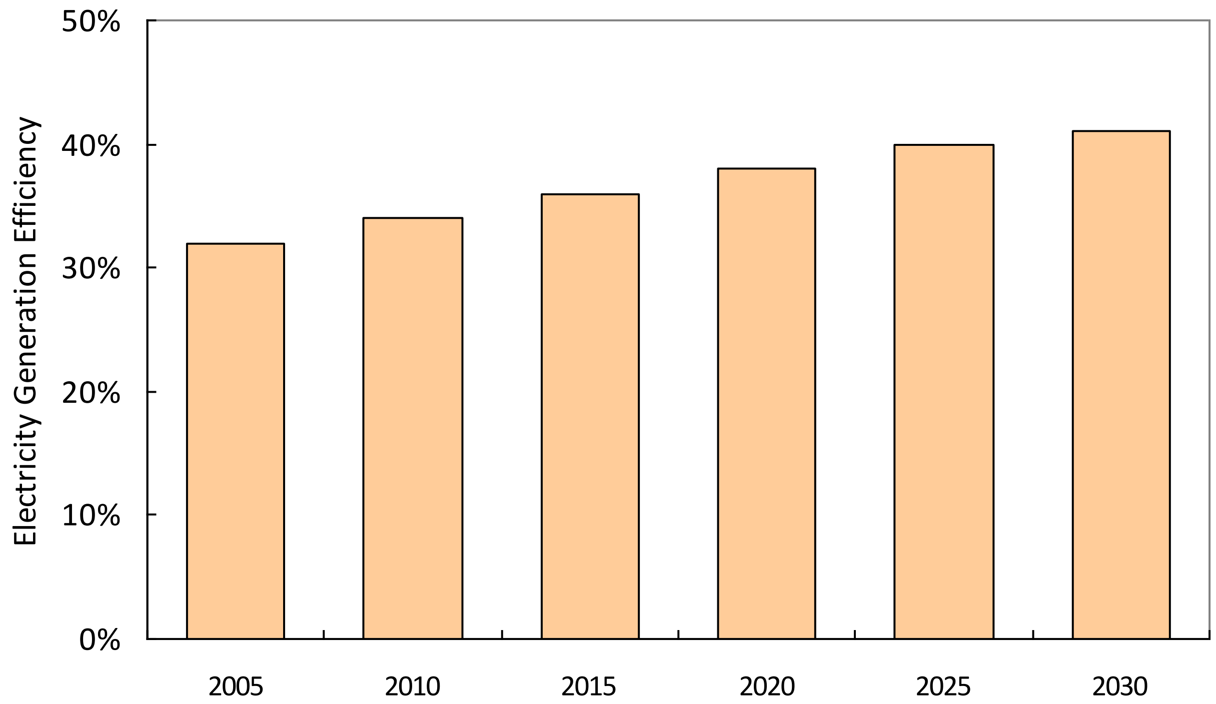


Average electricity generation mix - Regional

Regional electricity generation in 2010



Energy efficiency of coal power, 2010-2030



Data Sources:

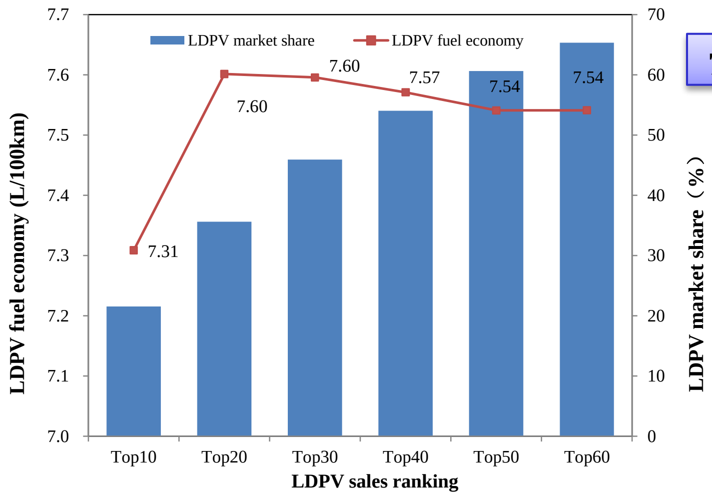
1) 2010's data (**34%**): China Energy Statistical Yearbook

2) Generation efficiency for supercritical (39%), ultra supercritical (42%) and IGCC (47%): IEA, ANL, local test data, etc.

3) The forecast of capacity of each major technology: IEA, CAE, ERI, CEPRI, etc.

Fuel economy estimate for light-duty gasoline vehicles in China, 2010-2030

Lab-test fuel economy values



7.5L/100km

On-road fuel economy values

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

Current situation

- Wang et al. (2010) reported 8.1 L/100 km in 2006, 12% lower than that in 2002 (9.1 L/100 km)
- Wagner et al. (2009) and Huo et al. (2011) further reported 7.9 and 7.8 L/100 km in 2009

The goal of fuel economy for future

- 2015: 6.9 L/100 km; *Plan for Energy Saving and New Energy Vehicles Industry Development* (the State Council, 2012)
- 2020: 5.0 L/100 km;
- U.S. National Academy of Science (NAS) scenarios and other data sources

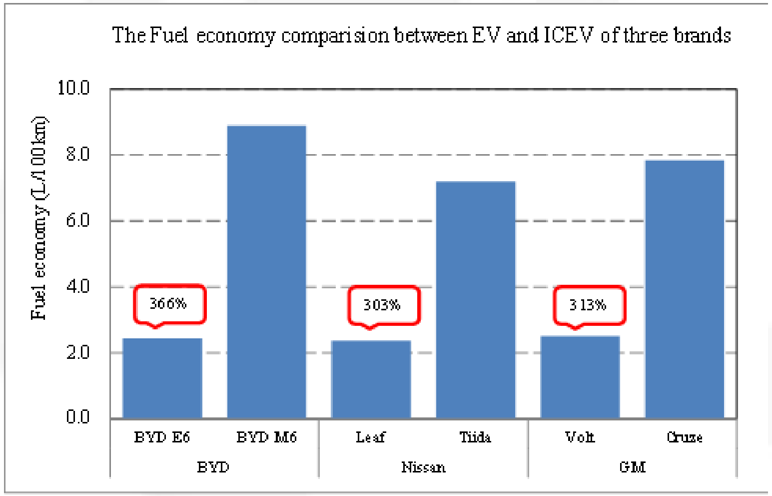
Adjustment of on-road vs. lab-tested fuel economy needs to be considered (~15% higher on road)

Fuel economy estimate for HEV/PHEV/BEV

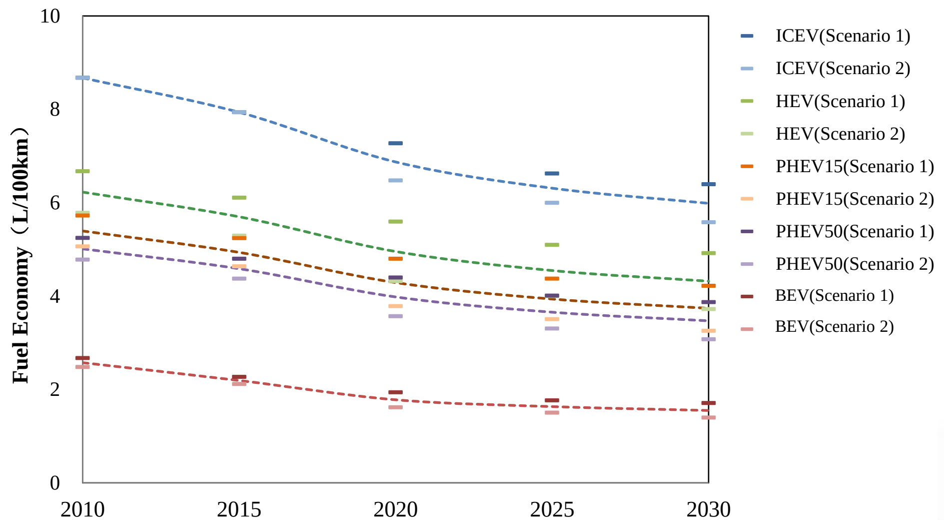
HEV (fuel economy)

Brand	Vehicle	Comparison Vehicle	Fuel Economy Improvement: User-Reported	Fuel Economy Improvement: Old EPA Combined	Fuel Economy Improvement: New EPA Combined	Fuel Consumption Decrease: User-Reported	Fuel Consumption Decrease: Old EPA Combined	Fuel Consumption Decrease: 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)



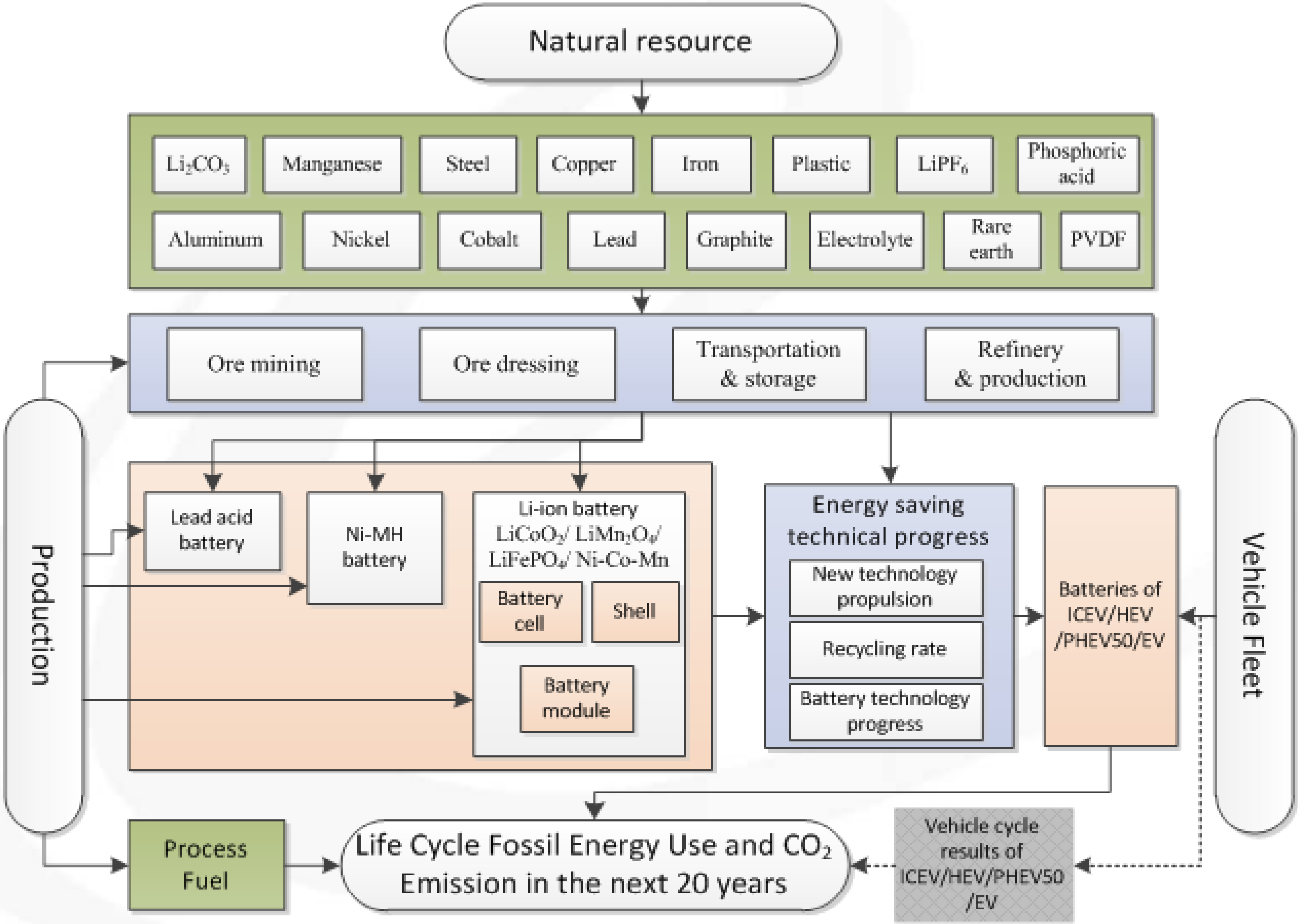
HEV/PHEV/BEV:



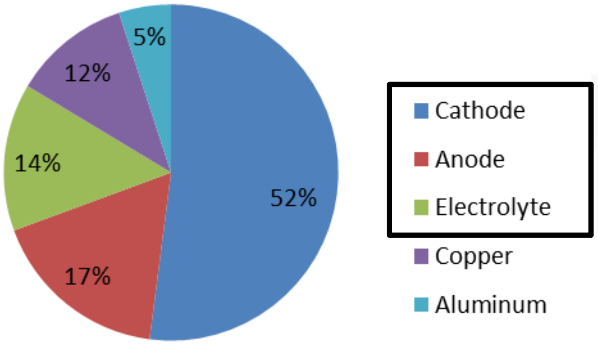
Data Source (fuel economy ratio relative to ICEV):

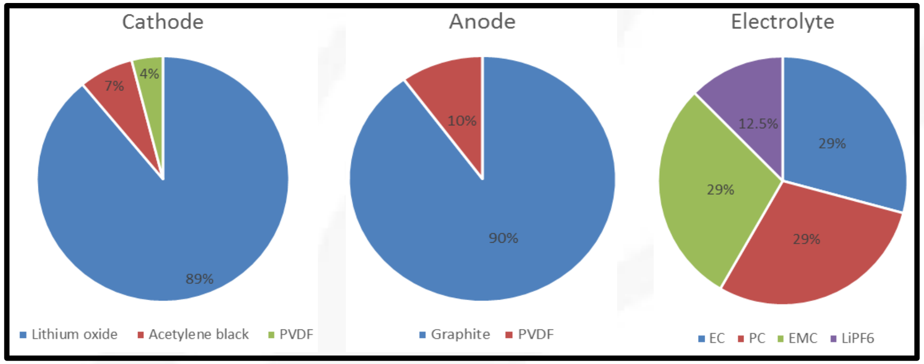
- ◻ HEV: **130-150%,** from GREET2012, Bennion and Thornton , etc..
- ◻ PHEV50: CD mode **270-290%**， CS mode **110-130%**; from GREET2012.
- ◻ PHEV15: CD mode **180-190%**， CS mode **150-170%**; from GREET2012.
- ◻ BEV: MY2010: **325-350%;** MY2030: **375-400%;** from GREET2012, and BYD E6 and Nissan Leaf test data.

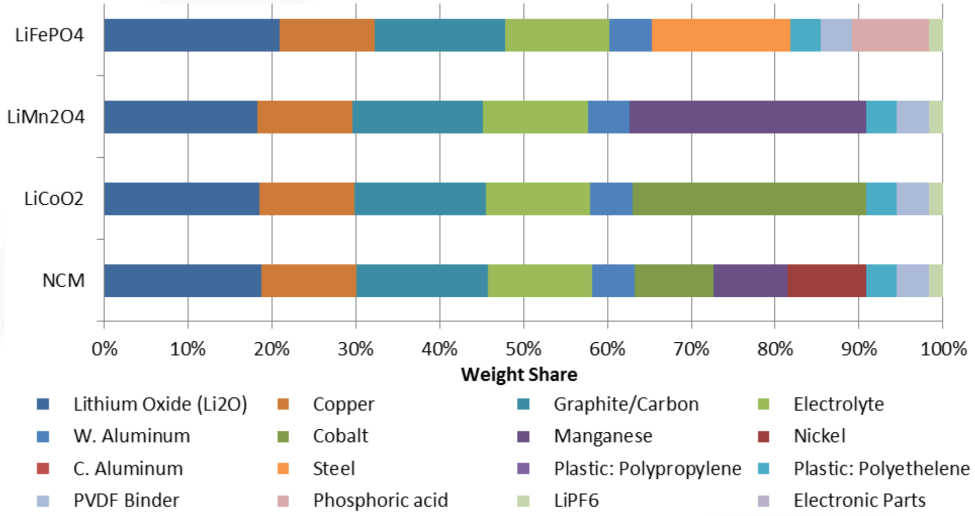
Vehicle material and component cycle



2.3 Material balance of major batteries



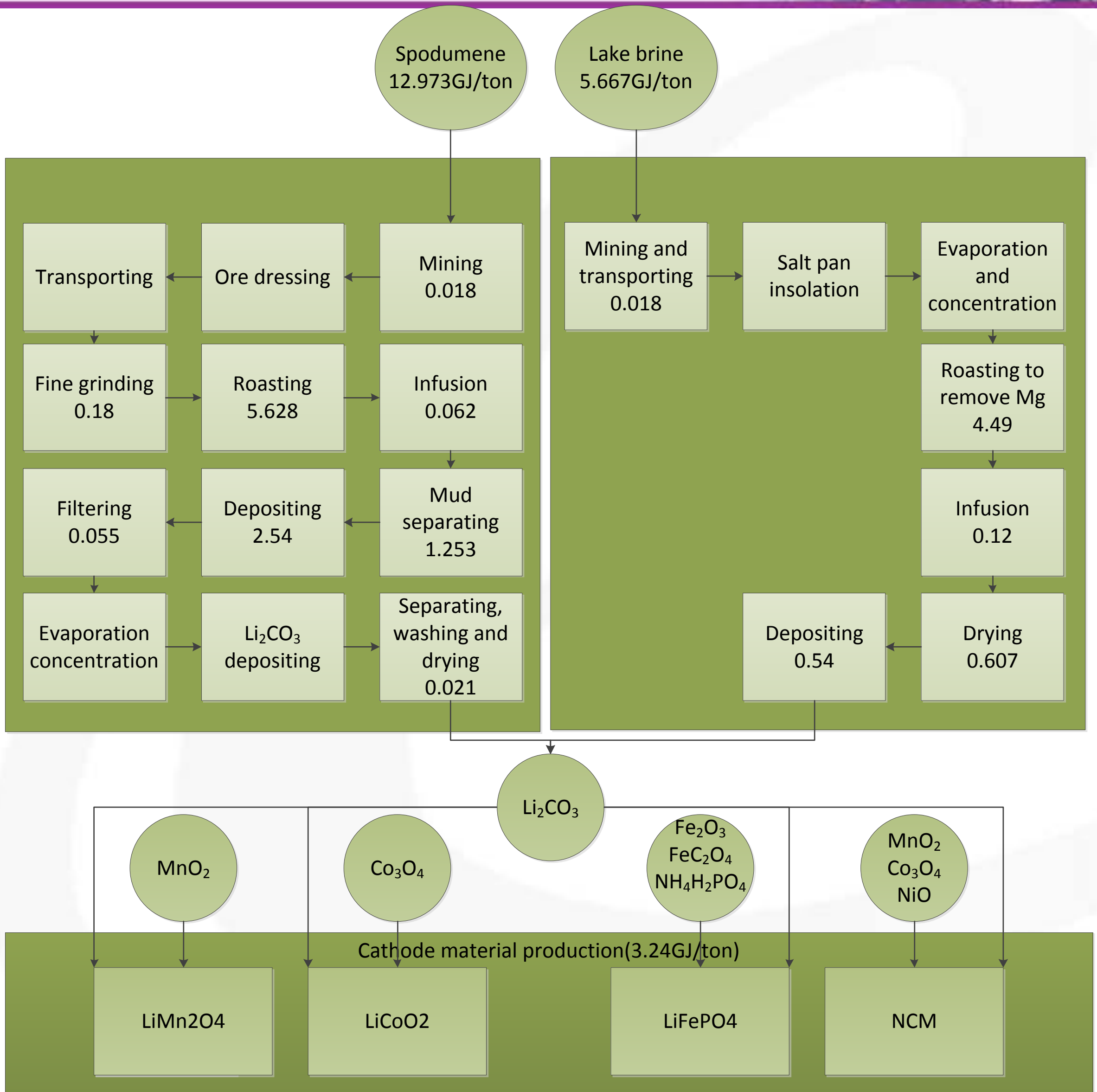




Stoichiometry Method

- Split the Li-ion battery into sub-components: such as anode, cathode, electrolyte, shell, etc.
- Li-ion battery has similar material composition for all sub-components except for cathode.
- Key material balance data are further proved by ICP/XRF test for a typical battery.

Energy use of key materials by major process: 1) Lithium

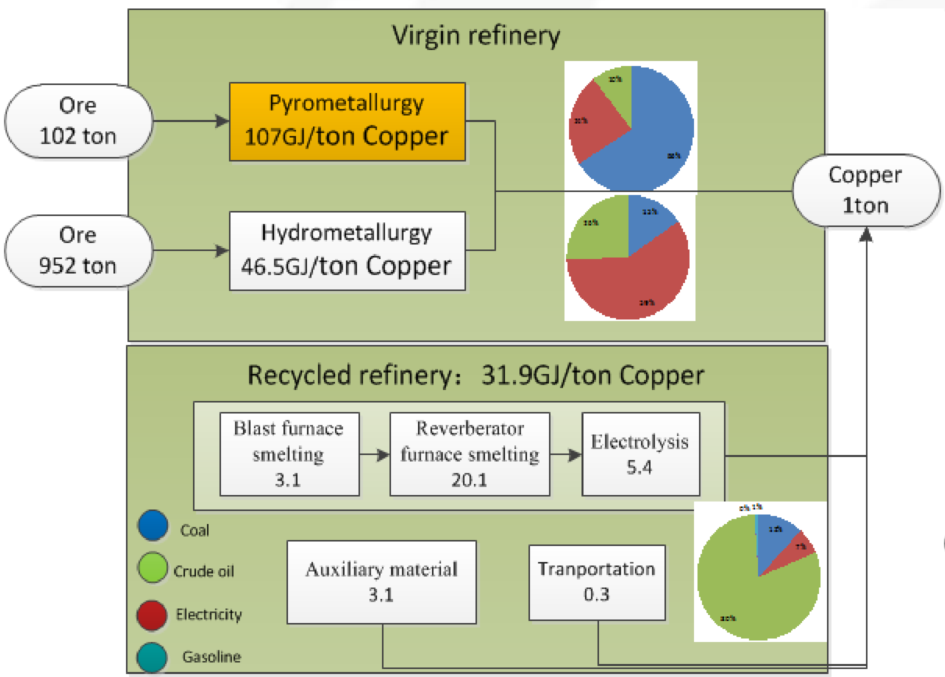


- Lithium, a major component in Li-ion battery, produced from two major sources: spodumene and lake brine (especially the latter).
- The energy intensity (5.7GJ/ton) for Li production from lake brine is 28% lower than that from spodumene.

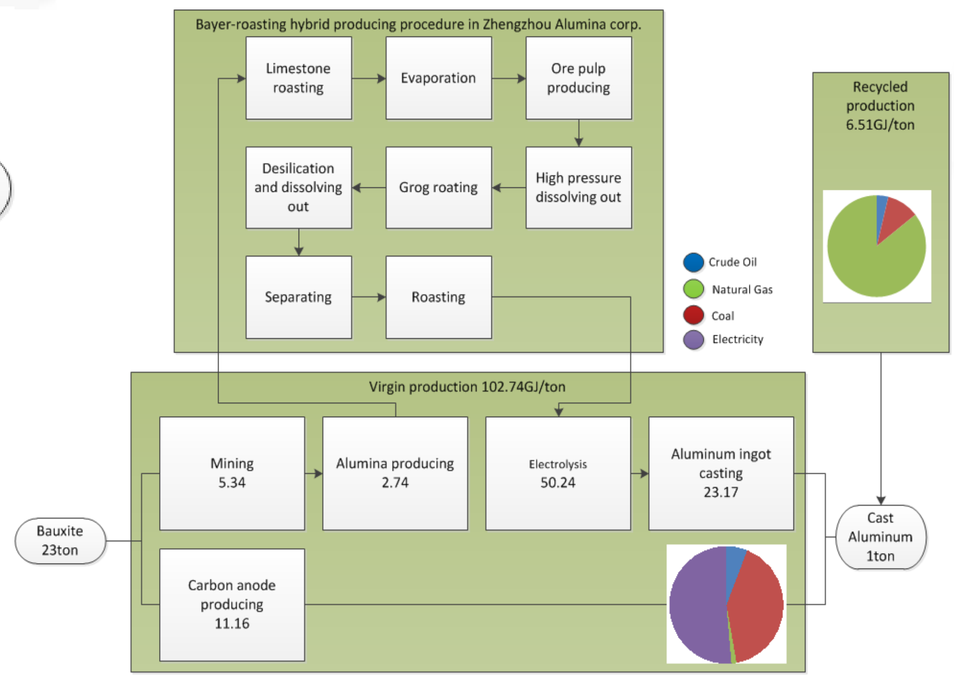
Energy use of key materials by major process: 2) Copper and Aluminum

- Copper/Aluminum are key materials in all batteries (acting as conductors and covers) as well as in other major vehicle components.
- Energy intensity might vary significantly by different production methods.
- Recycled material production consumes much less energy than the virgin material production.

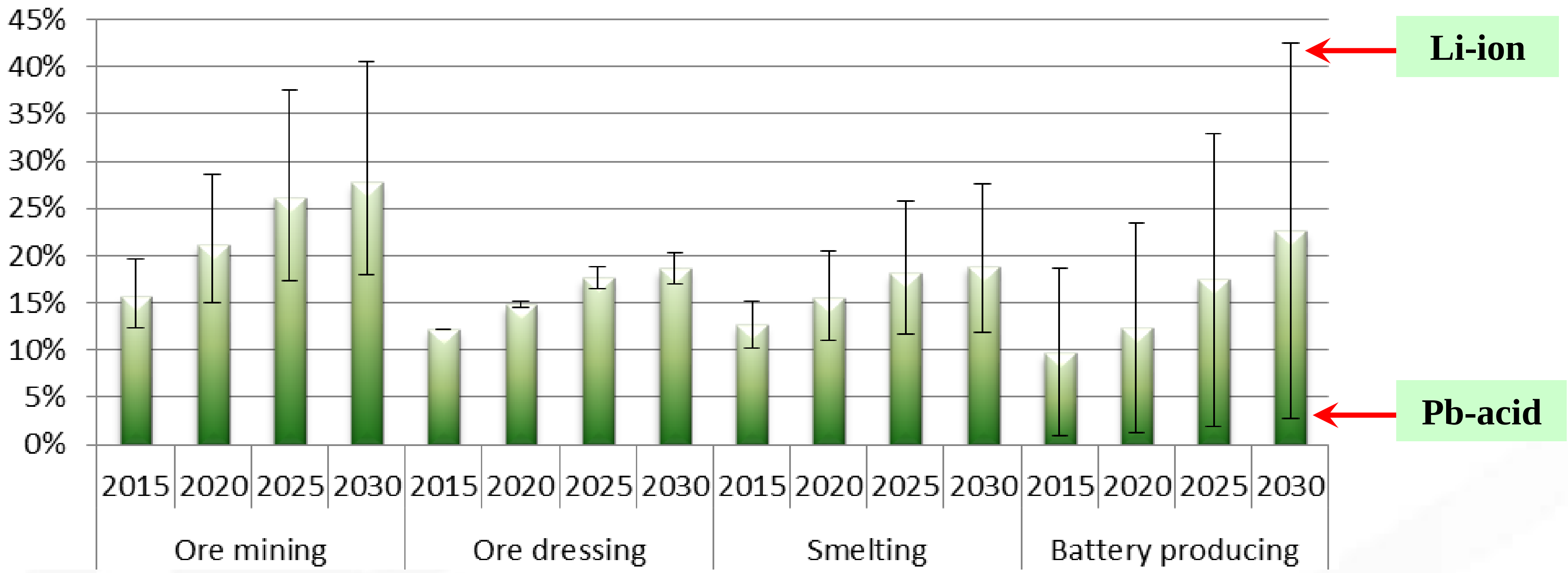
Energy and material flow of **copper** compounds in China



Energy and material flow of **aluminum** compounds in China

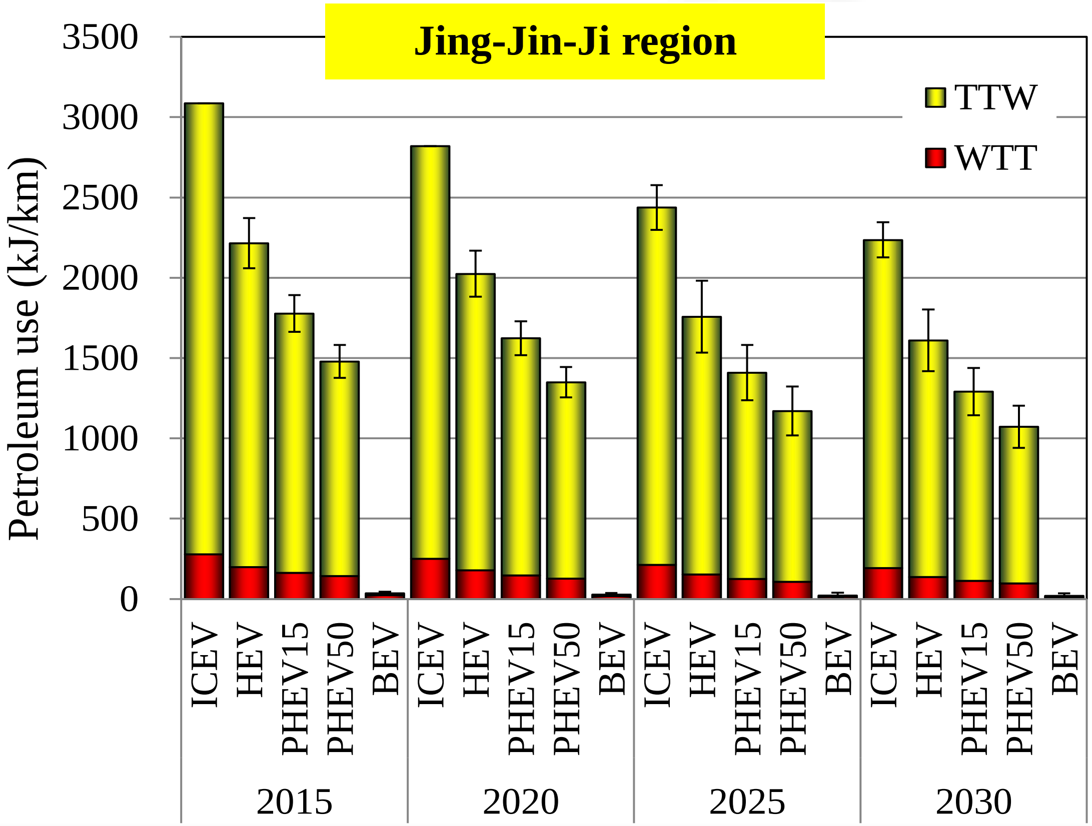


2.3 Technology improvement of material production and battery production



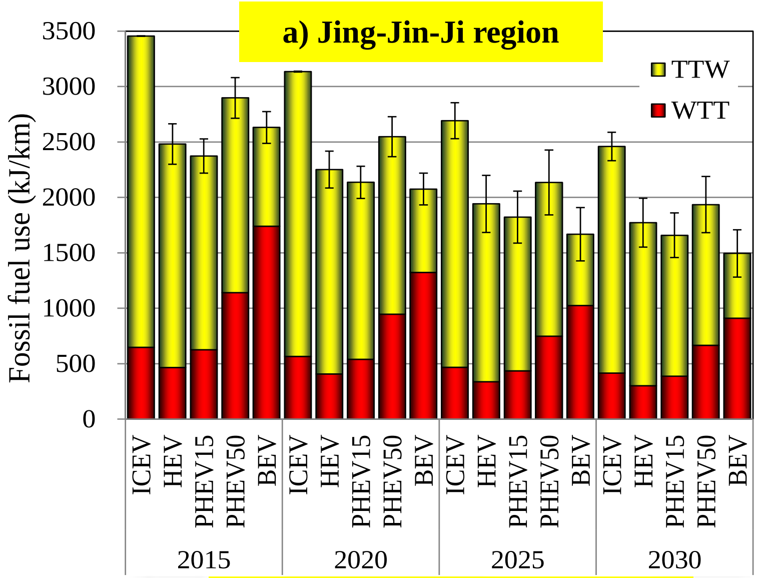
- **Many materials and vehicle components are experiencing significant improvement in production process in China:**
  - ✓ **4 different technology groups based on industry regulations were classified**
  - ✓ **Penetration of advanced technologies were projected based on a wide literature review**
  - ✓ **New vehicle component (e.g., Li-ion battery) might have more significant technology improvement than other traditional components**

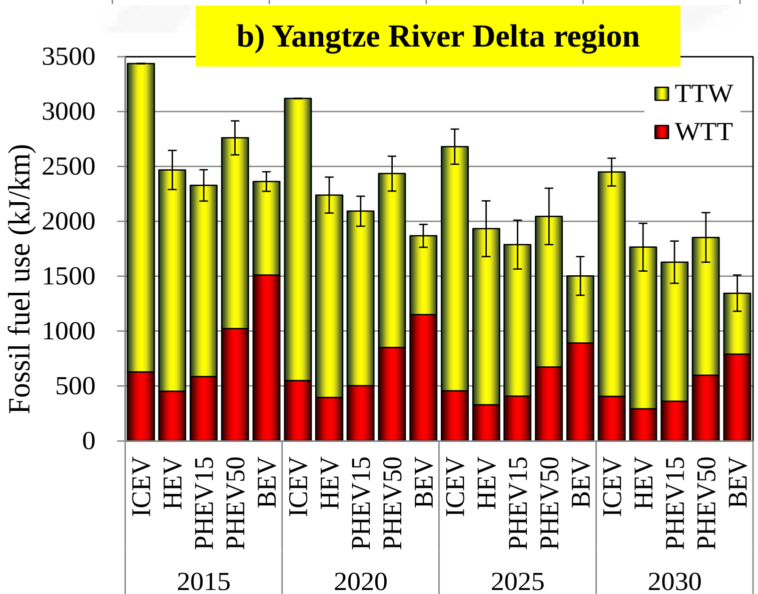
WTW petroleum use of ICEV/HEV/PHEV/BEV

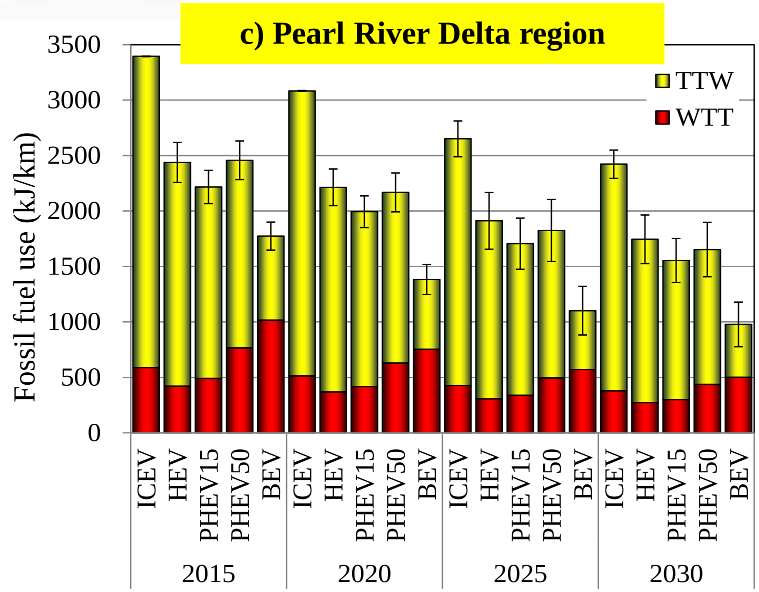


- HEV, PHEV15 and PHEV50 can reduce WTW petroleum energy use by ~30%, ~40%, and ~50%, respectively, relative to ICEV.
- BEV almost eliminates petroleum use.
- No remarkable difference among the six regions on petroleum use.

WTW fossil energy use of ICEV/HEV/PHEV/BEV

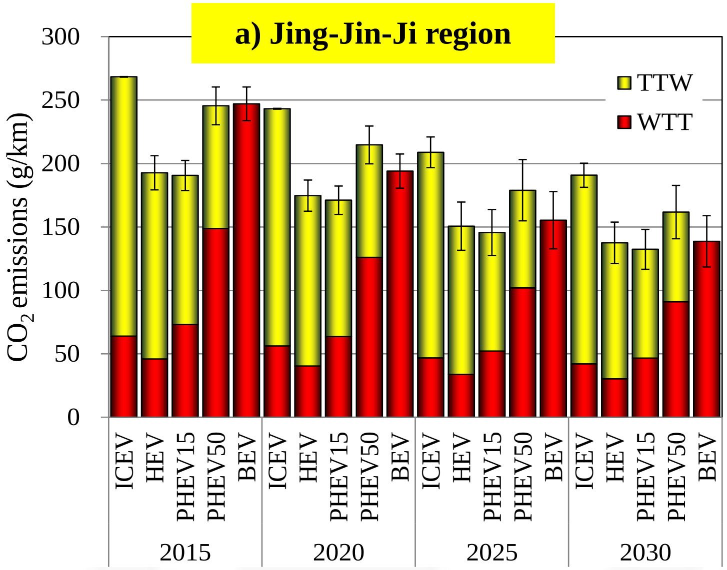


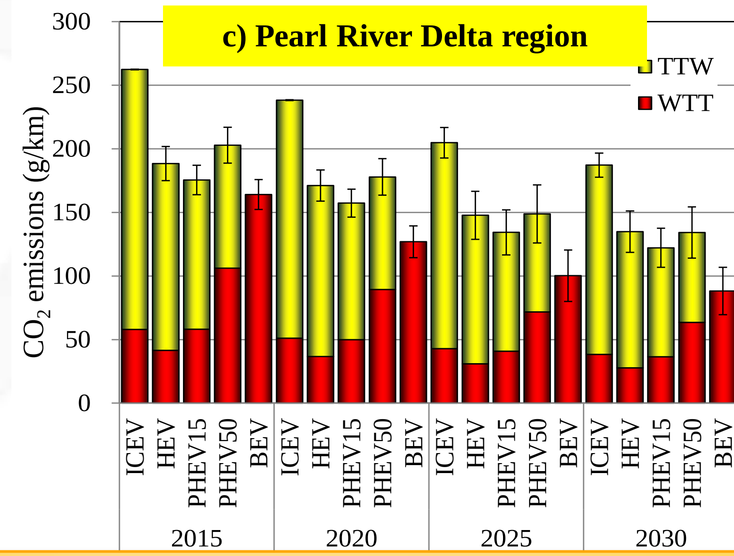


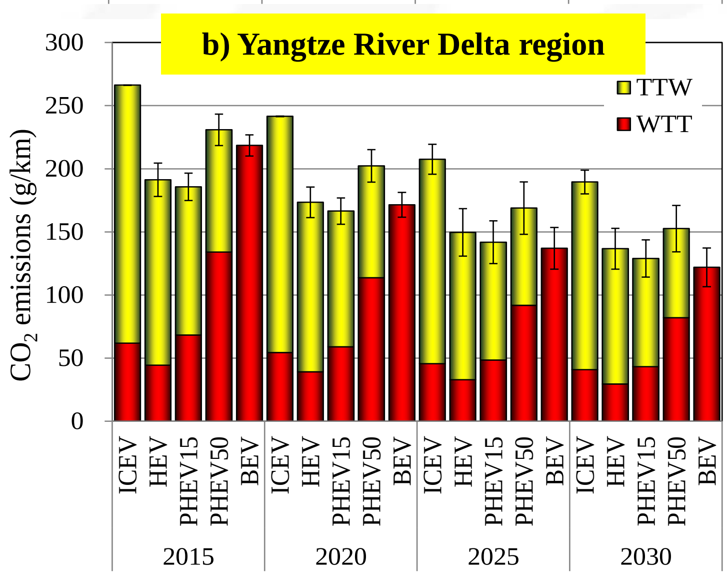


- **The WTW fossil energy use reduction benefit is less than that of petroleum use for PHEV/BEV.**
- **In those regions that have a sizeable proportion of clean electricity (e.g., Pearl-River-Delta region) will have considerable reduction benefit with promotion of BEV.**

WTW CO_2 emissions of ICEV/HEV/PHEV/BEV

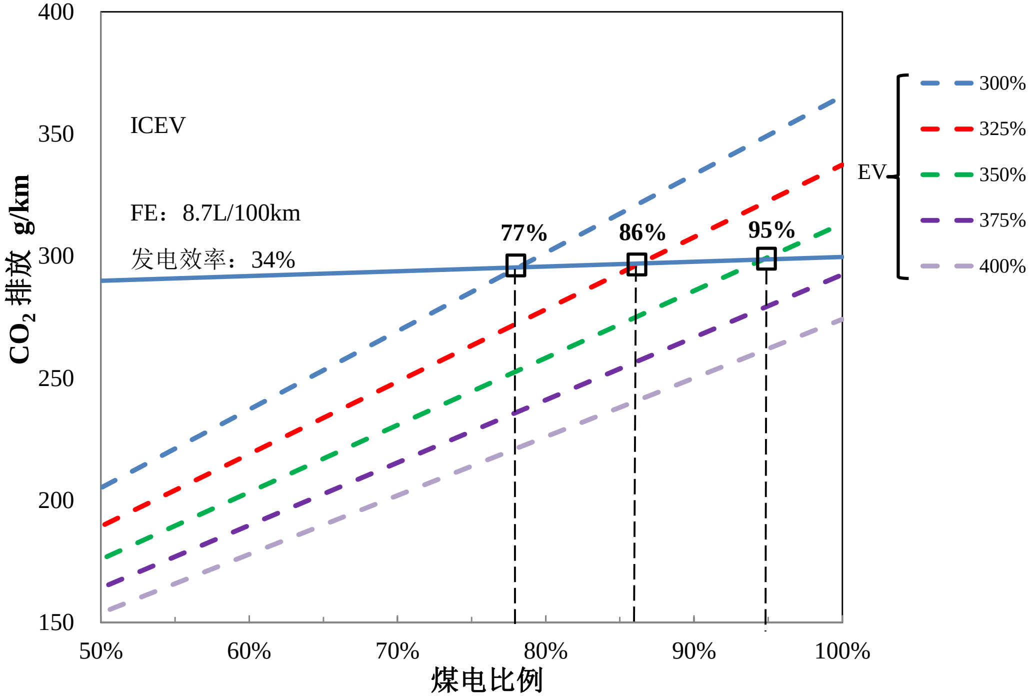


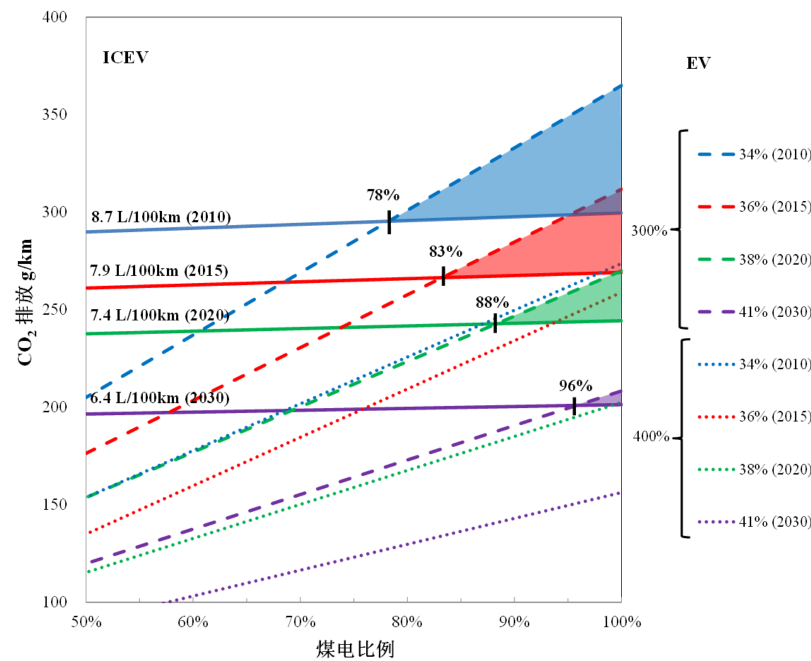




- **The WTW CO_2 reduction benefit is much less for PHEV50/BEV for those regions with dominant coal-fired power plants.**
- **In the region with a sizeable proportion of clean electricity will relieve the overall CO_2 burden substantially with promotion of BEV.**
- **HEV and PHEV15 is a better solution in near future to relieve WTW CO_2 emissions**

CO_2 breakeven of BEV vs. ICEV





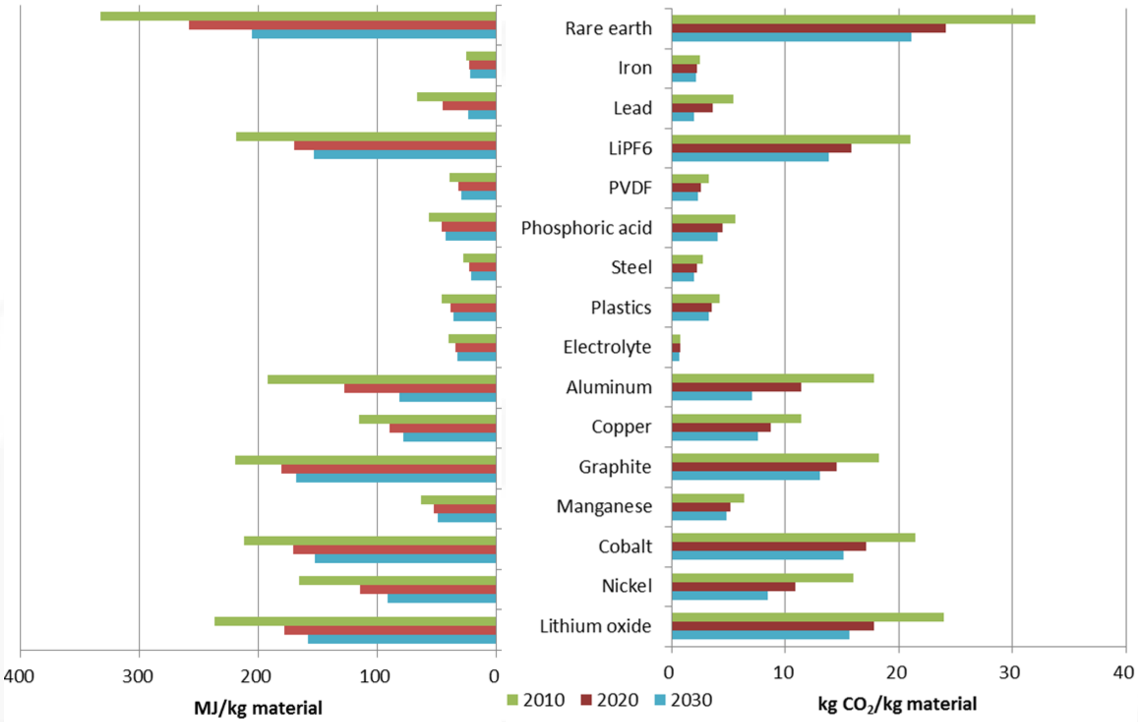
当发电效率为34%时（2010年水平）：

（1）BEV的FE为ICEV的300%：盈亏平衡点的煤电比例为77%。按照现在分地区电力构成，华北（96%），东北（89%），华东（83%）煤电比例均高于77%，ICEV优于BEV；其他地区BEV优于ICEV。

（2）BEV的FE为ICEV的350%：煤电比例为95%时ICEV与BEV持平。除了华北的所有其他地区BEV优于ICEV。

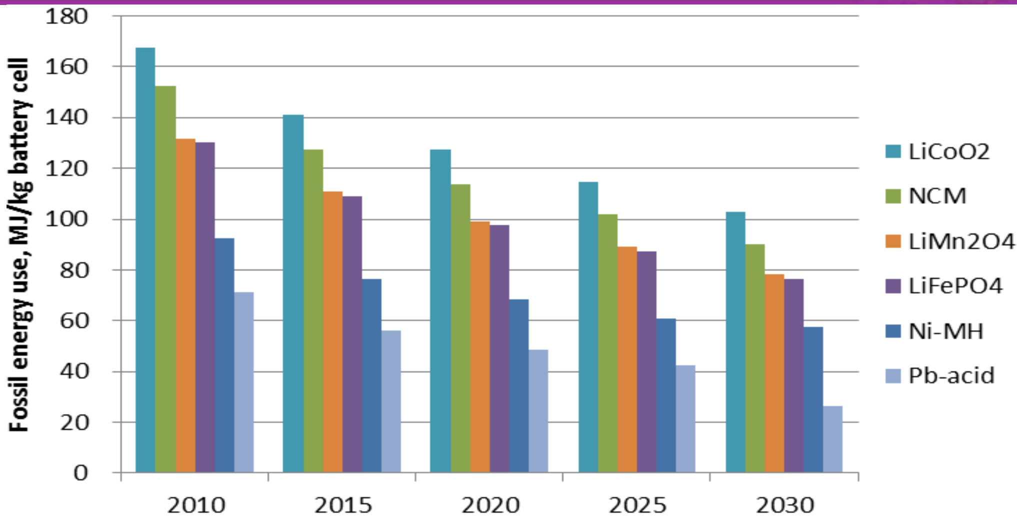
The CO_2 breakeven points between BEVs and ICEVs are relevant to several key parameters: fuel economy of ICEVs and BEVs, share of coal-fired power to total generation mix, and the generation efficiency of coal power.

Vehicle-cycle fossil energy use and CO_2 emissions of major vehicle materials



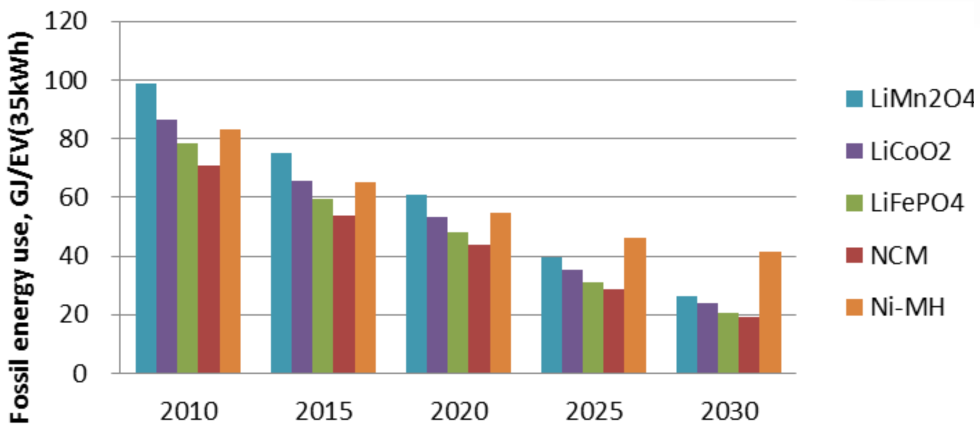
- In general, rare earth, aluminum, graphite, cobalt, LiPF6 and lithium oxide have relatively higher fossil energy use than other materials.
- Among cobalt, nickel and manganese, cobalt is the leading metal in both fossil energy use and CO_2 emissions.
- The fossil energy use and CO_2 emissions of almost 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).

Vehicle-cycle fossil energy use of different batteries

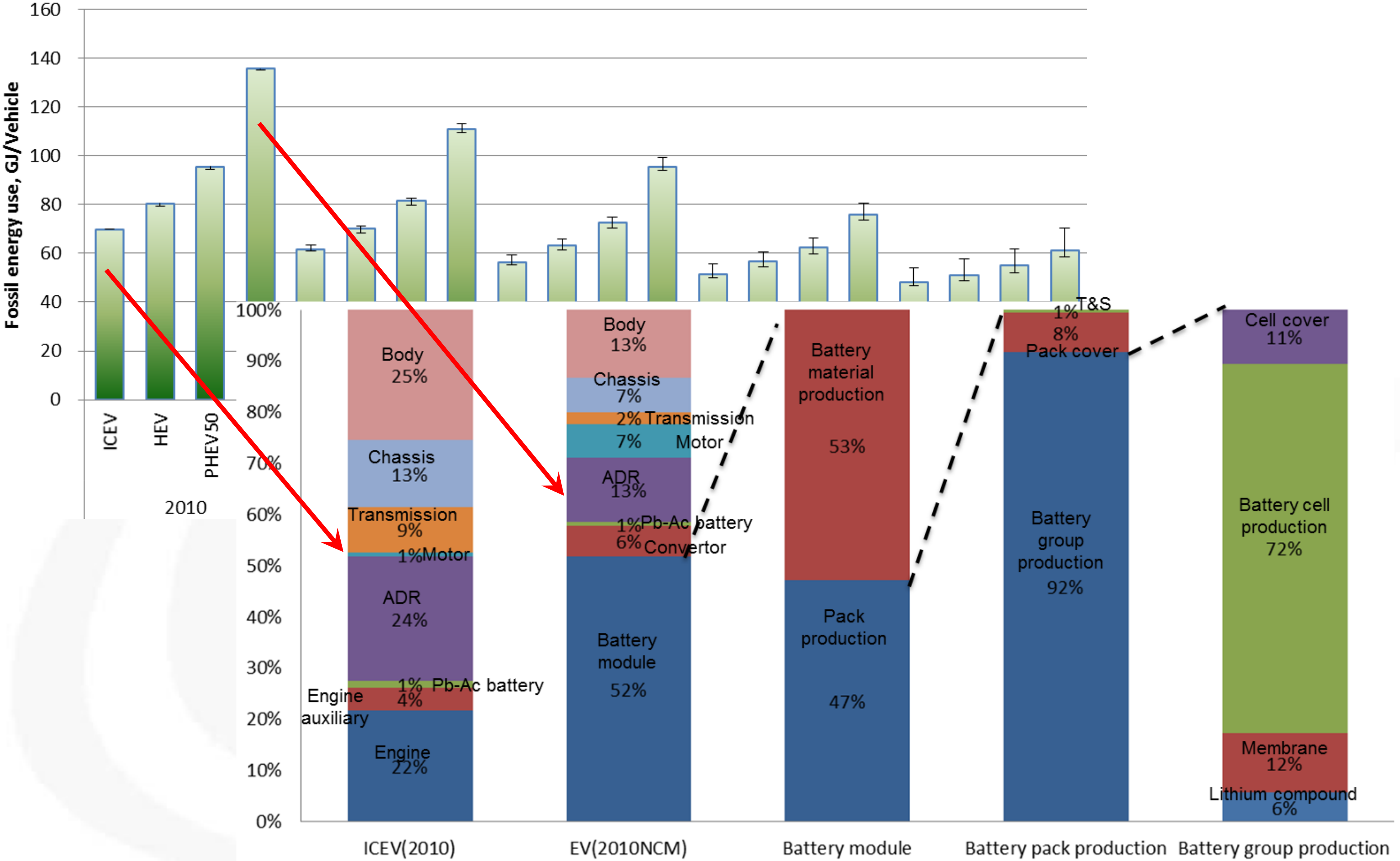


- **Based on per weight of battery, Li-ion battery consumes more energy: e.g., NCM is 1.5 times of Ni-MH and 2.4 times of Pb-acid in 2010.**
- **Among the four Li-ion battery cells, LiCoO2 has the highest fossil energy use per weight.**

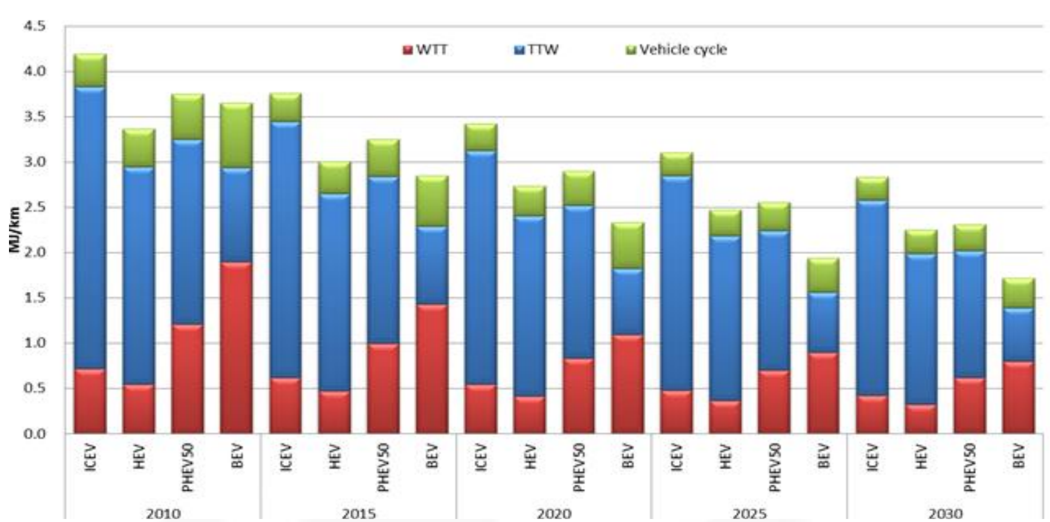
- **Considering the power density (e.g., 35 kWh for a AER=150km EV), Li-ion batteries have benefit from energy use, especially for NCM batteries.**
- **After taking technology improvement into account, Li-ion batteries would only consume much less fossil energy use than that of Ni-MH battery in a same EV.**

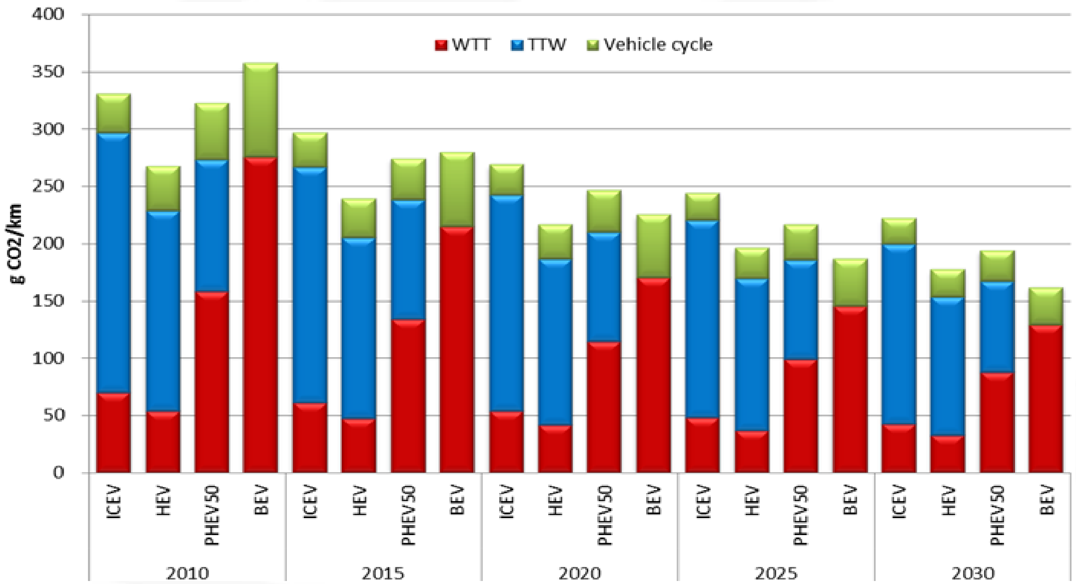


Vehicle-cycle fossil energy use of ICEV/HEV/PHEV50/BEV



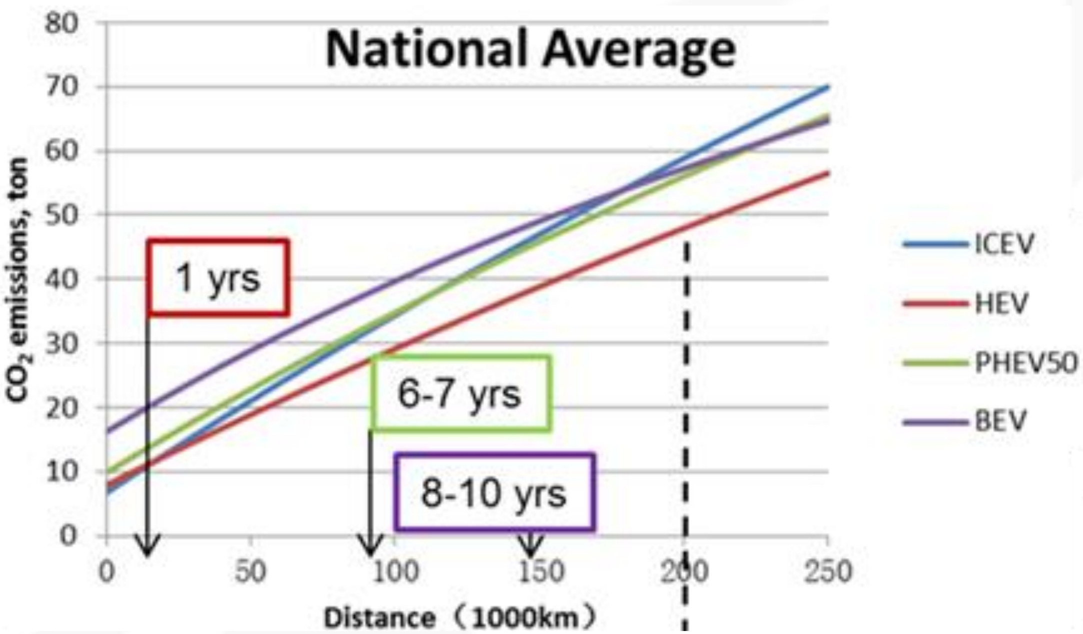
Full life-cycle fossil energy use and CO_2 emissions of vehicles

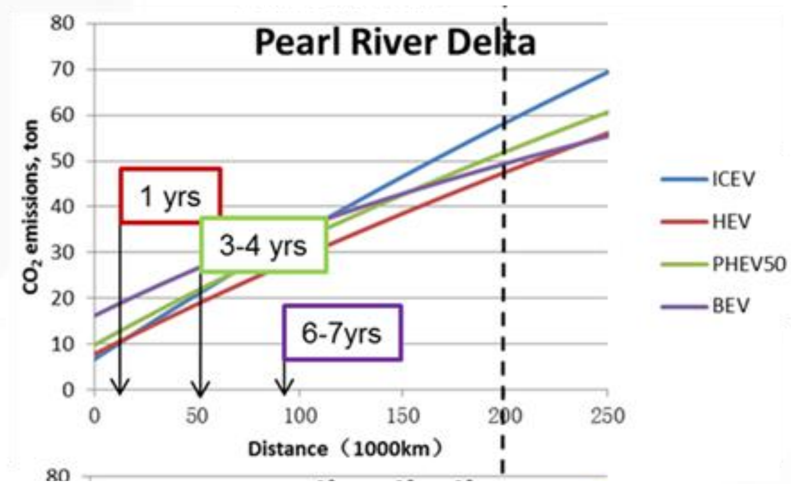


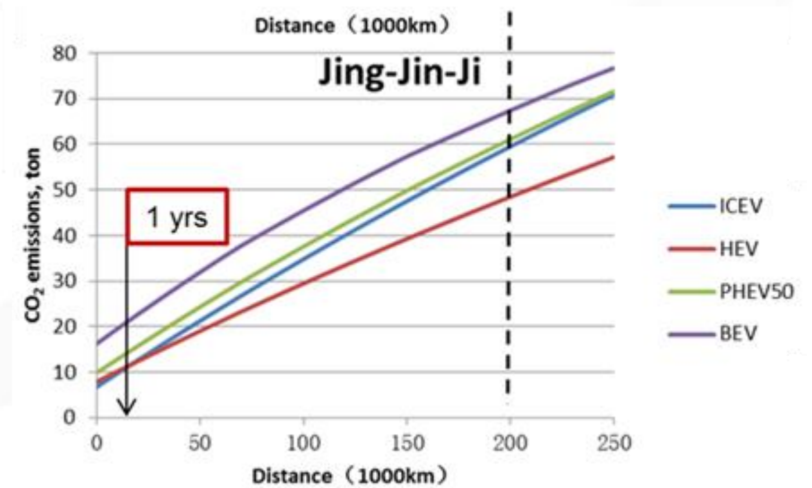


- **All three electric vehicle technologies achieve savings in full life-cycle fossil energy use relative to ICEV.**
- **BEV will show more advantage in fossil energy use over ICEV in the future.**
- **At the current stage, BEV and PHEV50 could not achieve full life-cycle benefit in CO_2 emissions over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

Breakeven points of accumulative full life-cycle CO_2 emissions of different technologies in China, 2010







主要结论和政策建议（1）
Conclusion and Policy Suggestion (1)

- 电动汽车推广对于**改善石油能源安全意义重大**
  - ✓ 插电式混合动力车（PHEV15/PHEV50）可减少40-50%的石油消耗
  - ✓ 纯电动车几乎不消耗石油
- **The promotion of EVs can greatly improve the oil energy security**
  - ✓ PHEV15/PHEV50 can reduce 40-50% petroleum consumption
  - ✓ BEV consume little oil

主要结论和政策建议（2）
Conclusion and Policy Suggestion (2)

- **电动汽车化石能源和CO_2减排效益与上游电力构成、煤电技术、车辆燃油经济性、车用材料等多因素强相关**
  - ✓ **电动汽车石油削减效益>化石能源削减效益>CO_2削减效益**
  - ✓ 在珠三角等清洁电力比例高的地区，PHEV/BEV的化石能源和CO_2减排效益显著；而在华北等煤电比例高的地区， PHEV/BEV的化石能源和CO_2减排效益大打折扣
  - ✓ 在我国煤电比例较高的地区，近期HEV和较小电池的插电式混合动力车（例如PHEV15）的化石能源和CO_2减排效益更佳
  - ✓ 目前纯电车全生命周期（燃料+材料+车辆运行）的CO_2与传统汽油车相比不具减排优势， 车用电池材料的节能也需要予以关注

- **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

主要结论和政策建议（3）
Conclusion and Policy Suggestion (3)

- **新能源车推广初期（2020年前）：从削减石油消耗或从削减车辆运行阶段排放考虑可给予其超低至零排放车待遇**
  - ✓ 纯电动车：燃油经济性、CO_2排放和污染物排放设为0
  - ✓ 插电式混合动力车：按照AER的不同和我国轻型车年均行驶里程综合设定其燃油经济性和排放改善比例
- **但在新能源车大范围推广阶段（2020年后），对新能源车能耗、CO_2排放和污染物排放削减效益的评估需从生命周期的角度考虑，并平衡能耗、CO_2排放和污染物排放的关系**
- **电动汽车的推广必须同步推动：**
  - ✓ 可再生清洁电力（太阳能、风能等）构成比例的显著提升
  - ✓ 更高效煤电技术（超超临界、IGCC等）构成比例的提升
  - ✓ 更高效车用电池材料和其他车用部件材料技术的采用
  - ✓ 在煤电后处理控制先进（FGD/SCR/高效除尘联合）的地区优先推动电动车的发展

主要结论和政策建议（3）
Conclusion and Policy Suggestion (3)

- **Before 2020: The new energy vehicles could be treated as zero emission vehicle, considering the petroleum reduction 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 consumption, CO_2 emission and pollutant emissions for new energy vehicles from the perspective of life cycle.**
- **The promotion of EV should:**
  - ✓ Increase renewable clean electricity (Solar energy and wind)
  - ✓ Use high efficient coal power technology (eg., ultra-supercritical and IGCC)
  - ✓ Use high efficient vehicle material technologies
  - ✓ In the regions with high efficient APCDs (eg., FGD/SCR/ combined PM removal), promote EV preferentially

致谢
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TOYOTA

Ford

Thank you for your attention！

Questions？

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