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SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

*An Institute of Transportation Studies Program*

# Long-term Fuel Economy Improvement Technologies and CO2 Reduction Strategies
# 远期轻型车节油路径选择和温室气体减排战略

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# The long term…远期的含义…

Thinking out to 2030, 2050, and beyond…

- How far can we go (and must we go) with fuel economy improvement, CO2 reductions?
- What are our options?
- Is there a logical pathway?
- How do we get there?

考虑到2030年、2050年甚至更长远

- 我们能在燃油效率改善、$CO_2$减排的道路上走多远、我们必须走多远?
- 我们有什么样的选择?
- 有没有一条合理的路径?
- 如何达到目标?

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# The options…我们的选择

- Improve conventional internal combustion engine (ICE) vehicle efficiency to “the limit”
- Adopt low-carbon alternative fuels and power train systems
  - Biofuel
  - Battery electric
  - Fuel cell electric

- 将传统内燃机效率推到极限
- 采用低碳替代燃料和动力总成系统
  - 生物质燃料
  - 电池
  - 燃料电池

**Some acronyms:**

ICE = internal combustion engine BEV = battery electric vehicles

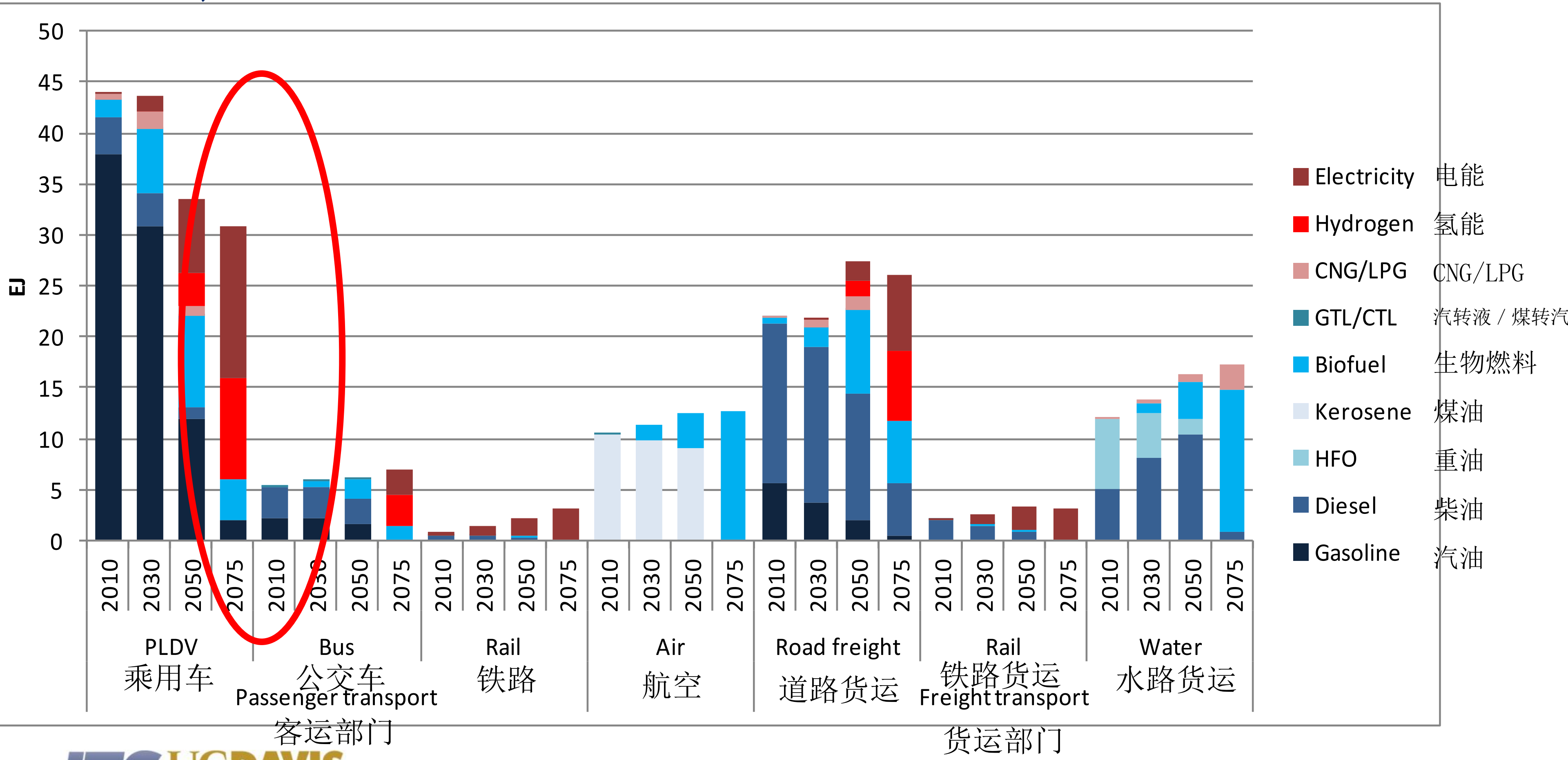
PHEV = plug-in hybrid vehicles FCV or FCEV = fuel cell electric vehicles

PEV = Plug-in electric vehicles (BEV+PHEV) ZEV = Zero emission vehicles (BEV+PHEV+ FCEV)

# IEA ETP-2012 Extensions (Fulton et al, draft paper) IEA报告

By 2050, Passenger Light-duty Vehicles (PLDVs) are moving strongly toward electrification; Biofuels shifting to use in heavier modes (trucks, ships, aircraft)

在2050年前，乘用车电动化的趋势强劲；大型车辆或交通部门（如货运卡车、船运、航空）则更多采用生物质燃料

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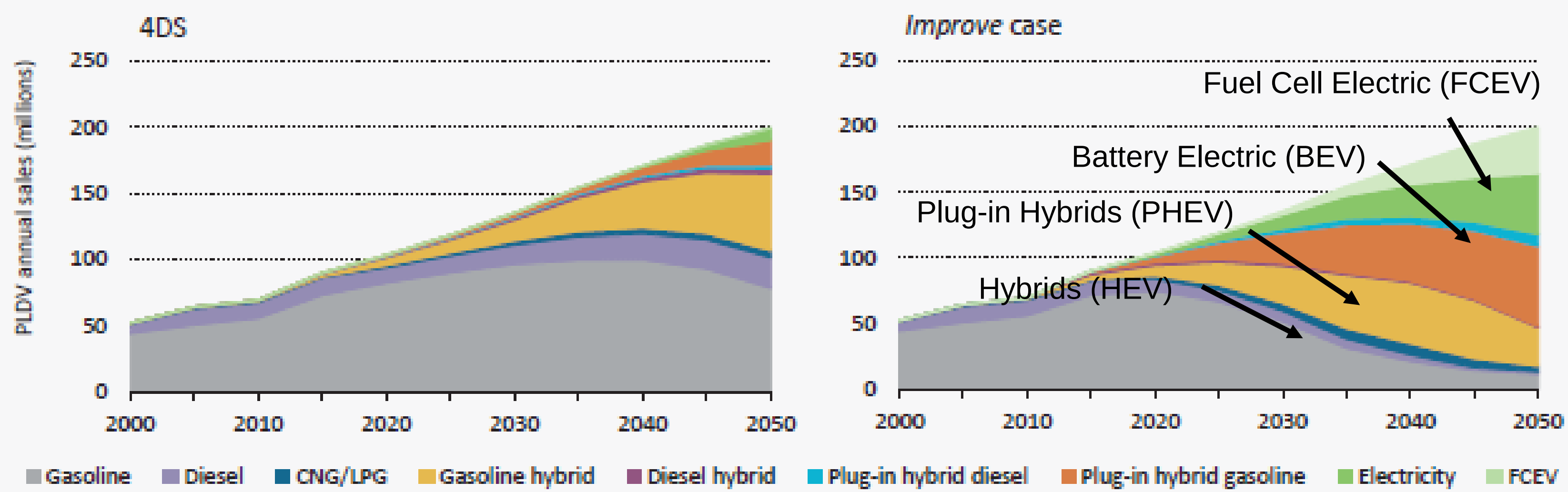
# By 2050 the world will need to shift to selling mainly near-zero emissions vehicles (plug-ins, or PEVs)

## 在2050年前全球新车市场要转型成接近零排放（插电式和纯电动）

**Figure 13.18** Global portfolio of technologies for passenger LDVs



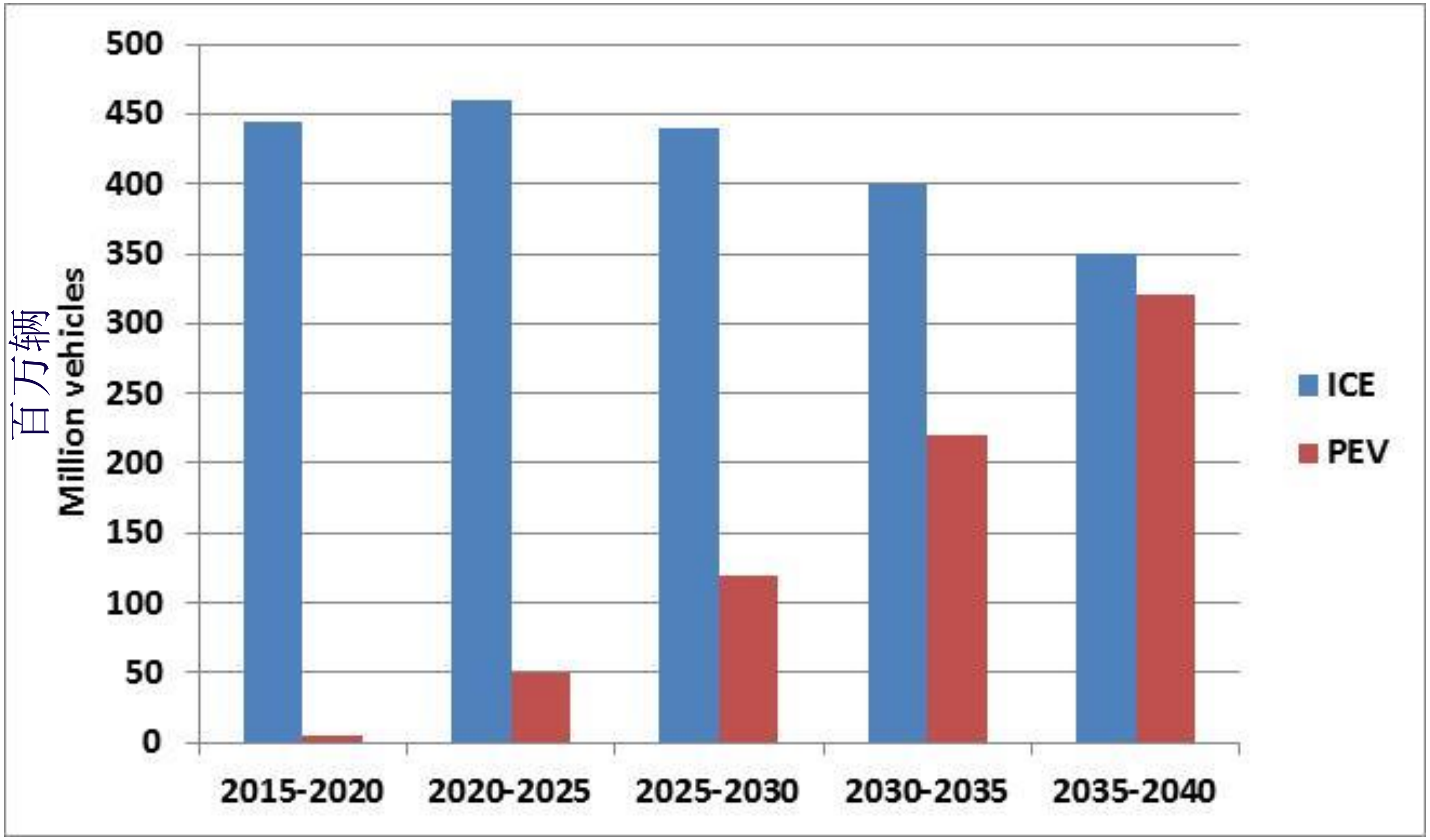

**Key point** *In the Improve case, electric, PHEV and FCEVs together account for nearly three-quarters of new vehicle sales in 2050.*

关键：在“改善情景”下，纯电动、插电式混合动力和燃料电池车一共占到2050年新车市场的75%

Source: IEA Energy Technology Perspectives (2012)

International Energy Agency

# But the next 2-decades will likely be ICE-driven, even with rapid Plug-in Vehicle (PEV) growth
# 但接下来20年可能仍是传统内燃机当道，尽管插电式车辆会有显著增长




**Note: this aligns with the IEA ETP 2012 2DS Scenario except with only 5 million PEV sales by 2020 instead of 20 million.**

注：这与国际能源署2012年ETP报告中2DS情景一致，唯一区别是对PEV的估计是5百万而不是2千万

# Maximum Fuel Economy Improvements to 2030
# 到2030年最大燃油效率改善

From the NRC 2013 report:

- Light-weighting of up to 25% in 2030, 50% in 2050 relative to 2010
- High efficiency accessories (e.g. air conditioning, lighting, tires)
- High efficiency engines (including but not limited to hybridization)
  - E.g. 25% improvement from turbocharged, downsized direct injection gasoline engines
- Overall Impacts:
  - By 2030, potential for 50% reduction in fuel consumption/CO2 per km at $2000-3500 per vehicle (through hybridization)
  - 66% reduction by 2050 at somewhat higher cost

根据NRC 2013 年报告:

- 2030年实现最高25%减重，2050年实现50%减重，都是相对2010年
- 高效附件的应用（如空调、照明、轮胎等）
- 高效发动机（包括混合动力）
  - 如通过使用涡轮增压、发动机小型化和汽油直喷发动机实现油耗改善25%
- 总的改善
  - 2030年前实现50%油耗或二氧化碳率减少，对应成本在2000-3500美元（通过混合动力化）
  - 2050年前以较高成本实现66%改善

# LDV efficiency improvements still have tremendous potential
# 轻型车能效改善仍有很大潜力

ICE potential, through hybridization and light-weighting (NRC, 2013)
内燃机的潜力包括混合动力化和轻量化（国家科学院NRC2013年报告）

| $CO_2$ g/km | Litres / 100km | Gals / 100 mi |
|---|---|---|
| 386 | 16.4 | 7 |
| 331 | 14.1 | 6 |
| 276 | 11.7 | 5 |
| 221 | 9.4 | 4 |
| 165 | 7.0 | 3 |
| 110 | 4.7 | 2 |
| 55 | 2.3 | 1 |
| 0 | 0.0 | 0 |

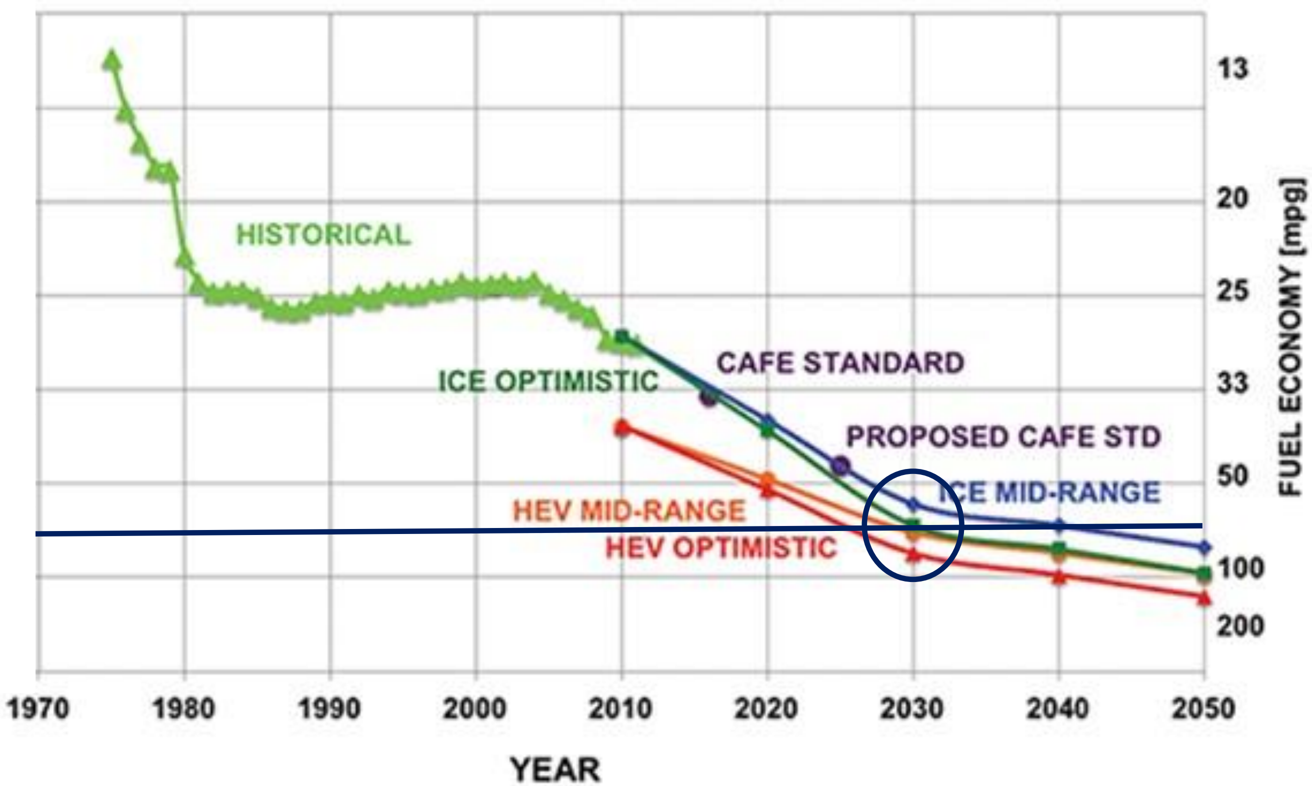
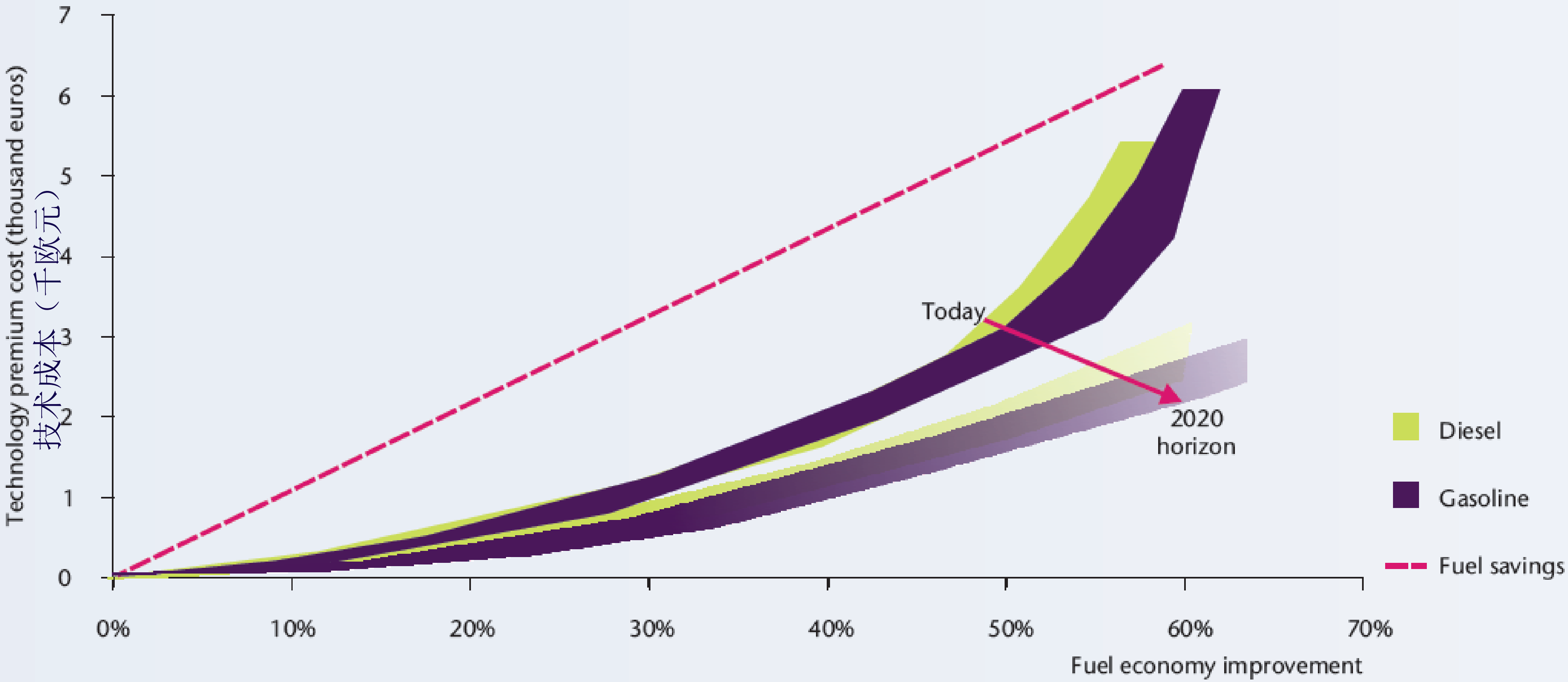



FIGURE 2.1 Historical and projected light-duty vehicle fuel economy.
NOTE: All data is new fleet only using unadjusted test values, not in-use fuel consumption.

# The cost of fuel economy improvements will likely decline over time
# 燃油效率改善的成本逐年递减




Source: IEA analysis based on TNO, 2009 and ICCT, 2012.

Note: Fuel savings over the lifetime of the vehicle are calculated based on 150 000 kms, for a base fuel economy of 8L/100km, with a fuel price of EUR 1 per litre (USD 4.7 per gallon), with no rebound effect as fuel economy improves.

- Analysis for the IEA "Technology Roadmap on Fuel Economy of Road Vehicles" showed that fuel economy of passenger cars could be improved by 50% at additional costs of around 3000€ per car

- IEA "道路机动车燃油经济性技术路线图" 里显示乘用车燃油效率可在每车3000欧元左右的增量成本下提高50%

# Long-term costs of technologies will drop – but by how much?
# 在长期新技术的成本会下降一关键是降多少？

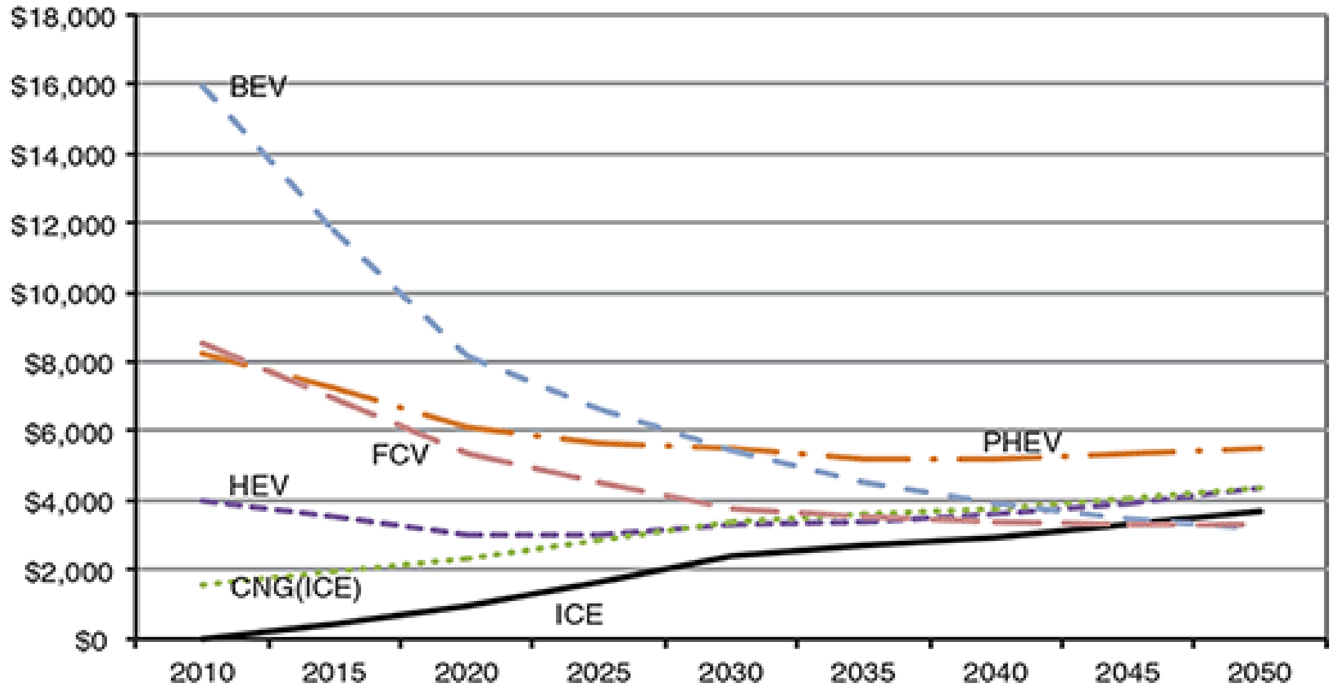
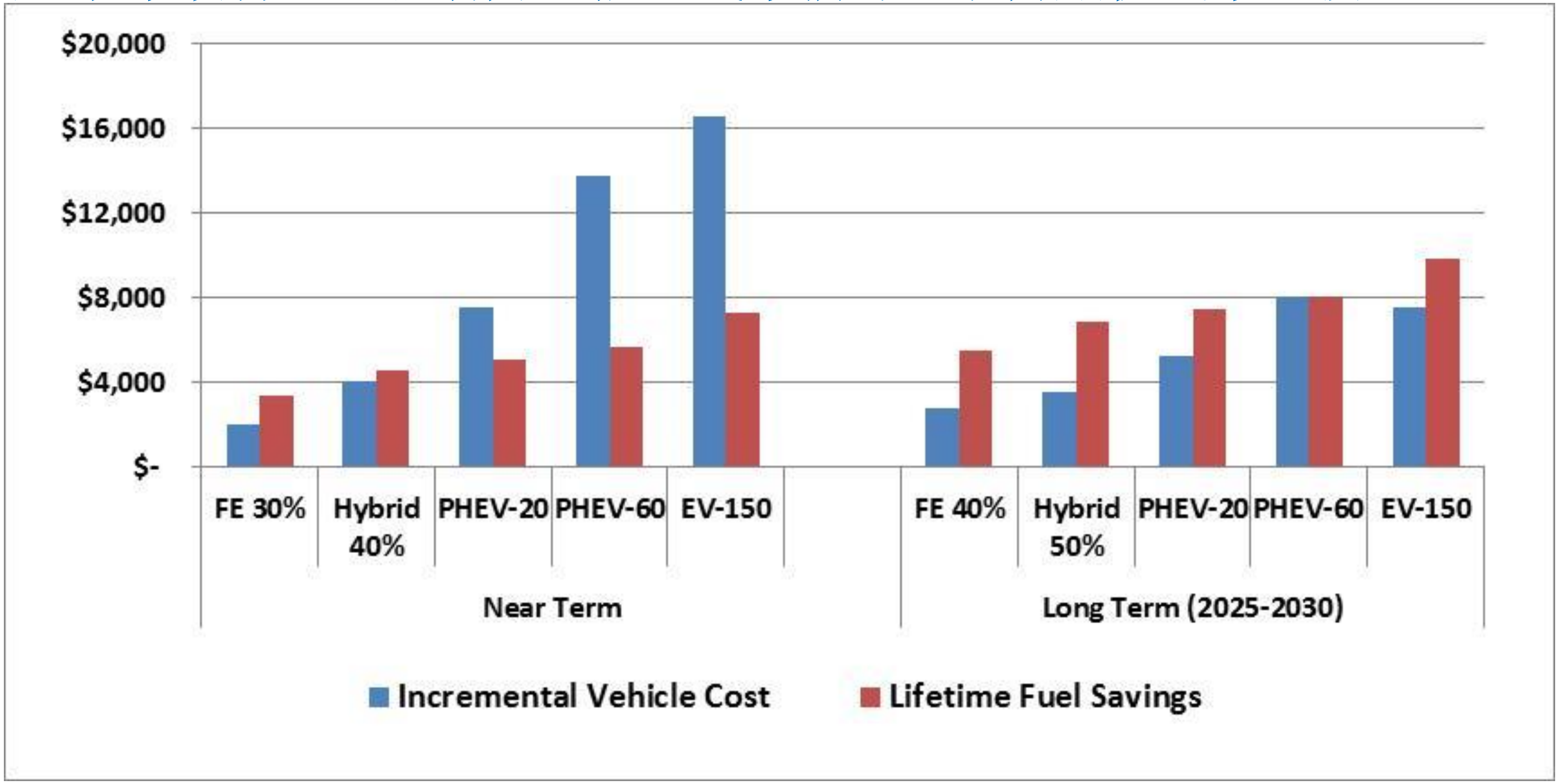



FIGURE 2.8 Car incremental cost versus 2010 baseline ($26,341 retail price)—Midrange case.

**Cost (RPE) for vehicle technologies over time (NRC, 2013)**

**RPE=retail price equivalent; BEV=Battery electric vehicle, PHEV=plug-in hybrid, FCV=fuel cell vehicle, HEV=hybrid electric vehicle, CNG=compressed natural gas, ICE= internal combustion engine vehicle.**

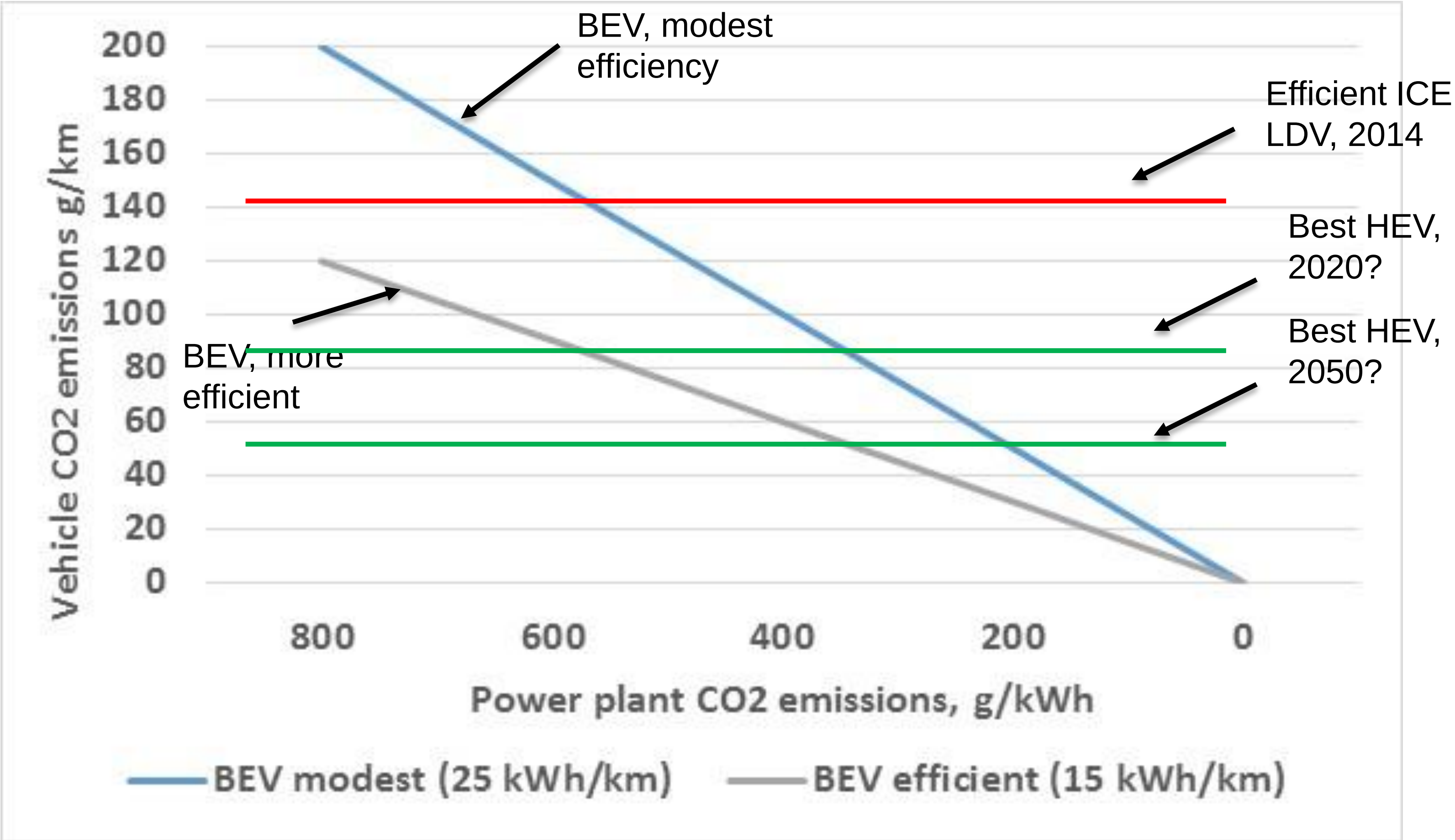
# Some cost/benefit estimates
## 成本收益分析
### FE Improvement, hybrids, PEVs v. a base ICE vehicle over time
### 燃油效率改善：混合动力、插电式车辆与基准内燃机汽车比较




**Notes: "FE 30%"=fuel economy improved by 30% in L/100km; "PHEV-20"= plug-in hybrid with 20 km electric range; fuel savings estimated over 160k kms of driving; all related to a base gasoline vehicle of 9 L/100km; oil prices $100/bbl near term, $130/bbl long term; battery costs decline over time from $600 to about $300/kWh**

# Electric vehicle v. ICE, with declining power plant CO2 emissions

## 在上游电厂CO2排放不断下降的走势下，电动车和内燃机车的比较

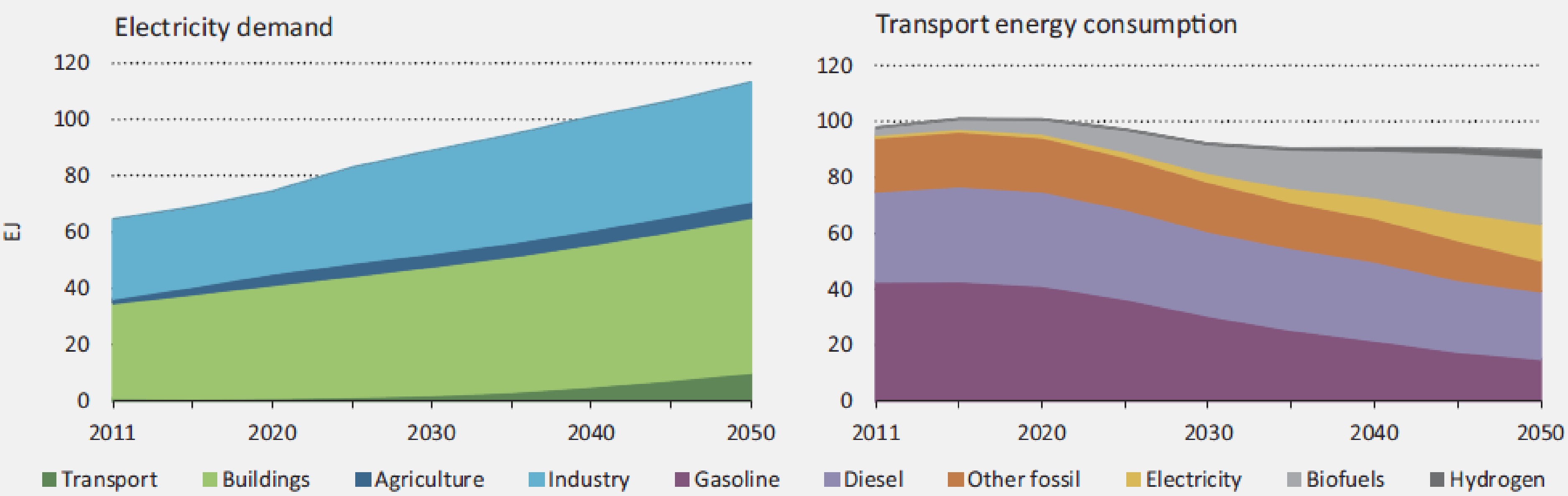



**Battery electric vehicles will probably be needed to get below 50 g/km, but we will also need deeply decarbonized electricity generation**

(Based on NRC, 2013 assumptions for fuel economy)

# 2DS ET electricity demand
# 2DS ET情景下电能需求量

电能需求　　　　交通能源消耗




交通　建筑　农业　工业　汽油　柴油　其他化石　电能　生物质　氢能

- … but still total electricity demand for transport accounts for only 13% of total electricity use by 2050
- 到2050年前交通部门总的电能需求仍只有13%

# Fuel Cell Vehicles – "the other guy"
# 燃料电池车 一另一种选择

- Fuel cell vehicles may provide longer range mobility than BEVs, with zero vehicular emissions
- Still some significant barriers
  - on-board H2 storage,
  - fuel cell system cost,
  - chicken-egg problems
- Costs have dropped sharply in recent years
  - estimated likely to be below $100/kW (or $7500 for a 75kW system) at high volume production within a few years, and competitive with gasoline vehicles by 2030)
- In 2015 we will see the roll out of FCEV programs in California, EU and Japan – a "renaissance" for FCEVs?
- Must have zero carbon hydrogen (e.g. electrolysis), not cost effective at this time

- 燃料电池车可以提供比电动车更长的续航里程，同样也是零尾气排放
- 仍需克服主要障碍
  - 车载氢能存储，
  - 燃料电池系统高成本，
  - 鸡生蛋蛋生鸡的问题
- 近年成本下降很快
  - 随着不久的将来量产化进程，估计会下降到低于$100/kW（或75kW的系统造价在$7500 ），在2030年前成为汽油车的竞争对手
- 2015年左右会看到加州、欧盟和日本燃料电池车的"复苏"
- 必须要有零碳排放的氢能（即电解），现在来说不具有成本效益

# Some conclusions 一些结论

- There remains substantial untapped fuel economy potential – there is no reason to think that we can't get well below 90 g/km average new car fuel economy worldwide by 2030 (in China, perhaps by 2025)
  - Technology costs will likely decline over time, new technologies will emerge
- Battery electric vehicles are important in the long term to move toward zero-emissions; but this must happen in concert with electricity improvements
  - In any case, to meet climate targets, strong efforts to expand BEV production and sales, and reduce costs, must happen now
  - Strong co-benefit potential with air quality improvements and cutting oil use

- 对于燃油效率的提高还有很多未开发的潜能，没有理由相信我们不能在2030年实现全球平均新车CO2排放在90克／公里以下（中国可能是2025年）
  - 技术的成本不断下降、新技术不断涌现
- 电动车对于实现远期未来零排放车队很重要，但前提是电厂排放须同步减少
  - 无论如何，为实现温室气体减排目标，需要大力推进电动车的生产和销售、降低成本，这些需要从现在做起
  - 对于改善空气质量和减少油耗也有协同作用

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# Some Implications for Policy
# 一些政策建议

- To go for rapid uptake of BEVs, super credits probably can not do this alone
  - Price incentives will likely play an important role
  - Incentives require a sustainable funding source, e.g. feebates
- Eventually move toward global alignment of policies?
  - Could include targets, measurement systems, tradable credit systems

- 为大幅推动电动车，达标配额激励这一项政策措施可能不够
  - 价格刺激可能起到主要作用
  - 为了能持续提供价格激励，需要稳定的财政来源，比如财税奖惩可以达到激励左右同时为政府平衡财政来源
- 最终全球是否会走到政策协同?
  - 协同可以包括共同的目标、衡量体系和配额交易系统

**Thank You!**

**谢谢！**

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